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Biomedical Science Education

Elements of History and Evolution of Brain Science in High School Work-alternative Activities

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Abstract

Modern and historical elements of international researches about Brain Science were integrated to realize innovative high school – work alternative activities (PCTO) into interdisciplinary educational itinerary with students that have good knowledge about basic elements of neuroscience.
Perspectives in future brain science researches were realized also with different seminaries of biology-didactic researcher and one coplanning innovative seminary with neuroscientist about historical and modern aspects of octopus studies for brain science applications; collaborative and creative activities with IBSE methodology learning in contamination between different disciplines. Students have participated to individual and cooperative working, modern laboratories activities for elaboration and interpretation in critical thinking of neuroscience original international articles, also about history and evolution of a neuroelectrophysiology technique. Classes were divided in little groups to realize, with specific role for each student, thematic works about different historical topics: neuroscientists' biographies and discoveries. One particularity of this project was the remodeling of second phase during COVID-19 pandemic, realizing some activities in smart working: students with students into different team work and students with biology researcher-teacher, also publishing in innovative digital platform created by biologist-teacher, also writing report in international 2020 brain science digital context. Neuroscientific literacy work and brain science reading activities were realized to create into each group innovative "digital brain posters", simulating role of scientist in realizing professional poster for international congress with guide and instructions of biologist – teacher. At the end of project was organized and realized a Virtual Neuroscience Conference as in real scientific congress with remote digital activities in which all students have presented different parts of realized brain posters. In the project monitoring phase students have expressed your idea about all realized activities important for world of work. Students have compiled terminal report of project in which have declared that digital activities were very useful to develop soft skills in cooperative team work realizing researches and final product of poster with specific role for each member of group. Were important for students oral and written communication skills, also in realizing virtual modern conference as "little scientists"; comparative cognitive competencies in analyzing some international neuroscience articles – reports and in relating elements of biographies of neuroscientists also with debate method.

Keywords: IBSE methodology, soft digital skills, brain science, multidisciplinary didactics, history of neuroscience, virtual brain conference

1. Introduction

Modern and historical elements of international researches about Brain Science were integrated to realize a high school – work alternative activities (PCTO) for scientific High School into modern educational itinerary with students that have good cognitive skills about based elements of neuroscience.

Perspectives in future brain science researches were realized also with different seminaries of biologist-didactic researcher and one coprojected innovative seminary with neuroscientist of International Brain Science Research Centre about historical and modern aspects of *octopus* studies for brain science applications; collaborative and creative digital learning with IBSE methodology in contamination between different disciplines, realizing multidisciplinary didactics (Biophysics, History of Science, Brain Science, Physiology, ICT).

With individual and team work, students have participated in different laboratory activities also for elaboration and interpretation of neuroscience international articles with cooperative working about discovery, history and evolution of an electrophysiology technique, integrating different experiences also to answer some questions. Elements of international scientific articles with key words and important concepts to know the different phases of neuroscientist' work also to elaborate written brief text about different questions: which part of article do you think more interesting and why, which more scientific difficulties to arrive at the different applications research of brain science techniques, at witch theoretical and practical experimental phases did you prefer to participate or to give contribution with motivation ofanswer.

2. Methods

In the first part of project students have worked with *critical thinking,* elaborating written answers to seminary about brain octopus intelligence and physiology studies: which elements of seminary do you prefer, which are objectives of researches presented, which relationship between scientific and historical disciplines in the seminary, which elements of seminary have permitted you to better understand experimental approaches of scientific researcher, analyzing the different parts of seminary – which scientific elements do you think to be useful for future researches about neuroscience and regenerative medicine with motivation of answer. In *cooperative working* and individual activity all students have also worked reading an article of Nature (The octopus's genome and the evolution of cephalopod neural and morphological novelties, Nature 524, 220-224, 2015) and observing a video about Genome of octopus to synthesize innovative elements of these researches presenting in class all important information and to communicate the results of works info team groups also constructing scientific section of brain site platform. A lot of interesting experiments have demonstrated the high capacity of cephalopoda to conserve information and to realize intelligent behaviour in different contexts, important researches also to project biorobot for biomedicine inspired to functions of these animals.

In the second phase of project all students have attended different seminaries of biology professor about "The brain science and the methodology work", "STEM Neuroscience for cooperative working: one innovative experimental technique for the neuroscience", "How to realize a digital platform for the brain science", in which was important the creation and the management of Neuroscience group Team in remote e of project in march 2020, mostly in realizing thematic posters into different team research brain science group.

High School students were divided in five little groups to realize, with specific role in each group (responsible, digital expert, text translate expert, oral and written communication expert), thematic works about different historical topics: neuroscientists' biographies and discoveries (Montalcini group, Golgi and Memory group, European History of neuroscience group, Golgi and Cajal group, Huxley group) working learning by doing. One particularity of this project was the new modulation of second phase of work during Covid19 pandemic, realizing some activities in smart working: students with students into different team and students with biology researcher-teacher, also publishing all written activities in innovative digital PCTO platform and publishing in international 2020 brain science digital context as partnership of international DANA Foundation Brain Science week after accepted documented written proposal of biology professor of classes.

3. Results

Neuroscientific digital literacy and brain science reading activities were realized to create into each group innovative "*digital brain posters*", simulating role of scientist in realizing professional poster for international congress with guide and instructions of biologist – teacher. At the end of project was organized and realized a *Virtual Neuroscience Conference* as in real scientific congress with remote digital activities in which all students have presented different parts of realized *digital brain posters*. In the project monitoring phase students have expressed your idea about all realized activities important for world of work.

Different integrated learning and IBSE strategies were realized in brain science project: from historical didactics research approaches to modern experimental impacts, from biography' *individual work* to cooperative group activities in which all students have specific role (coordinator group, articles' traslate specialist, informatics specialist for interactive poster, editor specialist for elaboration communication of different activities and researches, also control written texts). From individual with specific skills for different works to communication social activities for community, different activities realizing sharing all work's products in Brain Science Innovative *Interactive Collection Platform* was useful for evaluation of project by biology teacher.

In this Brain science itinerary were integrated different teaching methodology and strategies to guide students in learning and working by doing: to create an international scientific conference simulation, to consult international scientific database, to participate in brain science platform with cooperative working, to realize job strategies with IBSE research methodology in comparison international neuroscientific articles, to realize innovative digital brain science thematic posters and to present all posters in virtual constructed conference.

All these activities were useful to promote transversal skills related to written reports after reading scientific texts, to participate in active way to scientific seminaries identifying key elements, organizing competencies about respect for all work times, collaborative competencies in team work important in job reality. Others transversal skills about relational competencies as students referee or director in different activities, documentaries competencies to produce text also for international publication in Brain Science Week 2020, responsibility competencies in management of brain science group, debate competencies in relation thematic of different groups, capacity to follow the guidelines of professor responsible of project. Technical competencies in using informatics platform, in realizing scientific posters to work world, in individual communication into time work assigned, in using with correct way scientific language, both written and oral, also simulation of Neuroscience Conference. Original work of students was realized in reading and in analysis long and curious text “Rita Montalcini comic story – Montalcini a pioneer in neuroscience” – European Brain Research Institute R. Levi Montalcini (Franco Nobili e Manfredo Toraldo), scientific biography document with motivated identification report by student on which cartoons and images (five elements) were more interesting for team group.

All students have compiled terminal report of project in which have declared that different digital activities were very useful to develop soft skills in cooperative team work, realizing researches and final product of poster with specific role for each member of group. Students have considered very important the communication skills in realizing virtual modern conference as “little scientists”, cognitive skills in analyzing some international neuroscience articles reports and biographies of neuroscientists (R. Montalcini, A. Huxley, E. Kandel, R. J Cajal, C. Golgi) with elements of historical and modern evolution of researches.

4. Conclusion

Interdisciplinary approaches in distance digital working and learning were an important challenge in working methods for biology professor and students, were useful to create a different dialogue about part of project. Contamination between historical and experimental disciplines science, helping students to work with motivation and interest also in distance work sharing and communicating as little scientists all results of researches, was very important to guide the class in realizing digital elaborations of different activities in *project learning PCTO methodology*. Historical neuroscience itinerary with protagonists of discoveries and innovative technology applied in brain science was very useful to involve in inclusive way all students in reason reflections into scientific high school community, educating in critical thinking to elaborate conscious evaluations and ethical considerations about benefit and possible effect of achievements of modern brain science on social impact, about the future relationship with intelligent machines and devices capable also to do integrative or human replacement functions.

At the end of project all groups have presented reports of different activities realized in these PCTO itinerary. Students have answered some questions about different aspects of projects: considerations about historical and experimental elements with also possibility to explain individual idea for future impacts on society of modern brain science researches, to explain which neuroscience aspects of Brain Science PCTO work-alternative itinerary were motivating and orienting for individual future studies and professional career choice.

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Learning about Krebs and his Four Metabolic Cycles by Using a Problem-Based Learning Approach

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Abstract

In the context of an Educative Innovation Project (EIP) to be developed in the academic curses 2019-20 and 2020-21 and entitled "Collaborative learning of Biochemistry based on projects and case and problem solving" and two others previous EIP, we have designed and used problem-based learning (PBL) cases to help our students to study metabolism and tis regulation. One of these PBL cases was focused on the four metabolic cycles described by the Nobel prize winner Sir Hans Krebs. In two subjects dedicated to the study of metabolism regulation, one from the Biology Degree and the other from the Biochemistry Degree, we recruited volunteers to work in groups and collaboratively to solve the PBL cases. The final grades in the global evaluation of the students who participated in this activity were notably better than those who did not. In the present communication, this experience is analyzed and discussed. This work is supported by an Educative Innovation Project (PIE19-057, funded by University of Málaga).

Keywords: collaborative learning, Krebs, metabolism

1. Introduction

Biochemistry is considered to be a very demanding and difficult discipline for science students. Within the contents of a general biochemistry, metabolism, its regulation and integration are one of the most complex topics of study for students, due to its broad contents and the need of integrate them in a biologically meaningful manner [1-4]. We have incorporated collaborative and flipped learning strategies to make our students key players in their own learning process [5-13]. It has been claimed that collaborative learning strategies helps students to study biochemistry and metabolism [14-17]. The use of problem-based learning (PBL) has been of paramount importance in order to achieve this aim [4, 13, 18-20].

2. Design and contents of the PBL devoted to the four cycles described by Krebs

The whole activity was designed within the framework of a design-based research methodology [21] and applying a teaching learning sequence (TLS) [22] focused of a

PBL devoted to the four cycles described by Sir Hans Krebs [23, 24]. The same TLS can be applied for PBLs devoted to different metabolic contents, as illustrated by the flow chart of the TLS adopted by us in the case of another PBL devoted to glycogen metabolism [see figure 1 in 25]. At the beginning of the TLS the PBL should be designed and its contents selected. In the present case, we decided to prepare a set of activities helping the students to learn the four metabolic cycles described by Krebs, their regulation and their integration with other metabolic pathways. The critical role of Sir Hans Krebs in the elucidation of the urea cycle and the tricarboxylic acid cycle is well known and usually well described in general biochemistry textbooks [26-28]. However, it is much less known that Krebs also had a key role in the initial description of other two metabolic cycles, namely, the glyoxylate cycle and the uric acid cycle [23, 24, 26-29].

The "four Krebs' cycles" PBL included 46 guided tasks organized around four topics, as follows: (1) Historical aspects of the scientific studies of Sir Hans Krebs, six tasks. (2)

On the structure and properties of some molecules involved in the Krebs' cycles and the topology of theses cycles, 10 tasks. (3) The Krebs' cycles, their regulation and metabolic integration, 21 tasks. (4) Diseases linked to a misfunctioning of the cycles described by Krebs with biochemical foundations of selected clinical cases, 9 tasks.

A relevant part of these tasks was selected from known and prestigious textbooks and student's guides on biochemistry [26-29] as well as cases and patient profile cases contained in the instructor's resources of Voet and Voet Biochemistry [26] and Marks' *Basic Medical Biochemistry* [30]. Additionally, some tasks focused on pedagogical resources elaborated by students of our courses on metabolism enrolled in previous academic years, as well as on selected original and review scientific articles and the exploitation of useful online resources, including biological databases. In all the cases, the guided tasks were designed to stimulate critical thinking and cooperation, rather than competition.

Once designed and prepared the whole PBL, the complete set of activities was properly presented to all the students of the courses from which volunteers were later recruited.

3. Recruitment of volunteers and implementation of the tasks in a model of collaborative learning and flipped class

At our Faculty of Sciences (University of Málaga, Spain), metabolism is a topic covered in three mandatory courses (one in the second academic year of the Degree in Biochemistry, another one in the second academic year of the Degree in Biology and the third one in the third academic year of the Degree in Chemistry), which are mainly devoted to the study of metabolism, its regulation and its integration. For the present educational experience, we recruited volunteer students among those enrolled in the first two mentioned mandatory courses at the beginning of the second semester of the academic year 2018-19. Volunteer students signed a learning contract [12] and were split in groups of 3-4 components. Afterword, the PBL contents were presented and commented to all the groups, which started to work autonomously to solve the whole PBL on their own for the following two months. During this time of autonomous work, groups could demand tutoring from their professors any time they felt they need it. At the end of this period of time, each group had to present a report with the detailed answered to all the tasks of the PBL and the solutions provided by the different groups were contrasted and shared in a public session at the classroom.

4. Educational results

To evaluate the impact of this PBL activity on the learning process, three kinds of analysis were implemented: (1) all the enrolled students (volunteers that had signed the teaching contract and those that had not) anonymously answered the questions of a test on their knowledge regarding Krebs' scientific work and the metabolic cycles described by him both at the beginning and at the end of the semester; (2) the reports from every involved volunteer group were analyzed and evaluated; and (3) scores of volunteers and students not involved in the learning contract in the final exams were compared.

The increase in the percentages of correct answers in the post-test as compared with the pre-test was greater among the volunteers than among the students that did not signed the learning contract. Furthermore, global scores were remarkably better for those volunteer students that had signed the learning contract rather than for those who did not. Most of the volunteers declared that they felt that this PBL approach has been useful for them, believed that they had learned more, but that they also have worked more and harder than for the resolution of other kinds of tasks. Overall, around an 80% of students enrolled in this study declared to be "very satisfied" or "satisfied" with their experience.

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SimScape – Integrating Novel Teaching Strategies in Medical Education

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Abstract

A shift is needed from a teacher centered to a more learner centered approach in medical education to meet the needs of our current generation [1, 2]. We have incorporated innovative opportunities for peer-group learning, in a psychologically safe environment, to enhance retention of knowledge, encourage development of leadership, empathy and teamwork skills. Escape Rooms are a team-based activity where a group completes a series of puzzles to achieve the goal of escaping. They are emerging as a popular educational tool to impart new knowledge and skills with entertainment [3]. Medical Simulation has become an integral strategy in medical education; it provides a risk-free environment to teach complex, high-risk, low-frequency events without involving human patients [5]. We created a unique experience for our 4th year medical students during their orientation to Advanced Medicine Sub-internship. They solved an Escape Room, followed by medical simulation cases using high-fidelity simulators where they responded to a rapid response call together. We received overwhelmingly positive feedback on a survey that was conducted following the orientation. Among 111 students who have participated, 100% found these sessions helpful. With reference to the Escape Room exercise, 67.9% found it very useful, 20.2% found it moderately useful, 10.1% found it slightly useful and only 1.8% did not find it useful. In terms of the Simulation, 78.9% found it very useful, 14.7% found it moderately useful, 6.4% found it slightly useful and 0% found it not useful. Given these results, we are expanding our efforts and currently a pilot study is being conducted in our internal medicine residency program using these strategies. In our experience, incorporating play will innovate medical education for new learners. However, further studies are needed for successful integration into the medical curriculum.

Keywords: Escape Room, Medical Simulation, Medical Education, Internal Medicine, Sub-Internship

1. Introduction

Current medical education needs doctors to be better equipped with the adult learning skills necessary to adapt and change based on the community they serve. A shift from a teacher-centered to a more learner-centered approach meets the needs of our current generation [1, 2]. Adults are usually motivated by learning that is perceived as relevant, participatory, and actively involving them [2]. As medical education is a lifelong process, a physician's learning is usually problem-focused and builds on their previous experiences. Problem-focused, seasoned doctors can take responsibility for their own learning by involving cycles of action and reflection and building on their own experience to immediately apply them in their practice. However, the medical students and young doctors are overwhelmed by the vast amount of information they need to process with little experience with clinical application. They have a short time to reflect on their activities, and a small mistake can significantly dent their confidence and mutual trust as well as respect from their patients and peers, leading to stress in their medical careers.

Gamification based learning methods like a full-size clinical escape rooms and problem-based learning methods like programmable simulated mannequins help young doctors provide a means of improving self-confidence, time to reflect on their actions based on feedback, master the elements of team building, and develop mutual trust and respect to their peers to solve the complex problems [3]. These innovative methods provide exposure to complex real-life stressful situations with stress and risk-free environment to enhance their teamwork skills and application and retention of medical knowledge.

2. Novel Teaching Strategies in Medical Education

Subinternship is one of the first chances for a fourth-year medical student to be directly in charge of patient care, which is different from a basic medicine clerkship exposure as a third-year medical student. It provides the opportunity to learn and care for the patients in a safe, supervised, yet autonomous environment, just like someone would in their early postgraduate years. Although sub-internship is a fascinating and essential experience, it can be fairly intimidating [6]. The training takes place on general medicine services, intensive care units, or subspecialties and with the expectations of real-time application of medical knowledge to address the patients' critical needs. Due to the lack of clinical experience, understanding of care team dynamics and resource availability of different environments, depth of knowledge, the subinternship can be overwhelming and stressful. That in turn can make the experience sub-par, leading to low confidence levels and loss of self-belief. Sometimes, despite the patient's delivery of care with the right intention, an unforeseen complication leading to a near miss can cause a loss of mutual trust and respect from patients, peers, and supervising physicians. Young doctors should understand early in their career that patient care needs to apply acquired medical knowledge during initial medical training as a part of a collaborative team effort with appropriate navigation of time and resources while minimizing adverse events. To provide them with the window of opportunity to simulate the real clinical situations to improve self-confidence, team building, time management, and situational awareness with a risk-free and psychologically safe environment, we created a curriculum to orient subinterns before starting the advanced medicine rotation.

This curriculum involves the simulation of cases using a high-fidelity simulator, an innovative medical themed escape room, point of care ultrasound training on standardized patients, and a session of nuts and bolts of advanced medicine by faculty and/or chief residents. We received overwhelmingly positive feedback on a survey that was conducted following the orientation. Among 111 students who have participated thus far, 100% found these sessions helpful. In the written feedback, sessions were reported to be very interactive, entertaining, hands-on, serving as a medical knowledge refresher.

Participants were happy about learning teamwork, communication, and reported the session helped in alleviating anxiety around patient management in an emergency setting. One student mentioned, “This was a low-stress introduction to advanced medicine that outlined expectations”. The other student quotes, “It was a good balance of necessary information for success in the internship, with engaging, interactive educational sessions mixed in”.

2.1 Simscape – Incorporating Gamification into medical learning

Gamification is the application of typical elements of game playing in a non-game context [7]. The concept serves medical education as it promises to make stressful learning processes fun and enjoyable. It helps to motivate learners, increases engagement and encourages social interaction in a learning environment [8]. Escape Rooms are a team-based activity where a group completes a series of puzzles to achieve the goal of escaping [3]. To introduce gamification into our orientation curriculum, we added a medical themed escape room to our pilot project, SimScape. The objective of Simscape is to facilitate autonomy, effective teamwork, with sets of achievable goals for participants. The participant is expected to generate an idea with available clues, appropriately communicate with other team members to solve a complex medical puzzle within a given time constraint. With this activity, we aim to improve effective communication, team building, situational awareness, proper use of resources, and boost self-confidence. The three factors that attribute to the popularity of escape rooms in medical education are the new generation population, gamification’s societal impact, and its delivery convenience [3].

When asked about the escape room experience, out of the 111 students that were surveyed, 66.7% found it to be very useful, 21.6% found it moderately useful, 9.9% found it slightly useful, and only 1.8% did not find it useful. One student found this exercise helpful, quoting, “Learning to work as a team and understanding the importance of individual roles that enhance teamwork”. Based on encouraging positive responses to our Simscape project, we plan to continue this orientation curriculum as a long-term project, and hope to make a positive difference in the students’ education. We believe that despite appearing to be a superficial form of entertainment, Simscape when used effectively, will act as a low-cost, high-impact resource for a variety of learners. However, due to the pandemic, changes will need to be made to the structure of Simscape (such as masks, hand hygiene, reducing the number of students in each session, etc.) to ensure continued safe implementation until all the students are vaccinated. The limitations of an escape room session are lack of human factor, malfunctioning games/puzzles, initial moderately high costs to create and conduct a life size environment however once created, the games can be changed very easily based on learner objectives and learner levels.

2.2 Simulation – Risk-free environment for managing complex medical cases

Simulation is helpful to supplement training in real clinical situations. In the traditional medical learning apprenticeship model, the expectation is the learners should start with more manageable tasks and then proceed to more challenging ones. However, it is not always the case to have a graded exposure to challenges in the real world. The simulation creates an experience of undergoing a clinical scenario with graded levels without involving human patients to overcome these constraints [5]. In a psychologically safe environment, simulation allows learners to experience failure and recognize when they are approaching or crossing their competence limits. The ability to pause, restart and replay a clinical encounter during simulation provides invaluable opportunities to apply educational principles to the clinical setting. It is also possible to give the learners the tasks of a suitable level of challenge to provide feedback with the room to improve.

It also offers an opportunity to create tasks that would otherwise be impossible owing to limited materials or resources. We use high fidelity simulators to simulate various case scenarios replicating rapid response calls addressing critically ill patients and mock codes. We aim to educate medical students on the various aspects of medical care delivery to navigate patient evaluation, interact and effectively communicate with the multidisciplinary team in high adrenaline situations, situational awareness, timely decisions, and their impact on patient care. Regarding the high-fidelity simulation, among the 111 students who participated in the exercise, 77.4% found it very useful, 16.2% found it moderately useful, 6.3% found it slightly useful, and 0% found it not useful. When asked to describe the experience, a student stated, “Simulation helps not only how to work in teams but the medical management of acutely ill/crashing patient”. The strength of the simulation module is to have educators at various levels of training to understand the gaps and needs of the trainee and work towards the common goal of the improved educational experience. The limitations of the simulation are lack of human factor, malfunctioning mannequins, and high costs to purchasing and managing the simulation setting.

2.3 Other learning opportunities

Our orientation curriculum also incorporates learning the basics of point-of-care ultrasound (POCUS) for patient evaluation. The students well received the session and reported that this motivated them to learn more about using bedside ultrasound in clinical evaluation. When asked about POCUS, out of the 111 students who participated in the exercise, 75.6% found it very useful, 18% found it moderately useful, 6.3% found it slightly useful, and 0% found it not useful. Based on this feedback, the interest in POCUS in our new generation of students shows the willingness to incorporate new technology into medical training and the eagerness to learn and adapt with time.

The other aspects of our curriculum focused on nuts and bolts of advanced medicine, educating expectations from sub interns, educating polypharmacy, choosing wisely, pager education, sign-out process using I-PASS.

3. Conclusion

With the changing scope of medical education, the incorporation of learned-based education techniques like high fidelity-based simulations, escape rooms, and POCUS is well received by the current generation of young doctors in training. As an educator, we should continuously lookout for innovative ways for providing education to fulfill the aspiration of young budding doctors.

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Curriculum Development

Adaptation and Update of a Curricular Didactic Analysis Instrument from STEM Teaching and Learning Units

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Abstract

We begin this project by introducing an instrument designed for textbook analysis which has been brought forth from extensive research in which didactic analysis was used as a research methodology. It has proven itself necessary in the development of the teaching-learning processes of Science, Technology, Engineering and Math (STEM) [1]. Didactic analysis is considered a field of research in Mathematical and Scientific Education which allows for the examination and comprehension of the phenomena of Mathematical and Scientific Education, and their intervention with certain assurances. Despite the indisputable power of this instrument, we are adapting and updating it to include and consider the gender perspective, which was neglected in [1]. With feminism being a crucial element to our line of work, it proved essential to adapt this instrument so that the gender perspective took on the main role which we believe it deserves. Furthermore, the scheme has been simplified and updated to a more technological and easily accessible format. By implementing these modifications, we intend to facilitate the systematization and comparison of the analysis results, which is quite complicated within the current format. These enhancements are being tested by applying them to a sample of textbooks and thus validating them.

Keywords: Didactic Analysis, STEM, Mathematical and Scientific Education

1. Introduction

Overall, the main purpose of education is to provide students with the means to develop their physical, personal, social, and moral autonomy [2]. Therefore, Science-Technology-Engineering-Mathematical Education (STEM) in particular must not be limited to the exclusive learning of the use of mathematical and scientific instruments.

Instead, it must go much further by helping students comprehend math and sciences so that they can adapt themselves to their environment and thereby organize and transform it. Furthermore, it must prepare the individual to analyze the current options in any given situation and select the best one [3].

It has been three decades since [4], affirmed that certain forms of mathematical and scientific activity favour mainly the development and acquisition of cognitive abilities – hence the formative interest of its teaching. However, the formative values associated with mathematics and science are not simply limited to the cognitive aspect. They are active on a global scale and connected to human standards and values as well as to the emotional field.

Today, progress is being made on this idea, as [5] affirms that Mathematics has a threefold character: Instrumental, Functional and Formative. It is a uniquely interdisciplinary subject as it is related to virtually all fields of study, not simply in its scientific-technological aspect. For instance, it is interwoven within seemingly unrelated disciplines such as the Social Sciences, Music, Sports, Poetry and Politics. Although the formative character or Mathematics is usually forgotten in the teaching-learning processes, it still proves to be just as crucial of a component within the framework of a well-rounded society of the 21st century. For this reason, proposals in this regard are beginning to emerge [6].

Specifically, in [7], it is stated that in order for a quality STEM teaching-learning process to take place, one should promote the acquisition of attributes such as being an observant, predictive, critical-reflective person, among others. These attributes will allow for effort to be made regarding the scientific practices of modelling, inquiry and argumentation. Additionally, they will allow for other characteristics to emerge which deal more directly with social and moral skills and abilities such as being a respectful, empathetic or gender-conscious person. This document focuses on the last aspect, as it may be observed from the search for information regarding this matter that the scientific community has demonstrated that the historical and current position of women in mathematics and science has been utterly deprived.

We maintain that there are numerous explanations that have led to this: The non-inclusive language and images used, the overall scientific images or perception which have been transmitted to us through culture, and/or the gender stereotypes transmitted through the education system, families, social networks or the media.

In most cases, this causes girls to not have female role models to look up to, and it implies in a very direct way that the number of women pursuing STEM careers is vastly lower than the number of men, [8].

Thus, as an educational research team dedicated to teacher training, we set out to study the importance all of this has in overall teaching performance.

In order to analyze whether a STEM teaching-learning process accurately meets these characteristics, it was proposed to design a new instrument, which would allow precisely this.

As a starting point we focus on the teaching-learning processes suggested by the current textbooks, and for this we start from the analysis instrument proposed in [1] by teachers of the Faculty of Educational Sciences of the University of Malaga, based on Didactic Analysis (DA). DA is a non-empirical methodology of a meta-analytical nature for the study of a problem or a field of research in Mathematical and Scientific Education.

It allows examination and understanding of the phenomena of Mathematical and Scientific Education and intervenes on them with certain assurances. In this document, we use it to analyze a didactic unit, a textbook or a portion of a textbook (in its Didactic Curricular Analysis modality) [1].

It is necessary to recognize the leading role that textbooks have played in the entire didactic process, which has made them an object of traditional interest in didactic research [9]. The student body assumes that the textbook is the exclusive work and learning guide, and that it contains all the information that one needs to and must know [10].

After having repeatedly used the textbook-analyzing instrument [1] designed by Gallardo and González based on Didactic Analysis, one can see that it is quite tedious, both due to length and format. Furthermore, it does not take into consideration the aforementioned aspects [8].

The objective of this work is to adapt the instrument presented in [1], based on the Didactic Analysis, so that one may analyze the didactic potential of a given textbook with respect to the gender perspective. In addition to simplifying the scheme, it has been updated to a more-accessible and user-friendly technological format. These changes will permit subsequent systematization and analysis results comparison (both being quite complicated within the current format). Consequently, information may be obtained which will in turn help publishing companies in the designing of their textbooks.

2. Results

Part of the theoretical research work carried out by the group is gathered from [11], with the purpose of defining the categories and dimensions allowing us to adapt the instrument so that it responds to our concerns. After the theoretical study carried out, five main categories have been proposed for the new design of the instrument: "Images of Science", "Awareness of Female Role Models", "Non-Sexist Language and Images", "Gender Perspective Behavior" and "Emotions". These in turn are individually specified with a series of indicators (22 indicators in total) Table 1.

These five categories and their corresponding dimensions serve as the backbone of the new instrument.

Table 1. Categories and Indicators

CATEGORIES	INDICATORS
Images of Science	Importance in Society
	Collaborative Image of Science
	Image of Science Outside of Academics
	Image of Science Beyond the Empirical Field
	Non-Elitist Image of Science
	Stereotypical Image of Science and Technology
	Broad Professional Image of Science
	Image of Science, Technology and Mathematics Connected with Art and Creativity
Awareness of Female Role Models	Visibility of Women Scientists
	Visibility of Women Contributions
	Visibility of the Context in Which Contributions of Women Scientists were Created
Non-Sexist Language and Images	Usage of Alternatives to the Generic Male
	Characteristics of Non-Sexist Discourse
	Characteristics of Non-Sexist Images
Gender Perspective Behavior	Equality
	Women Appreciation
Emotions	Fun/Happiness/Enjoyment/Pleasure
	Expectation/Enthusiasm/Curiosity
	Attraction
	Interest
	Safety/Trust/Gratification
	Calmness/Peace

For each of these indicators, three exclusive levels have been defined, with which each indicator is valued as "Positively" (N3), "Neutrally" (N2) or "Negatively" (N1).

By using the instrument of [1] as a foundation and pairing it with the previously mentioned material, we have successfully developed the new instrument that can be found in http://u.uma.es/Z3/adtxinst/, Limesurvay platform. Figure 1 is the screenshot obtained from one of the parts of the instrument.

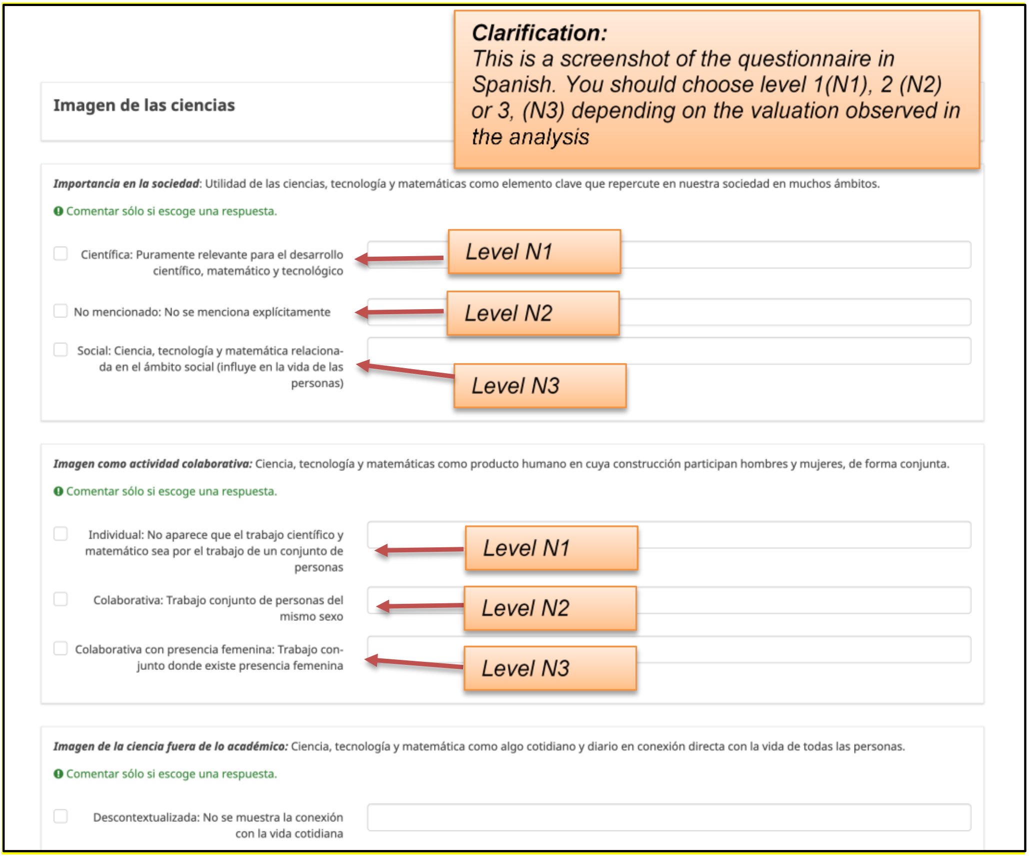

Fig. 1. Screenshot of a section of the instrument, with some clarifying notes overwritten

This new instrument has been tested in two high school textbooks, (Science and Mathematics respectively), and is currently being validated by a committee of nine experts.

3. Conclusion

The instrument that has been constructed through the adaptation and updating of [1] will allow for a new perspective in textbook analysis in which gender equality takes on the leading role which it necessarily deserves. Didactic Analysis, in its modality of Curricular Didactic Analysis, has served to examine and understand some of the phenomena of Mathematical and Scientific Education. Moreover, great progress is made in those studies which state that Mathematics has a threefold character (Instrumental, Formative and Functional).

Thus, it may be observed in a more direct way if textbooks truly promote the acquisition of certain attributes needed from citizens of the 21st century – specifically those related to social and moral skills and abilities. This is achieved through the appropriate usage of language and image, promoting the transmission of a more up to date image of science, where female role models can be seen, and allowing emotions and behaviors which favor equality between men and women.

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INSTRUMENT FOR THE EDUCATIONAL ANALYSIS OF SCIENCE TEXTBOOKS OF SECONDARY EDUCATION FROM A GENDER PERSPECTIVE. Comunicación presentada en 15th annual International Technology, Education and Development Conference.

Copyright Literacy as a Component of the Modern Information and Media Literacy in University Environment: Project Concepts

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Abstract

Introduction: *The diversity of platforms through which media content is disseminated and the digitalisation are changing the media culture. The future is oriented towards transcultural thinking and effective career development and that requires new skills. The new 21st century skills are essentials and are now obligatory for every student and copyright literacy (CL), as one of those skills, is a critical part of media and information literacy. CL and the modern media and information literacy in today's digital world go hand in hand and are built into the educational process together.* ***Presentation:*** *As a combination of knowledge, skills, practices for dissemination of information and knowledge in a new innovative way solve socially significant tasks that arise from real situations in everyday social life. In 2019 two scientific projects funded by the Bulgarian National Science Fund started at the University of Library Studies and Information Technologies, the first one entitled "Model for research and increase copyright literacy at the media in the university environment", financed by the National Science Fund of the Ministry of Education and Science of the Republic of Bulgaria (Contract № KP-06-M35/1 from 18.12.2019, led by Evelina Zdravkova-Velichkova, PhD). The main objective of the project is the research and practical activities related to the formation of the CL of students and professionals in the media. The second one "A Conceptual Educational Model for Enhancing Information Literacy in an University Information Environment" (Contract № KP – 06 – H35/10 from 18.12.2019, led by Prof. DSc Stoyan Denchev, aims to study the state of information literacy, with a special focus of intellectual property literacy in an university information environment among learners and trainers by challenging a civil debate on raising culture on issues of intellectual literacy among academics, which is extremely timely and necessary.* ***The aim*** *of this paper is to study and analyse the nature of CL as a component of the modern media and information literacy. Emphasis is placed on the presentation of two scientific project's results and research activities in the field of media and information literacy, whose main objectives are related to increasing the competence of CL of pupils and students.* ***Methodology:*** *The paper will make a short overview of the project's concepts, drawing out the main activities, related the paper's topic.* ***Conclusion:*** *Thanks to the education in CL students will acquire skills that will prepare them for everything that future holds for us. Creating conditions for the development of creative thinking and copyright competency as part of the media and information literacy in a university environment will contribute to a higher competitiveness of learners in the labour market and to the promotion of an active civil society. The connection of both projects is revealed, as they are both aimed at those new skills, essentials for the whole community, especially in university information environment.*

Keywords: Journalism, Electronic Media, Traditional Media, Intellectual Property, Law, Media Industry, Copyright

1. Introduction

With the rapid development of new technologies, when information becomes one of the most valuable resources, effective information literacy plays a leading role, both in the personal development of scientists and in their ability to pursue basic scientific research. In today's information and knowledge-based society, we are witnessing the expansive development of information and communication technologies (ICTs), which has led to the globalization of information and a new "revolutionary wave", the so-called information wave or wave of knowledge. Some authors call this turning point "the second Gutenberg advent." The amount of electronic information flow is growing exponentially and is reaching the so-called information boom. As Alvin Tofler points out, the creation and dissemination of information has become a major activity and source of power for humanity.

According to some authors, the increase in the growth of electronic information flow is due to the advancement in the field of printing, the multiplication of traditional sources of information and their dissemination on the Internet with the use of web technologies.

Information literacy (IL) has become a concept in recent years and is embedded in many international projects, programs and initiatives, with the main task not only to promote information literacy, but also to promote it as one of the possible solutions to overcome the "digital divide". IG is one of the key competences that builds the fundamental knowledge of modern society. Her upbringing was the initial step in the ability and ability to seek and use the huge information flow.

The achievement of information literacy, which not only corresponds to the contemporary social practice, but also to advance its development, is based on adequate educational models. At the heart of each modern educational model are values, standards, methods and requirements, with the research process based on them being the main approach to training in the context of transdisciplinary topics. In line with this principle, the structure of educational models typically incorporates a specific research program, which includes innovative training, in order to achieve both its educational and scientific objectives.

Intellectual property (IP) reaches the everyday life of each and every one of us, as a part of information literacy in a university information environment. Therefore, awareness of the importance and understanding of intellectual property is essential for today's students, who are the future information specialists, engineers, researchers, lawyers, politicians, and managers of tomorrow.

In the university information environment students have to master the important IP related matter and its application in their upcoming career development. Students and universities have to know how to utilize and benefit from the unparalleled richness of the technical and commercial information, found in IP-related documentation. It is necessary for universities to make efforts to raise awareness of IP issues in the academic community, to research IP right, by engaging in a transfer of technology to industrial partners to create value and benefit for society. Last but not least, students and universities have to be aware with the consequences of the lack of knowledge and the inability to protect their intangible assets under the form of IP, including from risks such as misuse of foreign intangible assets, industrial espionage, etc.

The new information environment imposes new requirements on the competences and knowledge of the young modern professionals, graduating from higher education.

Basic IP knowledge are of particular relevance to the fields of information and social sciences, as currently they are the most dynamically developing. The main areas of realization of specialists in the fields of information and social sciences are: regional and national media; government and non-government organizations and administrations; cultural, archival, and educational institutions. The specifics of the work in these areas are related to the use of a wide range of information resources and products, which is the basis of professional activity and condition for a successful realization. Here, however, the question of awareness and preparedness of IP professionals comes to the agenda. Their competence in the main aspects of IP, in particular the protection of copyright, related rights and industrial property, is an essential part of their complex information literacy, especially in regards to using IP objects on the Internet and the lawful use of digital content. It is here where the actuality of the researched problem is determined as the main goal of IP integration as part of the information literacy in the university information environment is to create a culture of respect towards IP among the academic fields and to increase the competitiveness of future specialists.

2. Copyright Literacy as a Component of the Modern Information and Media Literacy in University Environment: Project Concepts

IP is a special element of IL in university information environment, as to develop good skills, students must learn how to use effectively the wide variety of information products and services available in the digital space. The new information civilization including so called knowledge economy imposes new requirements for the competence and appropriate knowledge of modern young professionals, receiving their higher educational degrees. Especially it's characteristic of professional fields related to information and social sciences, as currently these sciences are one of the most dynamically developing. Knowing the specifics of the problem and typical country trends support the formation and development of proper strategies to improve and enrich the curriculum.

University of Library Studies and Information Technologies (ULSIT) has contributed to the successful dissemination of IP knowledge, as there are already 20 years of experience in IP courses for non-laweyers. ULSIT's contribution to the research of IP awareness in information and social sciences is indisputable, considering two projects that are fully focused on the research of future professionals and practitioners.

The first one entitled: "Model for research and increase copyright literacy at the media in the university environment", financed by the National Science Fund of the Ministry of Education and Science of the Republic of Bulgaria (Contract № KP-06-M35/1 from 18.12.2019, led by Evelina Zdravkova-Velichkova, PhD). The main objective of the project is the research and practical activities related to the formation of the Copyright Literacy (CL) of students and professionals in the media. Media plays an extremely important role in the dynamic and increasingly complex societies of today. The information society of the 21st century accelerates the pace of development of human intellectual activity. Unique creative outputs are created in industry, science, literature and the arts. The audience has potential access to an unprecedented range of journalistic sources. The legal rights of authors of creative products in the media are intellectual property rights, which should be regarded as objective and subjective law, discipline and science. There is no discipline in the curricula of higher education in the field of copyright in the media. So far, no research has been conducted on copyright literacy in the media industry among students learning in the fields of journalism, media, public relations, communications, as well as the establishment of copyright competence of specialists in this field. Observations show that this competence is not at the necessary level, there is a real need for additional knowledge and training. Existing models and best practices in Europe and in the world are also unknown. Within the framework of this project a study will be made related to the formation of copyright literacy of students learning in the professional field “Public Communications and Information Sciences” at ULSIT and students learning in similar specialties in other higher education institutions; will be studied also the educational content offered by higher education and programs that meet this range of knowledge and competences.

The main objective of the project is research and practical activities related to the formation of copyright competence of students and the creation of a concept for its further improvement.

The object of the study of this project is the impact of technologies on the transformation of media in an intellectual law aspect, in particular copyright literacy at media in university environment.

The subject of the study will be the disclosure of the state and peculiarities of the media as objects of intellectual property, in particular copyright and related rights, as well as their peculiarities.

The working hypothesis of this study can be formulated as follows: The lack of knowledge of copyright and related rights at the media in university environment and the increasingly obsessive tendency for the free use of journalistic material in the commercial digital space provokes the need for filling some of the gaps in media industry research related to the intellectual property aspects of the media industry, in particular copyright and related rights. The specific manifestations of the interaction between media product creators and consumers, their role as authors of knowledge, information and culture for society and overcoming the digital divide and isolation, and the need for this to be bound by copyright and related rights in the media – these components outline the relevance of the study.

In order to achieve the goals of the project, a training course will be developed in accordance with the professional direction of the students.

The second one entitled: “A Conceptual Educational Model for Enhancing Information Literacy in an University Information Environment” (Contract № KP – 06 – H35/10 from 18.12.2019, led by Prof. DSc Stoyan Denchev, aims to study the state of information literacy, with a special focus of intellectual property literacy in an university information environment among learners and trainers by challenging a civil debate on raising culture on issues of intellectual literacy among academics, which is extremely timely and necessary.

The role and place of creativity and innovation for modern societies has been repeatedly reaffirmed in various strategic documents, including the Europe 2020 Strategy for smart, sustainable and inclusive growth (COM (2010) 2020 final) and the European Commission Green Paper “Unlocking the Potential of the cultural and creative industries”, which, on the other hand, placed on a strong, competitive and diversified industrial basis with a view to building a society and knowledge economy, creativity and innovation are a common goal European Union, which implies a differentiated approach, reflecting the social, economic, cultural and educational differences between Member States. The future of the culture of society implies the development of new forms and policies that will change the current ones. The achievement of such a state of the culture of society requires the support of strategically important initiatives such as: preservation and promotion of cultural diversity, creative mobility, protection of intellectual property, enhancing intellectual literacy of society, and creation of conditions for development of quality education in the field of the cultural, information and creative industries.

This project is entirely in line with both the above-mentioned strategic documents and the National Research Strategy 2017-2030 as it aims to: study the state of IL, with a special focus of intellectual literacy in a university information environment among learners and trainers by challenging a civil debate on raising culture on issues of intellectual literacy among academics, which is extremely timely and necessary.

Conducting research related to the creation of a conceptual educational model for raising IL, in particular intellectual legal literacy in a university information environment, is conditioned by a number of prerequisites. First of all, there is a limited number of in-depth independent studies focusing on the relationship between IP and IL in a national perspective; secondly, the need to explore existing models and best practices for IP training for non-specialist lawyers in Europe and the world; third, to analyze the educational content offered and the curricula relevant to this spectrum of knowledge; in the fourth place, it is necessary to examine the foreign experience of existing networks in raising awareness of IP issues; Fifth, the need to examine the level of awareness of human rights and social sciences in the humanities and social sciences, both among trainees and university educators. After all, it has to be concluded that the issue of the positioning of IP in the context of the broader framework of IL is relevant, timely and necessary. The problem under consideration is extremely relevant, partly concerned with various aspects by other authors, but has not been fully disclosed so far.

The subject of the project proposal is interdisciplinary and covers current issues in the field of social and humanities, law, formal and non-formal education, pedagogy, sociology and other areas considered in the context of the contemporary information society. The project puts purposefully linked research tasks at three levels: The first level is of a theoretical nature: the accumulation of factual information in the form of bibliographical references on the subject of the project; studying models and good practices for integrating IS education into a university environment in the social and human sciences, on a national, European and international scale; developing questionnaires and conducting two surveys among learners and trainers; opening the international survey and conducting it in Italy and Australia. The second level has a practical application and the main task at this level is to create a common and comprehensive methodology for raising awareness of intellectual property issues in the university information environment, disseminating intellectual property knowledge and promoting the objectives, activities and results of the project by: creating a dedicated website for the project; organizing and conducting a scientific seminar with international participation dedicated to the International Intellectual Property Day (26 April).

The third level has a methodological and informational nature, and the basis of this level is the development of a model for formal and informal intellectual property education. Creating new learning content aimed at students in social and humanities, as well as creating training courses for university lecturers. Promotion of the innovative model for the integration of intellectual literacy in a university information environment.

Performing a series of master classes, workshops and public lectures aimed at both students, PhD students and young scientists in the team.

In order to achieve the stated objective and the resulting sub-objectives, the project will use interdisciplinary research tools, including: a complex approach; method of searching, analysis, synthesis and systematization of factual information; descriptive and comparative method; survey method; modeling method, etc.

The research team of the project consists of leading Bulgarian scientists and the interdisciplinary problem of the project is covered by researchers with corresponding scientific interests, achievements and international reputation in the field of theory and practice of intellectual legal issues, which is visible from the scientific publications mentioned in their biographies, lecture courses and participation in expert groups, committees and projects. The capacity of the scientific team is complemented by a core of prominent international specialists in the studied subject.

3. Conclusion

In conclusion we could say that ULSIT is one of the universities in Bulgaria appreciated the role and importance of Intellectual Property as a stimulator of innovation development and step by step carrying out the necessary steps to disseminate knowledge and information on Intellectual Property. As can be seen from the above-mentioned project initiatives, SULSIT works really very actively to achieve its ambition to train students on Intellectual Property Rights in all three forms of education: full, part time and distance, as well as three degrees: Bachelor, Master and Doctoral. These two projects make the relation between the science education in one hand and the media practitioners in other. It conducts its activities in support of the initiatives of the two leading organizations in the world – the World Intellectual Property Organization and the European Patent Organization, and implement its initiatives.

Acknowledgments

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Chemistry Education

Assessment Tool for Scientific Thinking and Reasoning Skills: An Inspiration for University Graduates in Natural Sciences

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Abstract

The competencies for the 21st century call for people with a broad and interrelated system of knowledge, skills, values and attitudes for the full application of an individual in personal and professional life. Education, including higher education, focuses therefore not only on the development of knowledge but also on inquiry, critical thinking, analytical thinking, problem solving and decision making. All these skills are often labeled as scientific thinking and reasoning skills. Our long-term research shows that employers from manufacturing and services firms in natural sciences may expect these abilities from their job applicants. However, they often do not find them at the university/high-school graduates seeking for a job. The students have a good domain-specific knowledge of content and basic procedures (in chemistry and biology, among other fields), but they are not able to apply scientific thinking and reasoning skills such as asking precisely formulated questions, drawing conclusions considering all evidence or communicating conclusions properly. This may be due to the fact that they do not have many opportunities to practice such tasks. In order to support both participants/sides, we have developed several tasks for specific positions in companies, such as quality control analyst, quality assurance specialist, or validation specialist. These tasks can serve as a tool for companies to evaluate the skills of scientific thinking and reasoning of employees, as well as tasks that will give the university graduate a clearer idea of the scientific thinking and reasoning skills, they must demonstrate during the job interview. A qualitative research study with representatives of manufacturing and services firms in natural sciences was performed: the data collected in structured interviews resulted in a scientific and reasoning framework. This framework and other information from the interviews served as a basis for creating specific tasks. The content and construct validity of the tasks were approved by an expert panel (representatives of the companies) and through pilot testing with a small sample of employees and students. Selected tasks will be presented and discussed in the context of scientific and reasoning skills.

Keywords: Scientific Thinking and Reasoning, Task, Science Education

1. Study background

The world has experienced significant changes in the last decades – digital, technological and scientific – which have influenced the labor market, as well as education. Entrepreneurship in today's economy calls for the creation of new opportunities in an environment characterized by a high degree of complexity and uncertainty; the economy and society focus on innovations [1]. However, such innovations require a greater capacity of human capital – workers with deeper cognitive, technical and soft skills and experiences, in other words, a broad scale of competencies known as 21st century skills. In turn, these requirements put pressure on educational systems that prepare students for their future careers. Therefore, education, including higher education, focuses not only on the development of deeper knowledge but also on inquiry, critical thinking, analytical thinking, problem solving and decision-making [2]. All these skills are often labeled as scientific thinking and reasoning skills in science.

In accordance with Albert Bandura's Social Learning Theory, success in the workplace depends not only on cognitive, technical and behavioral skills but also on an individual's self-efficacy. Self-efficacy is understood as an individual's perception of their ability to achieve a particular task [3]. The question is how self-efficacy can be developed in students during their studies. Coll and Zegwaard [4] argue that authentic work experience may play a key role in the development of graduate competencies contributing to self-efficacy, and such abilities can be developed by combining classroom-based instruction with one or more periods of relevant experiential learning in authentic work settings (e.g., work experience placement). We believe that creating tasks mimicking the real environment of companies in which students can solve problems and situations that commonly occur in such companies can enhance students' competencies and strengthen their self-efficacy. Solving authentic work tasks can help graduates get a specific job and manage everyday activities and problems they may encounter in their work. Therefore, this approach is beneficial for both graduates and companies. In our research, we focus on designing tasks related to authentic work problems that improve scientific thinking and reasoning skills of students such as asking precisely formulated questions, drawing conclusions considering all evidence, or communicating conclusions properly. Here, we present such a task (see below, Fig. 1.) based on the scientific thinking and reasoning framework developed in cooperation with selected companies.

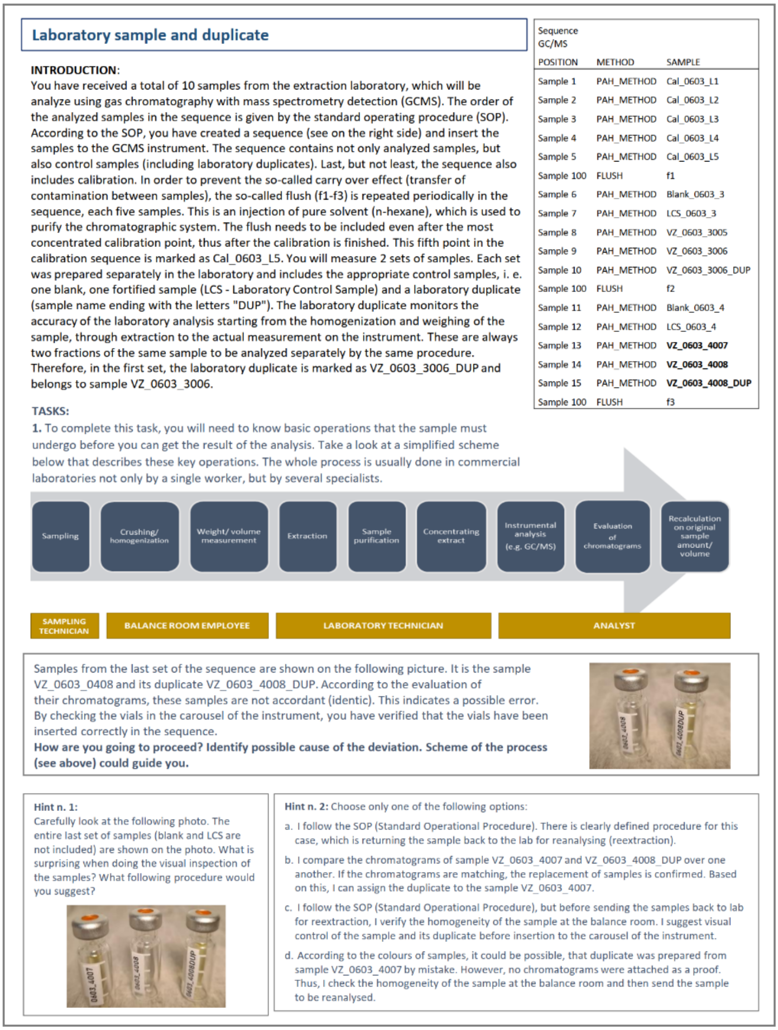
2. Methodology

In 2019 and 2020, a qualitative research study with representatives of manufacturing and services firms in natural sciences was performed [5]. A prototype of a scientific thinking and reasoning framework, based on methods of theoretical scientific research, was created and discussed with representatives of the firm. This research resulted in a comprehensive framework of scientific thinking and reasoning gathering general scientific thinking and reasoning skills (e.g., identifying a problem, asking precisely formulating question, drawing conclusions considering all the evidence), domain specific scientific thinking and reasoning skills (knowledge of content of the field and knowledge of industry-specific skills) and supporting general abilities and skills (e.g., ability to read and understand scientific texts, ability to write scientific reports, or the ability to present results and convey knowledge to different target groups). Now we have used this framework to create specific tasks proving scientific thinking and reasoning skills. The tasks are based on authentic work problems of firms which were selected by the author of the article based on many years of experience working in several manufacturing and services firms in different work positions. The content validity was approved by an expert panel – representatives of the companies [6] and the construct validity of the tasks was assessed by pilot testing with a small sample of employees – experts and students – novices [7], who checked the quality of the tasks.

3. Results

Our research resulted in a set of tasks reflecting authentic work problems of firms.

The tasks are set in the context of scientific and reasoning skills, i.e., each of the particular sub-tasks is labeled with a particular set of general scientific thinking and reasoning skills from the scientific thinking and reasoning framework perspective (see the task below). These tasks can serve as a tool for companies to evaluate the skills of scientific thinking and reasoning of employees, as well as tasks that will give the university graduate a clearer idea of the scientific thinking and reasoning skills that they must demonstrate during the job interview. The tasks also provide information to educators, who can include similar topics or tasks in their curriculum. Getting to know authentic problems within the education and the possibility to solve authentic/real tasks can help develop graduate competencies contributing to self-efficacy. Here, we show an example of a task for verifying the ability of students to identify the problem, to formulate an evidence-based scientific hypothesis, to draw conclusions considering all the evidence and to communicate conclusions, including argumentation (Fig. 1.).


Laboratory sample and duplicate

INTRODUCTION:
You have received a total of 10 samples from the extraction laboratory, which will be analyze using gas chromatography with mass spectrometry detection (GCMS). The order of the analyzed samples in the sequence is given by the standard operating procedure (SOP). According to the SOP, you have created a sequence (see on the right side) and insert the samples to the GCMS instrument. The sequence contains not only analyzed samples, but also control samples (including laboratory duplicates). Last, but not least, the sequence also includes calibration. In order to prevent the so-called carry over effect (transfer of contamination between samples), the so-called flush (f1-f3) is repeated periodically in the sequence, each five samples. This is an injection of pure solvent (n-hexane), which is used to purify the chromatographic system. The flush needs to be included even after the most concentrated calibration point, thus after the calibration is finished. This fifth point in the calibration sequence is marked as Cal_0603_L5. You will measure 2 sets of samples. Each set was prepared separately in the laboratory and includes the appropriate control samples, i. e. one blank, one fortified sample (LCS - Laboratory Control Sample) and a laboratory duplicate (sample name ending with the letters "DUP"). The laboratory duplicate monitors the accuracy of the laboratory analysis starting from the homogenization and weighing of the sample, through extraction to the actual measurement on the instrument. These are always two fractions of the same sample to be analyzed separately by the same procedure. Therefore, in the first set, the laboratory duplicate is marked as VZ_0603_3006_DUP and belongs to sample VZ_0603_3006.

Sequence GC/MS

POSITION	METHOD	SAMPLE
Sample 1	PAH_METHOD	Cal_0603_L1
Sample 2	PAH_METHOD	Cal_0603_L2
Sample 3	PAH_METHOD	Cal_0603_L3
Sample 4	PAH_METHOD	Cal_0603_L4
Sample 5	PAH_METHOD	Cal_0603_L5
Sample 100	FLUSH	f1
Sample 6	PAH_METHOD	Blank_0603_3
Sample 7	PAH_METHOD	LCS_0603_3
Sample 8	PAH_METHOD	VZ_0603_3005
Sample 9	PAH_METHOD	VZ_0603_3006
Sample 10	PAH_METHOD	VZ_0603_3006_DUP
Sample 100	FLUSH	f2
Sample 11	PAH_METHOD	Blank_0603_4
Sample 12	PAH_METHOD	LCS_0603_4
Sample 13	PAH_METHOD	**VZ_0603_4007**
Sample 14	PAH_METHOD	**VZ_0603_4008**
Sample 15	PAH_METHOD	**VZ_0603_4008_DUP**
Sample 100	FLUSH	f3

TASKS:
1. To complete this task, you will need to know basic operations that the sample must undergo before you can get the result of the analysis. Take a look at a simplified scheme below that describes these key operations. The whole process is usually done in commercial laboratories not only by a single worker, but by several specialists.

Samples from the last set of the sequence are shown on the following picture. It is the sample VZ_0603_0408 and its duplicate VZ_0603_4008_DUP. According to the evaluation of their chromatograms, these samples are not accordant (identic). This indicates a possible error. By checking the vials in the carousel of the instrument, you have verified that the vials have been inserted correctly in the sequence.
How are you going to proceed? Identify possible cause of the deviation. Scheme of the process (see above) could guide you.

Hint n. 1:
Carefully look at the following photo. The entire last set of samples (blank and LCS are not included) are shown on the photo. What is surprising when doing the visual inspection of the samples? What following procedure would you suggest?

Hint n. 2: Choose only one of the following options:

a. I follow the SOP (Standard Operational Procedure). There is clearly defined procedure for this case, which is returning the sample back to the lab for reanalysing (reextraction).

b. I compare the chromatograms of sample VZ_0603_4007 and VZ_0603_4008_DUP over one another. If the chromatograms are matching, the replacement of samples is confirmed. Based on this, I can assign the duplicate to the sample VZ_0603_4007.

c. I follow the SOP (Standard Operational Procedure), but before sending the samples back to lab for reextraction, I verify the homogeneity of the sample at the balance room. I suggest visual control of the sample and its duplicate before insertion to the carousel of the instrument.

d. According to the colours of samples, it could be possible, that duplicate was prepared from sample VZ_0603_4007 by mistake. However, no chromatograms were attached as a proof. Thus, I check the homogeneity of the sample at the balance room and then send the sample to be reanalysed.

Fig. 1. Example of a task for scientific thinking and reasoning skills assessment
(Note: The hints included in the task are on a separate page; whether the students need to use it or not depends on them)

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Bromination of Fluorescein – A Facile Model Experiment for Electrosynthesis in Chemistry Classes

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Abstract

Since electrochemical processes inherently benefit from the increasing share of renewable energy sources for power generation in the grid, they can play a valuable role in future processes in chemical industry helping to make production more sustainable and efficient. However, due to often complex setups and the lack of striking experiments, examples for electrosynthesis are rarely discussed in science classes.
The experiment presented herein describes the electrosynthetic bromination of fluorescein to Eosin Y (tetrabromo fluorescein) via reactive bromine generated in-situ [1]. The developed experiment makes use of bromide ions which are oxidized at the anode to form a reactive intermediate and is therefore avoiding the direct handling of hazardous bromine by school students. The reaction of fluorescein with bromine is well-established since it can be monitored easily by changes in both adsorbed and fluorescent colour and is commonly used as a detection reaction for bromine.
Within several minutes at low voltages of around 3 V, a significant change in colour from yellow to red is observable and at the same time the intense yellow green fluorescence under UV light vanishes at the given slightly basic pH condition. The product can be precipitated by lowering the pH and subsequently collected by filtration. In comparison with fluorescein, the tetrabromo derivative shows a greatly increased solubility in water which can serve as a suitable example for the concept of structure-properties-relations. Furthermore, a semi-quantitative analysis of the Fluorescein/Eosin Y ratio can be performed by thin-film chromatography where both components are easily distinguishable by their respective fluorescence colour under UV irradiation. This experiment can be expanded to a set of experiments by synthesizing the fluorescein in the lab course via reaction of resorcinol with phthalic anhydride as well as using the Eosin Y product as a photoredox organocatalyst [2, 3].

Keywords: Electrosynthesis, fluorescence, model experiment

1. Introduction

In this contribution, we present an electrosynthetic bromination experiment involving two disctinctly colored dyes. In these experiments, we convert fluorescein into eosin Y using electrochemically generated bromine. This *in-situ* formed reagent reacts immediately with the fluorescein, ensuring a low concentration of free bromine. Since the electrical energy production is shifting more and more to renewable sources [4], a process like this using electrical power to drive chemical reactions offers the possibility to be more sustainable than conventional synthesis strategies. These aspects, which can be discussed on the example of our model experiment, fit well to concepts from the green chemistry approach: Apart from the use of renewable energies, the in-situ generation of low amounts of toxic and reactive species reduces hazard risk, leading to a safer process for accident prevention as demanded in the green chemistry principles [5]. The following described experiments consist of a quick to perform synthesis of eosin Y, thin layer chromatography for semi-quantitative analysis, a protocol for synthesis and recovery of the solid product and a detection of intermediately formed bromine.

2.1.1 Electrosynthesis of Eosin Y

In this experiment, eosin Y is produced by electrosynthesis from fluorescein.

Equipment: voltage source, cables, stir bar, magnetic stirrer, iron electrode, graphite electrode, crocodile clips, voltmeter, beakers, spatula, scale, UV lamp (354 nm).

Chemicals: water, sodium hydrogen carbonate, potassium bromide, fluorescein (sodium salt).

Procedure: 20 g sodium hydrogen carbonate, 10 g potassium bromide and 40 mg fluorescein were dissolved in 200 mL water under stirring and gentle heating. The solution is then divided equally among four beakers. After cooling to room temperature three of these solutions are electrolyzed for different times at 3 V DC, with the graphite electrode as the anode and the iron electrode as the cathode. The samples are electrolyzed for 30 seconds, 1 minute and 2 minutes, respectively. The fourth sample is used as a reference.

Observations: The reference solution is strongly yellow colored and emits an intense green light under UV irradiation. It can be observed that with longer electrolysis times, the color becomes redder (figure 1). Analogous to this color change, the fluorescence intensity decreases with increasing reaction time.

Fig. 1. Fluorescein solution, electrolyzed solutions after 30 seconds,
1 minute and 2 minutes, respectively

Interpretations: At the cathode, water is reduced to hydroxide ions and hydrogen gas. At the anode, bromide ions are oxidized to elemental bromine. The evolution of bromine under similar conditions can be tested by addition of bromine to alkenes in chapter 2.3.

Oxidation: $2\ Br^- \rightarrow Br_2 + 2\ e^-$ Reduction: $2\ H_2O + 2\ e^- \rightarrow 2\ OH^- + H_2$

However, this bromine does not accumulate in solution, but reacts *in-situ* with fluorescein in the solution to yield tetrabromofluorescein (eosin Y). The increasingly red color indicates the progress of this bromination.

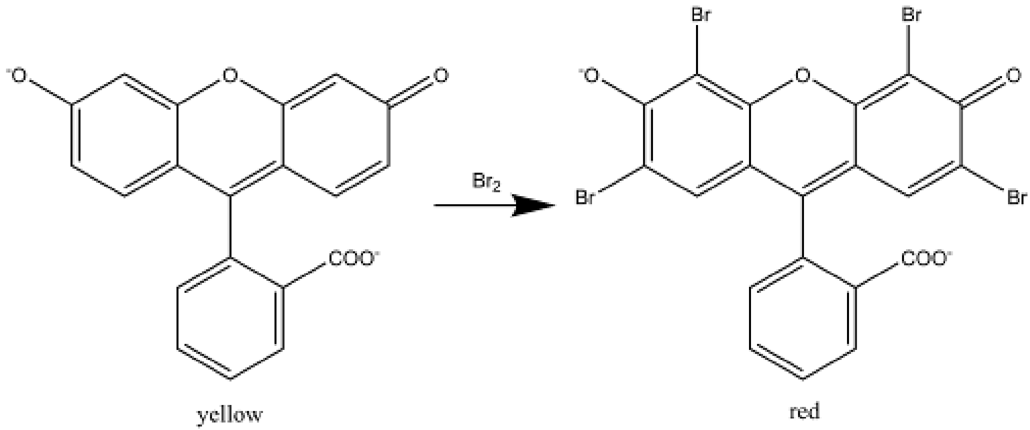

Fig. 2. Bromination of Fluorescein

2.1.2 Thin layer chromatography (TLC)

To show the effect of different reaction times semi-quantitatively, a TLC is performed to analyze the products from the previous experiment.

Equipment: thin layer chromatography (TLC) plate (silica gel), TLC chamber, glass capillaries, pipettes, beaker, graduated cylinder, UV lamp (354 nm)

Chemicals: solutions from experiment 2.1.1, butanone, concentrat.ed ammonia solution (25 wt%), ethanol.

Procedure: The mobile phase consists of 24 mL butanone, 2 mL concentrated ammonia solution and 10 mL ethanol. The TLC chamber is filled to a height of approx. 0.5 cm with the mobile phase and kept closed to enrich the atmosphere with the mobile phase.

A small drop of each solution is placed on the plate 1 cm from the bottom using a capillary. The plate is then placed in the chamber and removed when the mobile phase approaches the end of the plate. After drying, the samples are examined under UV light.

Observations: Figure 3 shows the results of the TLC both under daylight as well as UV light, with the sample on the left representing the reference solution with additional eosin Y added for comparison.

While sample 1 shows three spots, samples 2 and 3 each five spots. In sample 4, only one spot is visible.

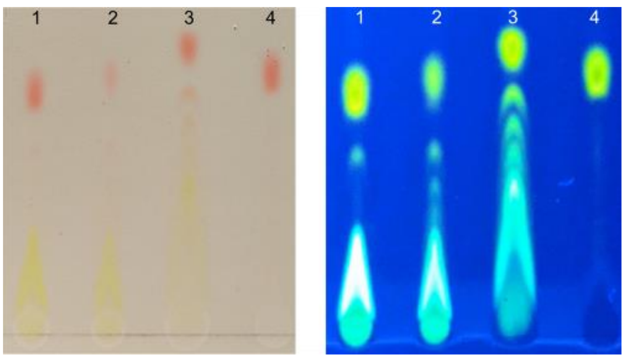

Fig. 3. left: reference solution with added eosin Y, electrolyzed solutions after 30 seconds, 1 minute and 2 minutes, respectively;
right: same TLC plate under UV light

Interpretations: In each case, the green fluorescent spot at the lower end can be attributed to fluorescein. The upper spot (whose orange color under UV cannot be properly displayed by the camera) represents the fully brominated species eosin Y. The intermediate spots can be assigned to the three incompletely brominated intermediates.

In sample 4, all of the fluorescein has been converted to eosin Y. The additional spot in sample 1 is due to impurity of commercial eosin Y.

2.2.1 Synthesis and product isolation

While the experiment 2.1.1 illustrates the progress of the reaction, the concentrations are too low to yield a solid product. Therefore, the experiment described herein uses a higher concentration of fluorescein to make precipitation of the product possible.

However, due to the high fluorescein concentration, the color gradient during bromination is not as visible as in experiment 2.1.1.

Equipment: voltage source, cables, stir bar, hotplate stirrer, iron electrode, graphite electrode, crocodile clips, voltmeter, beakers, spatula, scale, büchner flask, paper filter, büchner funnel, vacuum pump, vacuum tube.

Chemicals: water, sodium hydrogen carbonate, potassium bromide, fluorescein (sodium salt), hydrochloric acid (semi-concentrated).

Procedure: 5 g sodium hydrogen carbonate, 2.5 g potassium bromide and 0.4 g fluorescein were dissolved in 50 mL water under stirring and gentle heating. After cooling to room temperature, the solution is then electrolyzed under stirring at 3 V DC for at least 5 minutes with the graphite electrode as the anode and the iron electrode as the cathode.

The product is precipitated by acidifying the solution with semi-concentrated hydrochlorid acid and collected using a büchner funnel. After washing the red solid with cold water, it can be dried by gentle heating on a hot plate.

Observations: The orange solution (due to high fluorescein concentration) turns increasingly red in the course of the electrolysis. During addition of hydrochloric acid, gas evolution leads to the formation of foam. After neutralisation a red-orange solid precipitates, which turns more yellow-orange after drying.

Interpretations: As in experiment 2.1.1, the fluorescein is brominated to orange-red eosin Y. Acidifying the solution protonates the carboxylate groups of the residual reactands and products and thus form carboxylic acid groups. This lowers the solubility in water by reducing the polarity of the molecules and causes them to precipitate.

2.2.2 Thin layer chromatography of the isolated product

The isolated product can also be analyzed by TLC.

Equipment: thin layer chromatography (TLC) plate (silica gel), TLC chamber, glass capillaries, pipettes, beaker, measuring cylinder, UV lamp (354 nm).

Chemicals: precipitated solid from 2.2.1, butanone, concentrated ammonia solution, ethanol, sodium hydrogen carbonate, water, fluorescein, eosin y.

Procedure: The same mobile phase is used as in experiment 2.1.2. A few crystals of the precipitated solid are dissolved in a small amount of an aqueous sodium hydrogen carbonate solution and then applied to the plate as in 2.1.2. Fluorescein and, if available, purchased eosin Y can also be applied as a comparison.

Observations: Figure 4 shows the results of the TLC under UV light. As in experiment 2.1.2 the different spots can be observed. In comparison to 2.1.2 the separation of these spots is more clearly visible.

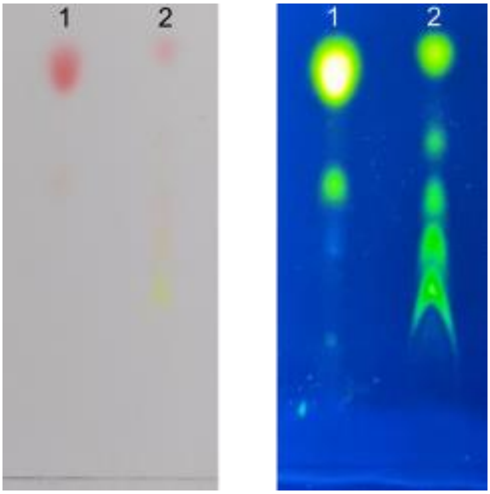

Fig. 4. left: solution with eosin Y and solution of the product;
right: same TLC plate under UV-light

Interpretations: The sample must be treated with basic solution to convert the carboxylic acid group back to a carboxylate group and make it more soluable. In comparison to 2.1.2 the formation of eosin Y can be confirmed. However, due to the higher amount of reactand, despite longer reaction time full bromination cannot be achieved.

2.3 Verification of bromine as an* in-situ *reactand

The synthesis instruction is performed without fluorescein to prove the generation of elemental bromine under the given electrochemical conditions.

Equipment: voltage source, cables, stir bar, magnetic stirrer, iron electrode, graphite electrode, crocodile clips, voltmeter, beakers, spatula, scale.

Chemicals: water, sodium hydrogen carbonate, potassium bromide, alkene (e.g., cyclohexene).

Procedure: 5 g sodium hydrogen carbonate and 2.5 g potassium bromide and were dissolved in 50 mL water under stirring and gentle heating. The electrogeneration of bromine is carried out according to the procedure described in 2.1.1 for 2 minutes.

Several mililiters of this solution are thoroughly mixed with a few drops of alkene (e.g., cyclohexene).

Observations: The solution turns yellowish during electrolysis. After adding the alkene and shaking briefly, the solution turns colorless (figure 5).

Fig. 2. left: solution after electrolysis;
right: colorless solution after the addition of the alkene

Interpretation: In the absence of fluorescein, the yellow color of the bromine is clearly visible, since it can accumulate in the electrolyte. The decolorization of this solution by reaction with an unsaturated hydrocarbon proves the presence of elemental bromine.

3. Didactical considerations

The series of experiments is valuable to discuss the benefits of electrosynthetic methods in a school environment. From a practical point of view, the experiments are facile and inexpensive to perform, so that they can be easily established in chemistry classes. The bromination experiment can be performed in 5 minutes and shows that even organic chemical reactions can be driven by electrical energy. The students can monitor the progress of the reaction by observing the pronounced change in color without any further analysis techniques. However, this experiment can be extended in order to cover analytical aspects and mechanistical considerations: Via TLC the students can verify the reaction progress semi-quantitatively and confirm that the reaction is completed after several minutes. Furthermore, the intermediate bromination products (mono-, di-, tribromofluorescein) can be identified as well. Independently, the hypothesis of bromine acting as the *in-situ* formed bromination species can be confirmed by the students (for example as part of an exploratory approach) using a detection method they are already familiar with.

The experiments enable the training of numerous competences: They cover typical laboratory skills such as the isolation and purification of products. Using the example of TLC, theoretical aspects of chromatography and underlying structure-property relationships can be adressed here. Structure-property relationships also includes altering the solubility through protonation used for precipitation.

As an interesting side note, the TLC analysis reveals that commercial eosin Y contains the same impurity as observed in our experiment.

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Digital and Low-Cost – Development of a Polarimeter on a Raspberry Pi

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Abstract

Digital data acquisition in science lessons is a particular challenge in terms of availability and operation of the devices. Classical laboratory measuring instruments often focus on data acquisition, which is why the handling in the classroom varies greatly depending on the manufacturer and equipment. Access to complex measuring equipment such as spectrometers or polarimeters is further complicated by high costs. With the help of individual electronic components and various materials or in combination with a 3D printer, some of these measuring devices can be reproduced, which makes access in STEM-classes inexpensive [1-3]. At last, the measurement values are recorded by handwritten transmission and application of measured variables or the strength of acoustic signals, which on the one hand requires time and on the other hand can make joint evaluation difficult.
The LabPi software [4], which was specially developed for the Raspberry Pi single-board computer, offers an additional digital solution to this challenge. This software combines different measuring instruments to a uniform low-cost measuring station with the help of a multitude of miniature sensors. It is didactically tailored to teaching and thus offers a basis for supplementing previously analog processing steps with the aspect of digital data acquisition and evaluation.
The article presents the development of a low-cost polarimeter based on the Raspberry Pi and the software LabPi. The construction and the functionality of the digital polarimeter are described by means of simple components. In addition, the possibilities for digital evaluation and visualization of optically active substances are presented by means of selected comparative measurements.

Keywords: Measurement Systems, LabPi, Digitalization, STEM Education 4.0

1. Measured value acquisition in STEM lessons

Digital measuring systems have become indispensable in everyday life. Whether in industry or in the laboratory, measured variables such as temperatures, pH values, conductivities or concentrations can be recorded and evaluated quickly and, in some cases, fully automatically with the help of computer-aided measuring systems.

Progressive digitization means that learners should be prepared for future challenges, but digital measurement acquisition in schools still represents a major challenge. The acquisition of digital measuring instruments such as spectrometers, gas chromatographs or polarimeters is often associated with high costs for schools. Once purchased, they are only available to teachers, which means that the devices are mainly used in demonstration experiments.

To enable students to use suitable measuring equipment, a whole range of low-cost measuring devices have been developed. These range from melodic conductivity testers to homemade LED photometers [1-3]. However, the evaluation is still often done by hand. A digital extension to this is offered by single-board computers such as the Raspberry Pi. Combined with appropriate sensors, the Raspberry Pi can serve as a basis for digital data acquisition and as a complete computer on which evaluation can be performed using suitable office applications.

In chemistry classes, polarimetry is integrated into the subject area of hydrocarbons, especially when the optical properties of sugars and chiralities are discussed. It is therefore all the more important that optical effects, such as the rotation of polarized light, can also be analyzed practically. This paper therefore presents the development and testing of a digital low-cost polarimeter based on the Raspberry Pi with its own software.

2. Development and the Software LabPi

Digital polarimeters are among the most expensive measuring instruments that can be used in educational institutions. Even the purchase of an analog measuring device can be in the high three-digit range. Even if the precision of the conventional measuring instruments is very high, the data acquisition is a big challenge. Reading of measurement data must be trained and are read differently by learners. Lastly, the comparability of data must be gathered from all learner groups if possible.

The digital polarimeter presented here should be able to be integrated with easily accessible components in the low-cost range. Furthermore, by building the device oneself, the functions of the individual components and their mesh are easier to comprehend, which can counteract the black box character for learners.

The angle of rotation is measured in a similar way to a photometer via the light intensity or the transmission of aqueous solutions. This is detected by a digital light sensor [4] using a yellow LED (570 nm) as the light source. Two polarization filters serve as polarizer and analyser, which can be purchased cheaply or taken from discarded 3D glasses. To be able to determine a rotation angle, the analyser was glued to a servo motor (Fig. 1).

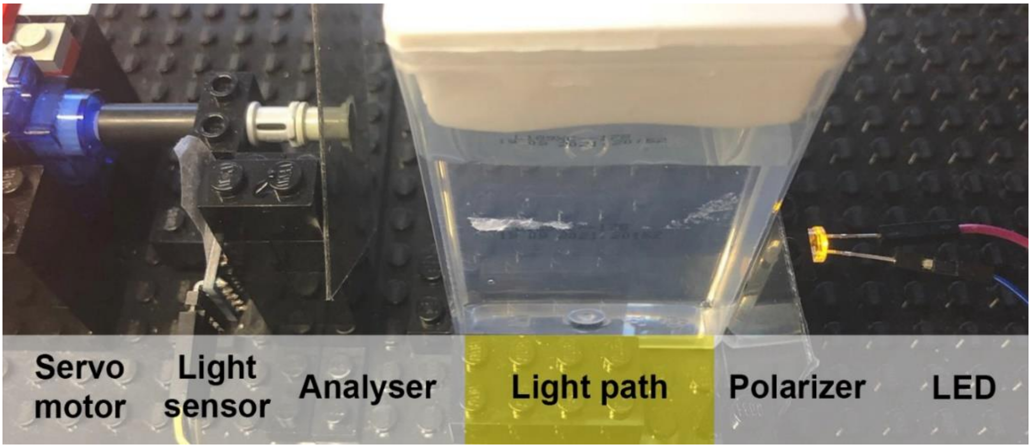
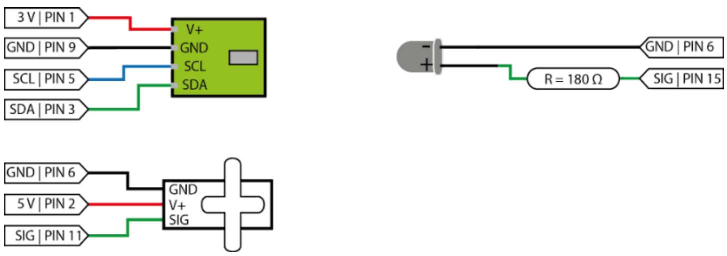


Fig. 1. The digital polarimeter buildup

The structure is supported using various Lego bricks. These serve to stabilize the servo motor, but also as a socket for the LED, which is used to define the light path. The light intensity sensor is placed behind the analyser exactly opposite the LED.

For measuring aqueous solutions, a large, transparent plastic jar for peppermint candy is sufficient that a cuvette is not required. The inner diameter was determined in advance (d=0.47 dm) and is necessary for the later experimental setup as a parameter of the layer thickness.

Figure 2 schematically summarizes how the electronic components are finally connected to the Raspberry Pi correctly. If the respective electronic components are connected as indicated and a suitable software operates the servo motor, it is possible to set a rotation angle from 0° to 180° and therefore to measure the respective light intensities.



Component	***Price***
Raspberry Pi	*40 €*
LED	*1 €*
Light sensor	*5 €*
Servo motor	*5 €*
Polarizer	*10 €*
Lego Bricks	*10 €*

Fig. 2. Schematic wiring of the of components on the Raspberry Pi's GPIOs and pricing of components

To control the sensors of the digital polarimeter, the already existing software LabPi was used [5]. This software is freeware and allows the measurement with different sensors without programming skills. In addition, it has a user interface tailored to teaching, which was developed for the Raspberry Pi. The software was first adapted and expanded to the functionality of the digital polarimeter. LabPi thus takes over automated processes, such as moving the analyser and recording the measurement points.

The software finally displays these in tabular and graphical form. The curve progressions and measurement data can then be compared directly in the software.

Depending on the requirements of the learning group and the experimental setup, differences can be visualized and displayed on the graphical interface or the measurement data can be exported for further analysis (Fig. 3). In addition to recording and displaying measured variables, an upload function to the COMPare Cloud platform can be used, which opens collaborative learning opportunities and makes recorded graphs easier to compare.

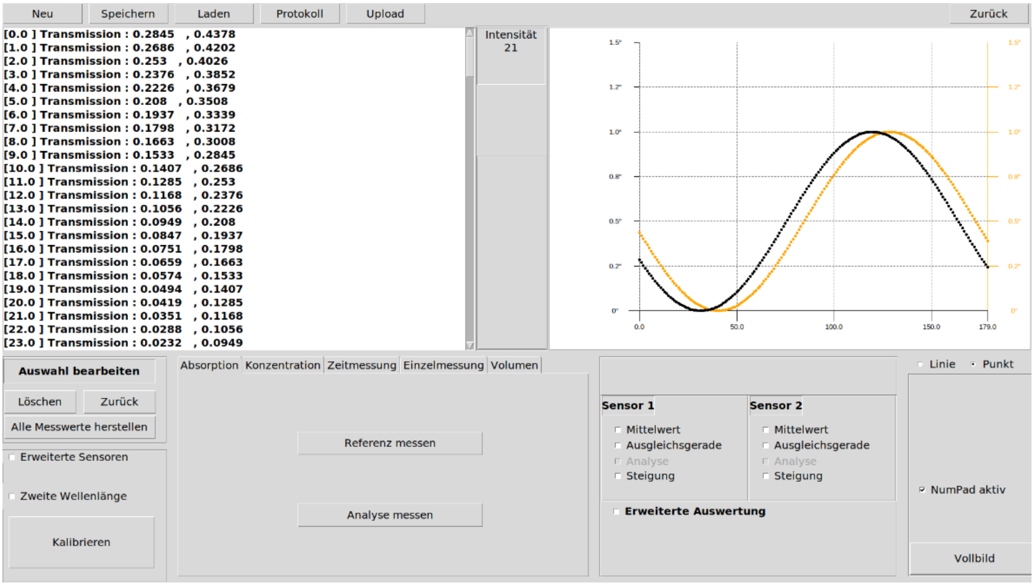


Fig. 3. Graphical User Interface of LabPi (in development) with measured water (black) and sucrose solution (0,3 g/ml)

3. Measurement and comparison

The angle of rotation is determined by rotating the analyser and recording the intensity values. The measuring points are recorded by LabPi and reproduced as transmission. This allows a complete sinusoid to be mapped when the analyser is rotated by 180°. The minimum and the maximum of this curve represent the measuring points for determining the change in the angle of rotation. These extremes, which are uniform in amplitude due to transmission, also help in the visualization of different sugar solutions. Depending on the concentration of the sugar solution and the layer thickness of the cuvette, the phase of the sinusoidal curve is thus shifted. The difference between the extreme points of the solutions to be measured allow the rotation of the polarized light to be determined (Fig. 4). To calibrate the digital polarimeter, the zero point was determined with distilled water.

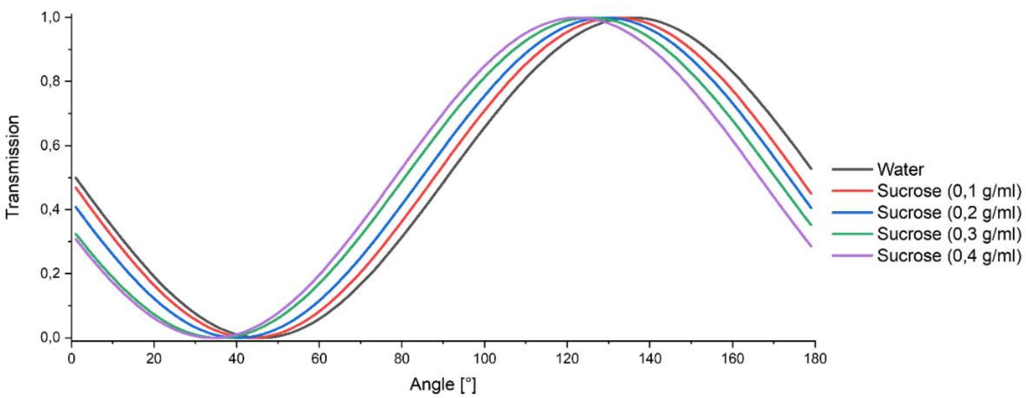


Fig. 4. Transmission of water and different sucrose solution by angle recorded with LabPi

To determine the precision of the digital low-cost polarimeter, the specific rotation angle of sucrose was determined via a concentration series. In parallel, the solutions were measured with a conventional, analog laboratory polarimeter by Krüss Optronic [6].

Table 1. Measurement results and comparison between the digital LabPi polarimeter and an analog polarimeter

Sucrose solution	*LabPi*	*Specific rotation*	*Deviation*	*Analog*	*Specific rotation*	*Deviation*
0.1 g/ml	*3 °*	*63.8 °*	*-3.87 %*	*12.65 °*	*63.3 °*	*-4.74 %*
0.2 g/ml	*6.5 °*	*69.1 °*	*4.14 %*	*27.75 °*	*64.4 °*	*-3.05 %*
0.3 g/ml	*10 °*	*70.9 °*	*6.81 %*	*38.65 °*	*64.4 °*	*-2.99 %*
0.4 g/ml	*13 °*	*69.1 °*	*4.14 %*	*52.40 °*	*65.5 °*	*-1.36 %*
Ø	*-*	*68.3 °*	*2.81 %*	*-*	*64.39 °*	*-3.03 %*

The table shows the calculated specific rotation angles in comparison. The deviations are related to the literature value of sucrose (α=66.47°) [7]. The angles recorded with the analog polarimeter appear about four times as large as those of the digital polarimeter.

This is primarily related to the choice of slice thickness, which corresponded to 2 dm for the standard cuvette and 0.47 dm for the plastic can. This difference is also one of the factors for the deviations from the literature value. The layer thickness also means that lower concentrations cannot be detected and are subject to greater error. Another point, which can enable a higher precision of the digital polarimeter, is the choice of the servo motor. The servo motor used here can align in 0.5° steps. Smaller steps can cause the motor to jitter severely, creating a much higher source of error for very small concentrations. Overall, the precision of the homemade polarimeter can be assumed to be sufficient for subject teaching and as a proof of concept.

4. Outlook

Both the polarimeter and the LabPi software are still under development. Especially for the polarimeter, further adaptations of the software are planned. At the current state, the determination of the specific angle of rotation is still dependent on office applications.

In the future, this shall also be done via the software LabPi, whereby the results can be switched on optionally with only a few steps. In the future, it will also be possible to perform time-dependent measurements and concentration determinations with the aid of adjustable parameters. At the hardware level, further adjustments will be made to enable even more precise measurements before piloting with learning groups.

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Drugs Within a Context of Chemistry Teaching

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Abstract

Synthetic drugs play an increasingly important role in today's meritocracy. The market for amphetamines has been expanding worldwide for several years [1]. In Germany, too, amphetamines and amphetamine derivatives continue to gain ground. There has been a steady increase in the quantities of amphetamine, methamphetamine and ecstasy seized [2, 3]. While helpful approaches and teaching materials with regard to health education and addiction prevention are provided, for example by the German Federal Centre for Health Education [4], the subject is inadequately addressed in German curricula and does not guarantee a deep structure of the organic substance class. In order to present a practical-methodical implementation, especially for chemistry lessons, a learning set was constructed which introduces the topic to students within the framework of an intervention study at the Friedrich Schiller University Jena. The article presents ten innovative learning stations focusing on the illegal drugs amphetamine, methamphetamine and MDMA (3,4-Methylenedioxy-N-methylamphetamine, also known as ecstasy). New knowledge about the structures, historical aspects, production possibilities, modes of action and detection reactions of the substances can be acquired. The stations are didactically diverse. In addition to theory stations, games and other creative elements, the study places its focus on experiments. While, for example, the effects of MDMA are explained in a learning video, experiments can be used as models to demonstrate the effects of amphetamine and methamphetamine. The materials developed are aimed particularly at students at the age of 16 to 18 and chemistry teachers. They can also be used in interdisciplinary science lessons. The materials have already been tested and evaluated several times with students and teachers [5].

Keywords: Educational transfer research, curricular learning modules, drugs

1. Initial situation

Due to the increasing prominence of the substance class of amphetamines, the primary goal of drug prevention is to provide young people with sufficient education and information. In Germany recent efforts show that the importance of addiction prevention has increased, that a large number of measures are implemented and that a wide variety of players are involved [6].

At state level, efforts by the Federal Centre for Health Education and the German Central Office for Addiction Issues envisage the development of substance-specific information and teaching materials for primary prevention that are accessible free of charge on the Internet [4, 7-9]. At federal level, in addition to police crime prevention, measures are taken in the form of school and extracurricular projects which address different target groups. For example, specialists and coordination agencies for addiction prevention list initiatives which address illicit drugs and party drugs. In particular, a large number of amphetamine-related offers can be found in focus regions such as Thuringia, Bavaria, Berlin, Saxony and Saxony-Anhalt [6, 10, 11].

Overall, a range of informative, digital and interactive offerings for students and teachers has been developed. Often the projects can be implemented in a playful way, for example as part of participatory courses. Topics such as illicit drugs and party drugs are taught across all substances. Substance-specific programs which focus only on amphetamine, methamphetamine and methylendioxy-*N*-methylamphetamine (MDMA) can rarely be found. As far as substance-specific measures are taken, the main part relates to methamphetamine/crystal meth, as is the case with the materials.

Although the topic of drugs appears in science curricula, no content or methodology is listed for the synthetic substance class in focus. Aspects are dealt with superficially or are completely absent. A positive example, however, is the Berlin-Brandenburg curriculum, which provides numerous approaches and impulses for teaching the topic of drugs in the elective subject of natural sciences in grades 7 to 10 [12].

As a result of the analysis of existing initiatives and reviewing of curricula, the constructed learning set is intended to provide added value in terms of in-depth chemical subject knowledge, to make a substance-specific contribution to addiction and drug prevention, and to be extended to chemistry education.

2. Aims of the research project

In order to follow the guidelines of contemporary addiction, drug prevention, health education, the strengthening of personal competence as well as risk and action competences are to be aimed at in equal measure through appropriate interventions [13].

The present intervention study is realized by designing a project day in the context of a laboratory study with constant framework conditions throughout the entire phase of data collection. Students at the age of 16 and 17 (grades 10 and 11) from five cooperating schools in Thuringia are acquired as target groups for the main study.

Questionnaires in pre-post design were designed to investigate feedback on interest and prior knowledge regarding the topic, acceptance of the program and the individual stations, and lastly, learning gains as a result of the intervention. The way in which the stations are worked through (intervention) takes place in collaborative work forms and is documented with the aid of a structured observation protocol by a trained team of observers. Students have 2 to 2.5 hours of self-organized laboratory time for every intervention. The results are recorded on a routing slip. Between five to 30 minutes are required for the various types of stations.

3. The stations of the learning set

A total of ten stations was constructed according to certain criteria and can be assigned to different learning occasions (Fig. 1).

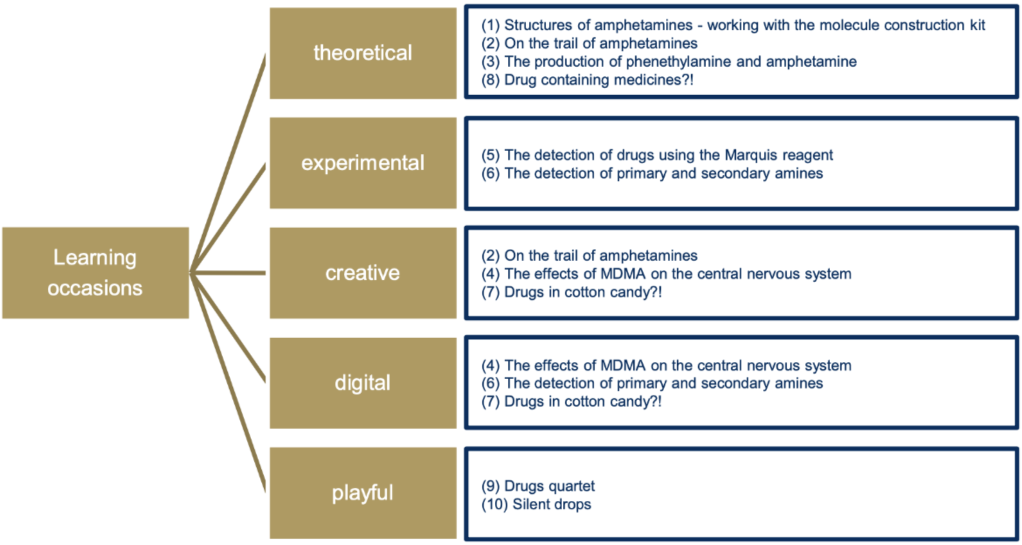

Fig. 1. Overview of the stations of the learning set

In addition to aspects of health education, the development is based on concepts of organic chemistry. Thus, basic chemical concepts such as the substance-particle concept, the structure-property principle and the concept of chemical reaction are focused on [14]. The project follows a comprehensive competence-oriented approach, since the stations vary methodically. In addition to the acquisition of specialized chemical knowledge regarding the three substances, students improve personal, social and methodological competences. The principles of linking subject-specific science and subject-specific didactics have proven particularly successful in the design of stations 3 and 5, where both university and non-university cooperation have taken place.

As an introductory station, station 1 centers on substance-particle relationships in the construction of molecular structures. At station 2, historical aspects are learned through text excerpts and secured in the form of a crossword puzzle. Station 3's focus on the nitroaldol reaction as an addition reaction ties into the concept of chemical reaction. To combine digital aspects with health education aspects, a self-produced educational video on the mode of action of MDMA in the central nervous system focuses on biochemical expertise in station 4. Stations 5 and 6 have a significant position, as they generate novel experimental approaches to rapid drug tests in the form of model experiments.

In particular, at station 5, a carbenium ion as a key chemical structure which can stimulate process thinking based on reaction mechanisms is created (Fig. 2) [15, 16].

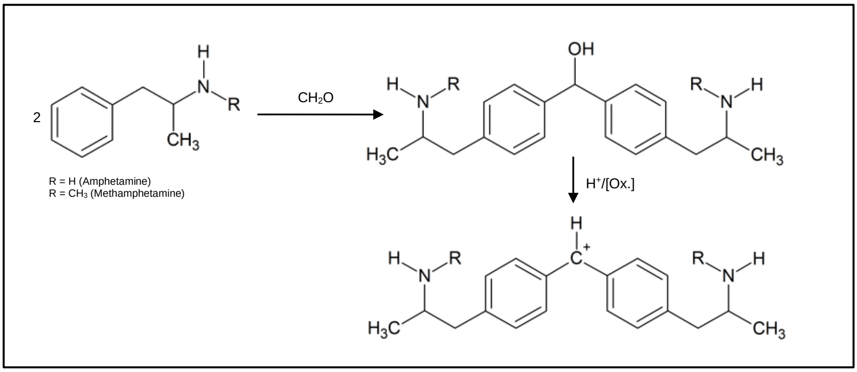

Fig. 2. Marquis reaction [17]

When amphetamines react with a drop of Marquis reagent, which is composed of concentrated sulfuric acid and 40% formaldehyde solution and is located at the bottom of the glass vial, it comes clear, that the produced carbenium ion is the cause of the color due to the newly formed conjugated system. As a result of the color reaction, new possibilities are created to make the submicroscopic level tangible. In addition, the students gain insight into the police work involved in handling the rapid test from ESA-TEST GmbH of Eisenach in Thuringia (Fig. 3) [18].

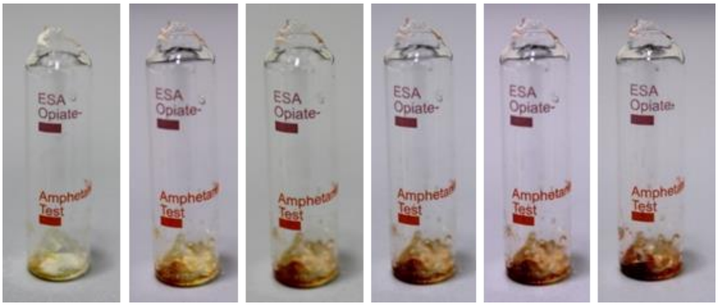

Fig. 3. Course of the color reaction (from left to right: after 10, 30, 60, 120, 180 and 240 seconds); own photography (taken on 20.12.2017)

Station 6 is also based on the structure-property concept and enables desired color reactions through structure-like compounds. While stations 5 and 6 aim at experimental action competences, station 7 deals critically with the handling of the rapid test.

Advantages and disadvantages are summarized in a radio play. In the context of health education, station 8 focuses on behavioral and risk competences in dealing with stimulant drugs and their structural similarities with the three illegal substances. The playful stations 9 and 10 are available as didactic reserves and characterize further drug classes, in which elements of health education and specialist knowledge are coupled in a quartet and a memory.

4. Outlook

Initial results of a pilot study yielded positive feedback of the program and individual stations. Both content and methodological changes were made for the main study. In order to be able to make a contribution to drug prevention in Germany, the materials are supposed to be available for use both in and out of school. Teachers have the opportunity to acquire specialist knowledge within the framework of teacher training courses. The provision of a manual with subject-specific information, instructions for experiments, copy templates and solutions can provide subject-related and interdisciplinary impulses for implementation in schools. The data evaluation of the main investigation will show whether this is an acceptance-oriented attractive learning arrangement.

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From Science to School – Educational Transfer Research of Modern Science Topics in the Interplay of Curriculum Development and Empirical Research

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Abstract

At the Friedrich Schiller University Jena, as at many other universities in Germany, measures for professionalization in teacher's training have been promoted since 2015 as part of the "Qualitätsoffensive Lehrerbildung". The goal is to develop a coherent education program for teachers. Furthermore, collaboration between all players in teacher's education is intended through both cross-phase and intra-phase cooperation. A closer connection between subject and subject education is particularly important for development of modern science teaching. Within the project Learning-to-Teach Lab: Science (LTL:S), a structure will be established which translates scientific innovations into school reality through educational transfer supported by empirical research [1]. Following the presentation of the underlying project structure the development process of curriculum innovation will be shown by applying it to the topic "self-healing materials". With the help of experimental implementations school-based approaches are presented. To investigate the use of such curricular innovations, an empirical research design was developed based on the topic "drugs as a context of chemistry teaching" and put into test in fall 2020. For this purpose, a standardized observation protocol was designed which documents the way in which students deal with the topic. The article will focus on the development of the research instrument and the different steps of the observer's training. Finally, the project's previous work will be systematized regarding digital learning communities.

Keywords: coherent teacher education, observational study, self-healing materials, professional learning communities

1. Coherence in Teacher Education

The demand for stronger networking in teacher education, both within and across teacher education phases, has been at the center of subject education discussions for several years. Since 2015, numerous project initiatives have been founded throughout Germany within the framework of the "Qualitätsoffensive Lehrerbildung" (QLB), in which a contribution is made to the promotion of teacher professionalization through greater coherence in teacher education [2]. The concept of coherence in teacher education presents itself as a multifaceted network of numerous content-related and structure-giving measures [3]. On the conceptual side, a distinction can be made between vertical and horizontal coherence. Horizontal coherence goes hand in hand with intra-phase networking, for example when courses are jointly designed by subject and subject education. The development of a deep structure within a discipline, for example through the application of theoretical knowledge in practical situations, can be described as vertical coherence. Furthermore, networking on a temporal level is divided into synchronous and consecutive networking. Synchronous coherence is present when, for example, pre-concepts are discussed in the subject education and the constructivist foundations are discussed at the same time in the educational sciences. The construction of a spiral curriculum (cumulative learning) or also the interweaving of the respective phases of teacher education (cross-phase cooperation) can be interpreted consecutively, i.e., chronologically. Eventually, relevant subject specifics (e.g., the methods for gaining knowledge in the natural sciences) or holistic educational concepts (e.g., education for sustainable development, inclusion) can also be integrated into the discussion on coherent teacher education.

2. Self-Healing Materials – an example for Curriculum Innovation

The guiding principle of subject-subject education linkage, which is currently discussed in the subject education landscape, is accompanied by the demand for more modern science teaching. In order to develop new subject content for science teaching, current research work must be reviewed, elementarized to the fundamental contexts of meaning and implementation strategies for teaching derived. Within teacher education phase, this results in the necessity of cooperation between subject scientists and subject education experts. Within the framework of such cooperation with the Institute of Organic and Macromolecular Chemistry, the topic of “self-healing materials” was developed in student seminars in the summer term of 2020. After an introductory and educationally reduced lecture, small groups worked on partial aspects of this topic. These included self-healing in nature, self-healing polymers and self-healing concrete and asphalt. For each aspect, initial educational structuring was developed and, under the guideline of educational reduction, fundamental principles were focused on, technical terms reduced and corresponding simplifications integrated. The first results are presented here.

2.1 Self-healing polyurethane-based films

Self-healing films have been marketed for some years as paint protection for automobiles or coating for mobile phone displays. Their self-healing function is based on a network of strong covalent bonds and weaker hydrogen bonds [4]. In simple experiments, the self-healing of such films can be investigated in an everyday context and used as a motivating introduction to the topic.

2.2 Model experiment of a self-healing asphalt

Self-healing asphalt is based on a composite of bitumen and steel wool. By means of inductive heating, fine cracks in the asphalt can thus be healed by melted bitumen [5].

In a model experiment (Fig. 1), a mixture of candle wax and graphite flakes is used.

In an electromagnetic alternating field (microwave), the mixture begins to melt, so that cracks are healed. As a comparison, it can be shown that pure wax does not melt in the microwave.

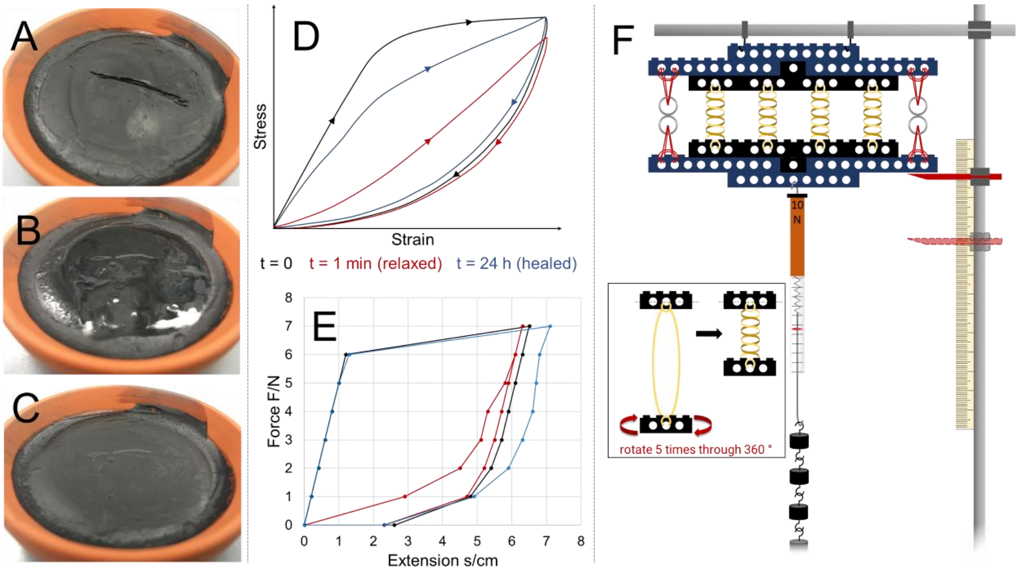

Fig. 1. Experimental approaches to the topic of self-healing materials. ABC: Model experiment on self-healing asphalt after damage (A), after 10 s microwaving (B) and after curing (C). DEF: Model experiment on the self-healing of the adhesive hair of the California mussel. Ideal stress-strain diagram after three cycles (D) [6], sketch of the model experiment created (F), tensile force-strain diagram for the model experiment after three cycles (E)

2.3 Model experiment on self-healing of shell hair

The adhesive hair of the California mussel shows a self-healing mechanism in stress-strain experiments, which is due to proteins with β-sheet structure and coordinative bonds between zinc ions and histidine-rich proteins [7]. When stretched beyond the elastic range, the coordinative bonds break at the yield point. The folded sheet structures are abruptly unfolded by the acting force. When stretched again, the curve is clearly flattened, as now only the β-sheet structures contribute to the modulus of elasticity. After some time, however, the coordinative bonds are formed again. This process was simulated in a model experiment (Fig. 1) in which twisted rubber bands represent the β-sheet structures and further rubber bands with magnets represent the proteins with coordinative bonds.

3. The empirical research design based on the topic “drugs as a context of chemistry teaching”

Data collection for the intervention study was conducted with students at the age of 16 and 17 (grades 10 and 11). Questionnaires in a pre-post design are designed to collect feedback on interest and prior knowledge regarding the topic as well as acceptance of the program and the individual stations. Short-term program effects on content learning gains will be asked in an open response format in the post-test. The way in which the test persons work through the stations and which process-related competences can be observed will be documented by a trained team of observers. The focus was set on observing the processing of the stations in collaborative work forms.

The design and content of the measuring instrument was based on work from the fields of chemistry didactics, pedagogy, psychology, and classroom research [8-10].

3.1 Training steps of the observer training

In order to generate reliable data and objective assessments, adequate observer training was designed (Fig. 2).

Fig. 2. Sequence of training steps for observer training

The goal was to explain the developed measurement instrument with associated rating manual to the observers. In order to become familiar with the method and to gain a feeling for the sensitivity of relevant behaviours, a video simulation was planned to determine observer agreement with the measurement instrument [11]. For verification, multiple simulation videos were double-coded by two independent observers. Cohen's Kappa (κ) was chosen as the measure of observer agreement. Specific values for interrater reliability were obtained, so that the instrument can be used for the upcoming main study.

3.2 The observation protocol of the main investigation

Four main categories are defined for the documentation (Fig. 3). Each main category is broken down into three observation foci, which are assessed by four evaluation scales.

In addition, a column with comments and a field for special anomalies are provided.

A rating manual contains feature descriptions and scale expressions. A trained team of observers codes the measurement instrument parallel to the intervention. The observers take the role of pure observers without interacting with the research field. To ensure a laboratory study with a continuous framework, each observer acts as an expert of an assigned station for the entire phase of the main investigation [12, 13].

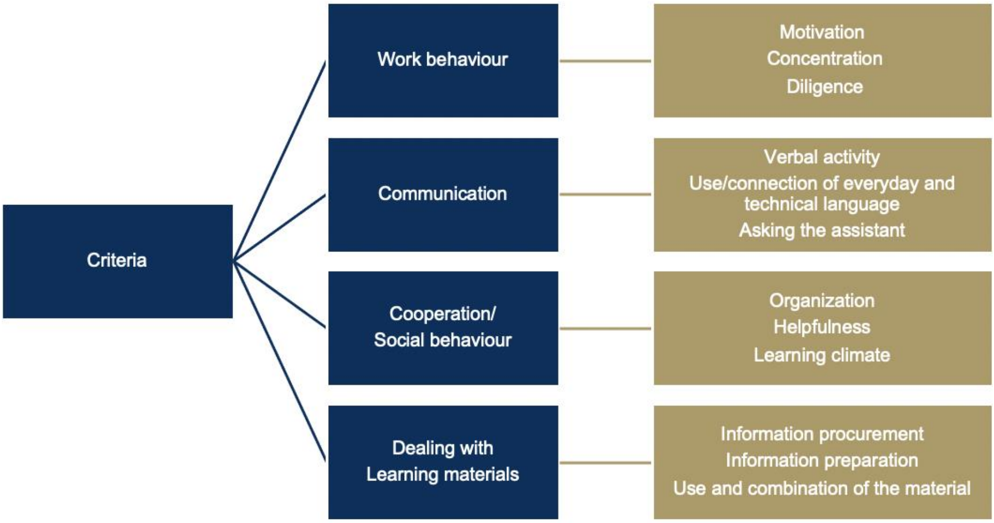

Fig. 3. Main- and subcategories of the observation protocol

4. Digital Learning Communities – a new Approach in Teacher Education?

In this article, a procedure was presented in which current subject content was developed for teaching at the interface of subject and subject education. It also showed an example of how such material developments can be evaluated and examined socio-empirically. Within the QLB, further modules were developed, tested and evaluated in chemistry education at the Friedrich Schiller University for a coherent teacher education.

These include: Tandem teacher training (tandem of subject scientist and subject education expert), promotion of the professionalization process of prospective teachers through early practical experience as well as courses on inclusion, digitalization or interdisciplinary teaching as cross-cutting topics. To implement these curricular innovations, cross-phase cooperation between university and school is necessary. The project “Digitale Lerngemeinschaften zur kohärenten Lernbegleitung im Jenaer Modell der Lehrerbildung” (Digital Learning Communities for Coherent Learning Support in the Jena Model of Teacher Education) focuses on increased cooperation between teachers and the educational sciences and subject education experts of the university through digital learning formats. The cooperation of the involved actors ties in with the proven concept of professional learning communities as an effective cooperation structure for sustainable effects in school development [14]. All in all, these digital learning communities serve to translate subject education and pedagogical as well as curricular innovations into everyday school life.

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Improving Scientific Practice Skills in a Virtual Chemistry Lab Course

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Abstract

The laboratory has long been considered the best setting for science teaching and learning for many reasons ranging from the opportunity to develop skills in handling materials and equipment, to achieving the goal of familiarizing students with scientific reasoning and the way science is done. From the perspective of scientific competences development, the capacities that should be highlighted in the teaching of experimental science are more clearly identified, such as the pertinent application of scientific knowledge, involvement in research to address problems, as well as proposing, developing and sustain solutions to them. The usual practice in teaching laboratories is mainly focused on following established procedures that lead to concrete results that allow the student to be assigned a grade. However, this way of working provides very few opportunities for the development of scientific skills in students. The current situation of health emergency has caused unavoidable changes in the way experimental science is taught and, with this, a wide variety of alternatives has been opened that can promote the development of the scientific capacities of students. This work reports the result of monitoring the development of skills for scientific practice, without considering manual skills, in a virtual laboratory course in general chemistry for first-year students at a Peruvian university. These skills were evaluated by means of a rubric that considers the progress achieved in four levels. The results were compared with those obtained by students from a previous cohort who had the same course under the standard modality. Chi square statistic was used, and it was verified that there were significant differences in the achievements obtained by both groups, being these favourable for the group of students that followed the virtual modality.

Keywords: Scientific skills, science education, instructional design, assessment

1. Introduction

The current situation of global health emergency has revealed a series of critical aspects related to organization of society and governments, the relationship between people, environment, and education, among the most important. In this last aspect, scientific education undoubtedly assumes a truly relevant role, since it is necessary that people make use of a set of abilities related to the knowledge of some aspects of science and the way it is developed to understand the problem in its real dimension, the preventive actions that are necessary, and the control proposals of the competent organization. In that sense, for several years scientific education has sought to contribute to the development of abilities to assess the quality of scientific information; describe, explain, and predict natural phenomena; identify the scientific issues that determine political decisions and assume informed positions related to various situations that involve science and technology [1], [2]. This concept of scientific literacy is closely related to that of scientific competence, which includes both scientific knowledge and the use made of that knowledge to identify questions, acquire new knowledge, explain scientific phenomena, and draw evidence-based conclusions on matters related to science and its social impact [3], [4]. That is, scientific competence implies abilities linked to knowledge, the practice of science and the individual's attitudes towards it.

Regarding the practice of science, the related capacities involve the abilities to deduce the objective of a determined scientific experience, identify the variables that can be controlled or measured in an experience, pose problems, formulate hypotheses, propose research strategies, collect, and process information. In addition, it includes the skills to elaborate, communicate and support conclusions based on scientific evidence; assume, and support a position related to them; and reflect on the social impact of the advancement of science and technology [3], [4].

The laboratory has long been considered the natural context for science teaching. If the activities to be developed in the laboratory are designed with clear objectives and with an adequate assessment scheme, high levels of achievement can be achieved in the development of abilities for inquiry, reasoning, problem solving, as well as skills for the correct handling of materials and equipment. Additionally, opportunities for the development of skills for collaborative work and communication are promoted [5].

However, in the specific case of chemistry laboratories, reports have been made that indicate that it is frequent that the goals of experimental teaching are not aligned with the results regarding the learning achieved. The organization of the laboratory session usually implies that the students follow an established procedure and record the results obtained in a format structured by the teacher. There is a greater emphasis on learning hands-on techniques and few opportunities for the development of critical thinking, analysis and discussion of results, development and integration of concepts, and development of communication skills [6], [7], [8].

The changes that have been made in the way experimental chemistry is taught in the context of the health emergency have opened a series of alternatives that can help to promote the capacities that make up scientific practice and that go beyond technical skill.

This paper reports the results of the comparison of two groups of first-year students from a general chemistry laboratory at a Peruvian university. The comparison variable was the level of achievement in the development of abilities for scientific practice, without considering hands-on techniques skills, between a virtual laboratory course and another developed in traditional mode.

2. Methodology

2.1 Participants

The participants in this study were two cohorts of first year students of Science and Engineering from a Peruvian university. They were enrolled in a General Chemistry Laboratory course.

Traditional cohort: 39 students who took the traditional course. They were aged 17-20 years, 84,62% was male and 15,38% was female.

Virtual cohort: 42 students who took the virtual course. They were aged 17-20 years, 78,57% was male and 21,43% was female.

2.2 Context of the study

The students were organized in permanent groups of three members. The design of the laboratory course considered three stages:

a. Pre-laboratory stage: individual preparation stage that consisted of developing some short activities, such as reviewing some concepts related to the work session, looking for some physical properties of the substances to be used in the laboratory, analyze a video related to the experience, as well as to do some simple calculations.

b. Development of the experimental session: In the traditional group the students developed the laboratory experience following general guidelines for the hands-on activities, data collection and processing. The teacher was a facilitator during this stage and, promoted the academic discussion of what was being worked on.

In the virtual group the students worked with simulators available online. These resources offer the possibility for the students to intervene in the manipulation of experimental conditions and verify the result in a short time for analysis and processing.

In some cases, they can visualize the phenomenon at the molecular level. The student maintains an active role throughout the process and the teacher can monitor his work, the interaction with his group mates, the quality of the discussion and analysis, through the platform used.

c. Report preparation: The working groups prepared their work report after the end of the laboratory session. This should be sent for review a week later.

2.3 Instrument

A rubric to assess abilities for scientific practice was applied during the semester in all the practical sessions. Figure 1 shows the rubric in detail.

RUBRIC TO ASSESS ABILITIES FOR SCIENTIFIC PRACTICE

ACCOMPLISHED	PARTIAL ACHIEVEMENT	WITH DIFFICULTY	UNACHIEVED
• The student is on time for the session and is ready to start work. • The student works in an organized manner with his fellow group members. • The student performs observations, data collection, calculations, and interpretations in a correct and autonomous way with his groupmates.	• The student is on time for the session and is partially ready to start work. • The student works in an organized manner with his fellow group members. • The student makes correct observations, data collection, calculations, and interpretations with his fellow group members, but requires guidance.	• The student is on time for the session but is not ready to start work. • The student's work with his group mates has organizational problems. • The student makes observations, data collection, calculations, and interpretations with his fellow group members, but with frequent errors.	• Student is on time for the session sometimes and not ready to start work. • The student's work with his group mates has serious organizational problems. • The student makes observations, data collection, calculations, and interpretations with his fellow group members, incompletely or with serious errors.
• The student presents his results in an organized and coherent way with the objectives of the experiment, the methodology and procedures followed. • The student correctly analyzes the results relating and supporting them with the corresponding theory. He discusses possible sources of error, comments on the similarities and differences of his results with those of the other work groups and makes suggestions to improve the experiment. • The student integrates the results obtained with the concept or scientific principle involved. He mentions the level of achievement for each of the objectives initially raised, relating to the theory and possible sources of error. Report difficulties or unexpected events indicating the way in which they were solved.	• The student presents his results in an organized and coherent way with the objectives of the experiment, the methodology and procedures followed. • The student correctly analyzes the results relating and supporting them with the corresponding theory and discusses possible sources of error. • The student integrates the results obtained with the concept or scientific principle involved. He mentions the level of achievement for each of the objectives initially raised, relating to the theory and possible sources of error.	• The student presents his results in a partially organized and coherent way with the objectives of the experiment, the methodology and procedures followed. • The student analyzes the results relating and supporting the corresponding theory, but with some confusion. • The student integrates the results obtained with the concept or scientific principle involved.	• The student presents some results, but with a lack of organization and coherence with the objectives of the experiment, the methodology and procedures followed. • The student analyzes the results poorly, with serious confusion in the application of the theoretical concepts related to the experiment.

Fig. 1. Rubric to assess abilities for scientific practice

2.4 Analysis of data

The data were analyzed using Statistical Package for the Social Sciences (SPSS) 23 software ®. Level alpha was established a priori in 0,05. Chi square statistic was used to verified if there were significant differences in the achievements obtained by both groups.

3. Results

Figures 2 and 3 show the frequency at each level of achievement for each laboratory session of the traditional group and the virtual group, respectively.

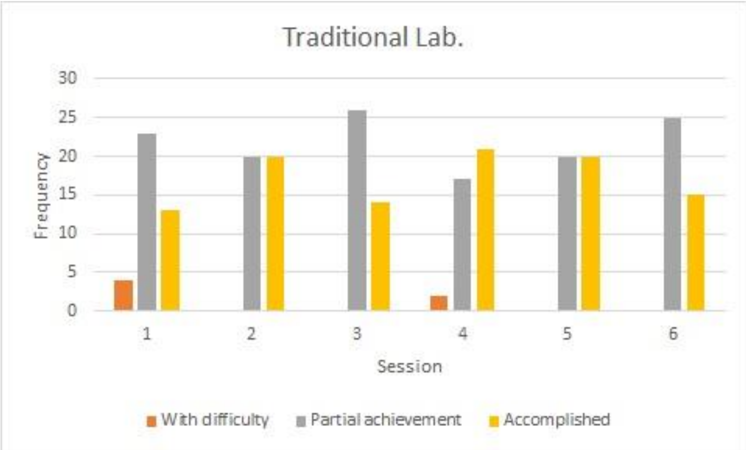

Fig. 2. Level of achievement for each lab session of the traditional group

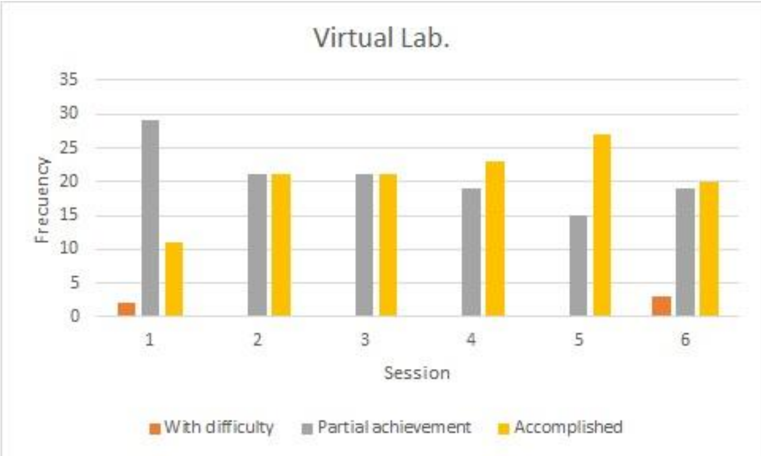

Fig. 3. Level of achievement for each lab session of the virtual group

Figure 4 shows the average achievement level for the two participating groups.

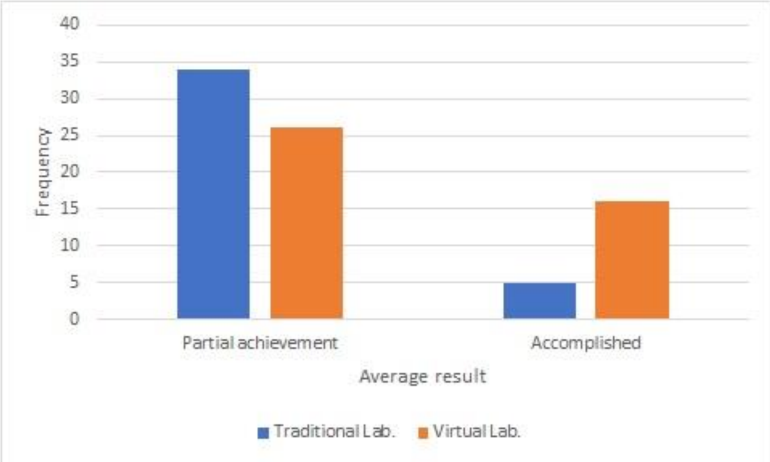

Fig. 4. Average achievement level for the two participating groups

The results of the Chi-square test showed that 100% of the cases were valid. Table 1 corresponds to Level * Group crosstabulation.

Table 1. Level * Group Crosstabulation

		Group		
		traditional	virtual	Total
Scientific practice abilities	Partially achieved	34	26	60
	Accomplished	5	16	21
Total		39	42	81

The value of the Continuity Correction statistic, since it is a 2x2 table, was 5.475 with one freedom degree and p-value=0.019. 0% of cells had an expected frequency lower than 5, the minimum expected frequency was 10.11. According to these results, it can be affirmed that there is significant evidence of association between the variables, that is, that the highest proportion of people who qualified at Accomplished level can be associated with the virtual group.

The results clearly show the effect of working using informatic resources, such as simulators, on the level of achievement achieved in developing skills related to scientific practice. Unlike traditional experimental work, the students of the virtual group showed greater engagement in the observation and study of the phenomenon or process studied, enriching the discussion and analysis of the data obtained. The exchange of ideas, the formulation of their own questions and the elaboration of conclusions had greater emphasis in the work of the virtual group. Additionally, the teacher's supervision of the students' work was carried out more efficiently through the platform, providing a greater opportunity for interaction and monitoring of the dynamics followed by the students.

Additionally, the work carried out in the synchronous session contributed more significantly to the preparation of the final report, whose quality was notably higher in the virtual group.

4. Conclusions

The goals of science teaching in laboratories should involve skills for technical work and those that promote scientific reasoning, problem solving, critical thinking, and scientific communication. The results obtained provide evidence to consider alternatives to achieve these objectives. The challenge for educators is to develop pedagogical designs that take advantage of both direct experimental work and the use of computer resources, seeking a coherent alignment between educational goals, the design elaborated and the corresponding assessment system. The laboratory is still the best context for learning science, but the variety of resources that can enhance student learning achievements should not be lost sight of.

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Nanomaterials in Cancer Therapy – a Model Experiment for Chemistry Education

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Abstract

With the continuing COVID-19 situation, science has moved closer to the focus of society, with research into new vaccines and therapeutic options being the central focus. It seems therefore appropriate to take up this current interest in science and medicine, which has been intensified by media, and to address medical topics in STEM lessons to motivate students [1]. Beyond COVID-19, however, research continues into many areas such as cancer or anti-inflammatory strategies [2]. A promising approach for the treatment of both examples (and many more) is related to nanotechnology. Nanomaterials can be used as a transport system for active ingredients and transport them more specifically to the location where they are intended to work. It is therefore known as "drug delivery" or "drug targeting" [2, 3]. But the nanomaterial itself can also be used as an active ingredient or adjuvant for a therapy. Magnetite nanoparticles (Fe_3O_4) are an important material for both approaches. Due to their outstanding magnetic properties, their good biocompatibility and good availability, they are subject of many research projects and offer great potential for modern medical solutions either as part of a carrier system or, for example, to induce heat to damage cancer cells [4]. The synthesis of magnetite nanoparticles with educational means is already sufficiently documented and ferrofluids are already available for purchase at low cost on the Internet. This results in the potential combination of medicine and nanotechnology, which provides a wide range of learning opportunities for STEM education. In this contribution will be shown how magnetite nanoparticles can be synthesized with simple school chemicals and stabilized as ferrofluids. Subsequently, the ferrofluid will be used in a model experiment to illustrate the hypothermic treatment of tumor cells and first practical experiences with students in the student laboratory will be presented.

Keywords: nanotechnology, ferrofluid, medicine

1. Introduction

Current medical research, in particular the development of a vaccine for the coronavirus, has been observed by society with great expectations. But other research projects not related to corona are not less important or exciting. Research is continuing to look for a cure for cancer and Alzheimer's disease or on combating multi-resistant germs, with a wide variety of approaches being pursued. One example is nanotechnology. The corresponding nanomaterials have not only established themselves for use in products for end consumers and industry, but they hold great potential for medicine too [1]. In addition to silver, which is also important as a non-nanomaterial for medicine, magnetite nanoparticles are being investigated for medical purposes. If nanoscale magnetite is bound to an enclosed active ingredient, it will be transported directly to the intended site of action with the aid of an appropriate magnetic field due the magnetite's superparamagnetic properties. This is referred to as “drug delivery” or “drug targeting”.

But nanoscale magnetite can be used as an active agent itself too. When it is placed into a magnetic field that changes the orientation of the field at a certain frequency (also referred to as an alternating or oscillating magnetic field), the magnetite heats up so much that a tumor can be consequently damaged or even destroyed. If the tumor is damaged, other agents can better act on the tumor. In this way nanoscale magnetite can support other active ingredients [4].

Since the phenomenon of induction heat is already an exciting topic for its own, this offers the option of a promising expansion of the subject area, which will be explored in the following.

2. Objectives

For students in STEM classes, evaluation competence is of great importance, since they should be able to evaluate scientific results in everyday life contexts based on their knowledge. Current research topics, which chances and risks are still to be assessed, provide a great context to develop or promote this competence. The nanosciences has emerged as an especially suited field for this. Many different materials and contexts have already been successfully used for this, like potential harms and chances of zinc oxide or titanium oxide nanoparticles from sunscreen [5]. Magnetite nanoparticles are sometimes prepared in schools as they show impressive magnetic properties; the application as active agents in tumor therapy, however, has not yet been developed for chemistry education so far. The next chapters describe a simple ferrofluid synthesis with a subsequent model experiment for its application in tumor therapy.

3. Didactic Reconstruction

For local hyperthermal treatment, a water-based ferrofluid is initiated into the affected tissue. The ferrofluid consists of magnetite nanoparticles dispersed in water with the aid of a stabilizer. Without the stabilizer, the particles would agglomerate and lose their useful properties. The affected tissue is now placed in an alternating magnetic field, generated by a strong induction coil operated with alternating current. Depending on the strength of the magnetic field, the frequency of the current and the nature of the nanoparticles (such as how much energy is required for an alignment), heating of these particles occurs.

A similar phenomenon is known from the kitchen while cooking with induction.

Analogously, a magnetic pot or pan is placed on the field and analogously exposed to an alternating magnetic field, causing it to heat up. Although there are many parallels in both processes, there are nevertheless serious differences. For example, the pot is ideally ferromagnetic, while the nanoparticles in the ferrofluid are superparamagnetic.

Simplified, a non-magnetized ferromagnet consists of various elementary magnets that have the same orientation in magnetic domains. By applying a magnetic field, all elementary magnets of all domains now align themselves with it. After the magnetic field is removed, the alignment remains for a certain time and hold its own magnetic field. In case of magnetite nanoparticles, each particle represents its own magnetic domain. If these are brought into a magnetic field, their elementary magnets and thus the domains align with it, but the particles are also able to align themselves with the field by rotation.

If the magnetic field is now removed, this order is lost again. Compared to the pot, the material does not retain an own magnetic field; it has no remanence. In an alternating magnetic field both materials change their magnetic orientation regularly and heat up due to the magnetization losses. These are based, among other things, on the so-called hysteresis losses, which occur during steady remagnetization, and the eddy current losses, which occur due to electrically induced currents. In the case of nanoparticles, there is an additional effect: not only can the magnetic orientation within the particle change, but the entire particle can rotate according to the constantly changing field direction, thus generating additional heat (see Fig. 1) [4].

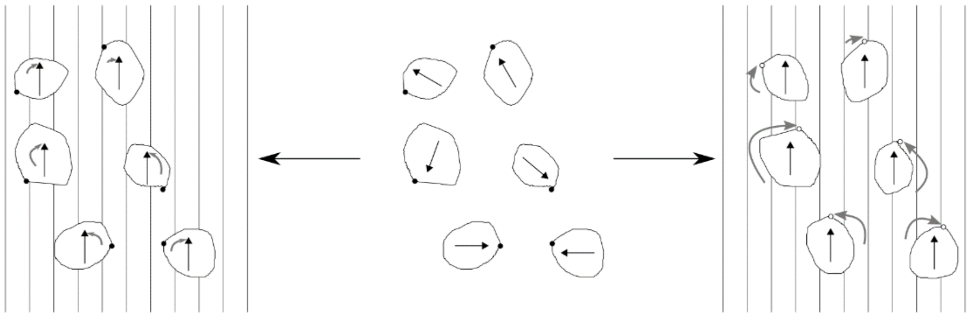

Fig. 1. In an external applied magnetic field, the spin (left) and the whole nanoparticles align (right) to it

This exciting subject area, located between physics and chemistry, provides a suitable context for an introduction to nanotechnology with insights into current medical research. According to empirical findings, the medical context is particularly interesting for female students [1] while nanoscience education appeals to both genders equally [6].

Therefore, there are at least two experiments on the subject. On the one hand the synthesis of the ferrofluid and on the other hand a model experiment to determine the heating of a ferrofluid in an oscillating magnetic field.

3.1 Synthesis of Ferrofluids

Many instructions are already published for the synthesis of ferrofluids, and some are now also commercially available at low cost. Best results were obtained with an adapted variant of Berger *et al*., [7], which has also been used for further nanoscience teaching projects such as magnetic nanocomposites [8]. The synthesis consists of two steps.

- In the first step magnetite nanoparticles are prepared and stabilized to obtain a ferrofluid. For this, 3.5 g of iron (II) sulfate and 2.0 g of iron (III) chloride are dissolved in 25 mL of water. To this, 100 mL of a 2 M ammonium hydroxide solution is added over the course of about 5 minutes with vigorous stirring.
- During the addition, the initially yellow liquid quickly turns deep black. After the base has been completely added, the solid can be fixed to the bottom by means of a strong neodymium magnet and the liquid poured off. By adding water again and then decanting analogously, unreacted educts and interfering products are removed.

After washing several times, about 0.3 g of Tetrabutylammonium hydroxide solution

(“TBAH”) is added and stirred well. If the magnet is held about 3 cm away from the mixture, Rosensweig lines indicate the presence of superparamagnetic nanoparticles (Fig. 2).

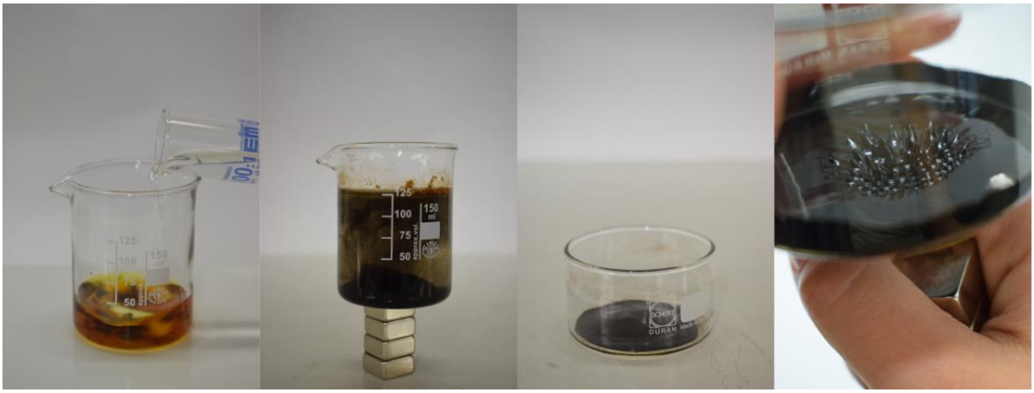

Fig. 2. from left to right: Solution upon addition of ammonia, sedimentation of nanoparticles with the magnet, washed nanoparticle dispersion, ferrofluid stabilized with TBAH.

3.2 Tumor therapy: hyperthermia model experiment

For the measurement, two snap-cap vials are placed on an induction plate. One vial is filled with the ferrofluid and water, the other with the same amount of water. A thermometer or temperature probe is now held in each of them. Now the field can be switched on and the temperature is measured in both vials. After 20 minutes with a power of 3.500 W, a clear trend can be seen: the ferrofluid heats up more than the reference.

By using Styrofoam plates, the influence of external factors is reduced (e.g., radiated heat) and the effect can be intensified. The measurement with the LabPi measuring station has proven itself well in the student laboratory, since not only the initial and final temperature, but also the course of the curves can be compared. Although the aluminum coating of the sensor also heats up during operation due to the magnetic field, the effect is the same for the reference and therefore negligible.

Fig. 3. Experimental setup: Induction hob with both vials. The left one contains a ferrofluid, the right one only water. Temperature measurements are acquired with LabPi measuring stations

4. Practical Experience

While the synthesis is mainly chemical in nature, the model experiment is very good to incorporate in physics lessons. However, the knowledge of induction and eddy currents is very important for this, so it is typically addressed in secondary level K-12 grades.

Both experiments have been piloted with students during a summer school; the synthesis has also been included in a laboratory practical course of the teacher training program at the Friedrich-Schiller-University in Jena. In both cases, the experiments were carried out successful by students and described as exciting and motivating. When the pandemic situation allows further evaluation, this experiment series will be carried out in regular chemistry and physics lessons and implemented into teacher formation.

The didactic potential of nanomedicine will be enhanced by and linked with further research areas and contexts, such as polymer chemistry for e.g., targeted drug delivery [2, 3] or smart material design [8].

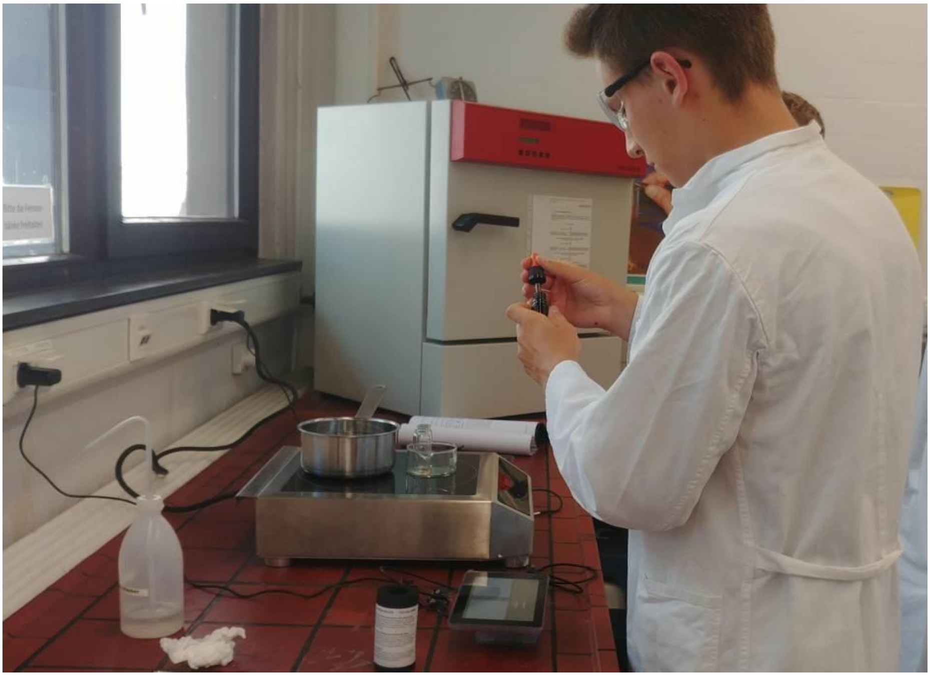

Fig. 4. Students in the lab preparing samples for the model experiment

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Reducing the Cognitive Load: Facilitating Learning in Organic Chemistry by Incorporating Mechanism Videos

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Abstract

Chemistry as a science about the structure, properties and transformation of substances heavily relies on adequate forms of visualization. Due to the high complexity and abstractness of representations, organic chemistry in particular is regarded as a challenging subfield of chemistry. When working on complex reaction mechanisms, students must spend high amounts of their cognitive capacities on the processing of symbolic language, which means that fewer resources are available for actual learning [1].
In this respect, cognitive psychology calls for consideration of the architecture of human working memory. According to the Cognitive Theory of Multimedia Learning, working memory is divided into two autonomously working subsystems [2]. Both subsystems process information according to their codality (symbolic vs. linguistic). Traditional teaching formats of organic chemistry most often exhaust capacities of the symbolic subsystem while valuable resources of the linguistic system remain unused. Meaningful learning could hence be fostered by evenly distributing information between both subsystems. Furthermore, the symbolic subsystems of the working memory can be relieved by outsourcing cognitively demanding processes (e.g., complex rearrangements within a mechanism) into the learning environment [3].
Unpublished preliminary work has shown that it is possible to apply the design features derived from the Cognitive Theory of Multimedia Learning to videos with learning contents from higher organic chemistry (electrophilic aromatic substitution). Within the framework of a doctoral project, it shall now be investigated to what extent learning with dynamic representations differs from learning with static representations. In addition to measuring cognitive load, transfer and retention in a control group design, it will also be examined whether spatial ability and prior knowledge influence learning success.
This paper presents the Cognitive Theory of Multimedia Learning as a theoretical framework for video-based learning with complex mechanisms in organic chemistry. Based on this consideration, hypotheses for higher transfer and retention performance when learning with videos are derived.

Keywords: chemistry education, organic chemistry, animation, multimedia, reaction mechanism

1. Introduction

Chemistry as a science about the structure, properties and transformation of substances heavily relies on adequate forms of visualization. Since particles on the sub-microscopic level cannot be observed chemists developed various tools to visualize and share information in their field of work. Most of these visualizations, with the structural formula as the most prominent one, hold a lot of implicit information which are not readily accessible for novices.

Studies in higher education show that organic chemistry in particular is perceived as a challenging sub-discipline of chemistry by many students. This is due to the frequent change in levels of representation as well as the expansive and information-rich symbolic language of the subject [4]. Complex reaction mechanisms in particular pose a challenge for students, as many cognitive resources must be devoted to interpreting the symbolic language. As a result, students increasingly focus on surface features such as functional groups and do not recognize the underlying structural properties of the molecules [5].

However, it is these properties that provide crucial information to the course of chemical reactions, so students often make erroneous mechanistic predictions. The high workload of the cognitive system also results in fewer resources available for constructing and modifying mental models, which impairs learning and performance [1].

Based on a cognitive psychology approach, the following will explain how learning organic chemistry reaction mechanisms can be facilitated by incorporating dynamic multimedia in learning environments.

2. Theoretical Framework

Since the term (dynamic) multimedia has a variety of definitions, a clarification of terms shall be given first. Media can be distinguished by the senses through which they are perceived. This property of media is called modality. Though information can be received through all five senses, this article focusses on the sense of hearing and the sense of sight. Media that convey information through the sense of hearing are referred to as *auditory*. Media that convey information via the sense of sight are referred to as *visual*. Media can also be assigned different forms of codality according to the symbol system which is encoding the presented information [6]. Media that convey information encoded in the form of images are called *pictorial* while media that encode information in the form of speech are called *verbal*. These distinctions result in four possible modality-codality combinations (Fig. 1). Due to the low relevance of the auditory/pictorial combination, only the three combinations voice, text, and picture will be considered in the following.

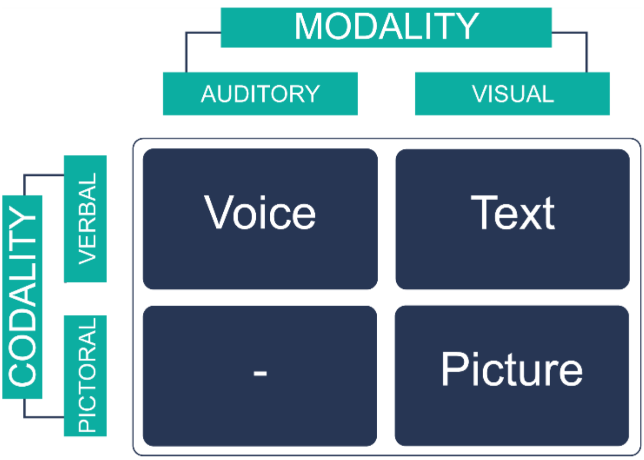

Fig. 1. Possible Combination for modality and codality

In consideration of that multimedia can be defined as media that combine the characteristics of multimodality and multicodality [7]. Thus, they must (1) convey information using the sense of sight as well as the sense of hearing and (2) use language and images as symbol systems.

Dynamic multimedia is of particular interest for chemical education research because they can adequately depict dynamics at the sub-microscopic level, whereas their static equivalents can only indicate such dynamics by reaction arrows and dashed lines.

This clarification of terms allows to scientifically frame oftentimes indistinct terms such as “learning videos” as dynamic multimedia and thus make them accessible for research.

Mayers Cognitive Theory of Multimedia Learning [2] provides a valid model for learning in multimedia learning environments. (Fig. 2) According to the theory the human cognitive system is divided into long-term memory and working memory, with the working memory being the core of the model. It is considered to be strongly limited in its capacity and thus represents the limiting factor in the learning process. An overload of the working memory results in the so-called cognitive overload, which results in an immediate termination of the learning process. Consequently, all design principles to be derived from the Cognitive Theory of Multimedia Learning aim at reducing the cognitive load in the working memory.

Furthermore, the theory assumes a division of the working memory into two autonomously working subsystems. Both channels process information according to their modality and codality, however they can be simplistically assumed as a language channel and a picture channel [2]. Due to the use of extensive symbolic language, conventional teaching formats in organic chemistry overuse the picture channel of the working memory, leaving valuable resources of the language channel unused.

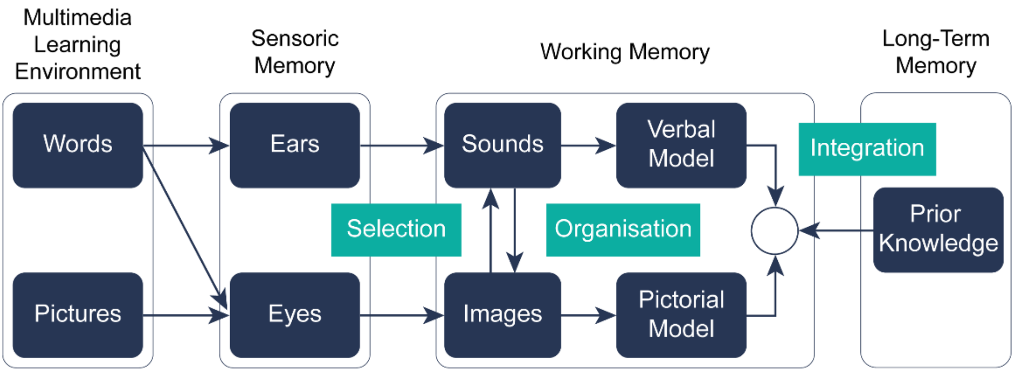

Fig. 2. Cognitive Theory of Multimedia Learning

When learning with dynamic multimedia however, both channels can be engaged equally. The cognitive resources saved are then available to students for performing other demanding cognitive tasks. Furthermore, the even load allows the exchange of information between both channels and results in the construction of a verbal model and a pictorial model which are equally valid. With this a more elaborate and more comprehensive mental model can be created in the step of integration (Fig. 2).

In Addition to that, dynamic multimedia can cognitively relieve students through supplantation [3]. In conventional teaching format’s reaction mechanisms are often displayed as static representations and hence unable to depict dynamics on a sub-microscopic level appropriately. Consequently, students must emulate the dynamics through cognitive modelling which requires a large number of cognitive resources, especially for complex reaction mechanisms [8]. However, with dynamic multimedia's ability to depict dynamics, sophisticated cognitive modelling (e.g., intramolecular rearrangements) can be outsourced to the learning environment. The capacities saved this way can be used for the construction of elaborate mental models.

3. Preliminary Work

In the context of an examination thesis at the Friedrich Schiller University of Jena, it was investigated to which extend the approach outlined above could be used for the creation of dynamic multimedia in chemistry education. Based on the Cognitive Theory of Multimedia Learning [2], six design principles were used for the criteria-led construction of dynamic multimedia. Electrophilic aromatic substitution was chosen as the learning content because the underlying mechanism requires high visualization and, due to the mesomeric-stabilized complexes, benefits especially from the dynamic multimedia format [9].

In order to evaluate the material, student teachers in the 8th and 10th semesters were surveyed (N=28). A questionnaire was used, which asked with an ordinally scaled, four-step Lickert scale whether the respondents considered the individual design principles as implemented or not implemented. This questionnaire provided a positive sentiment and was able to show that (1) student teachers evaluated the learning video series as positive without knowledge of the model and its design criteria and that (2) student teachers considered the elaborated design criteria as implemented with knowledge of the model and its design criteria. Therefore, it can be concluded that the Cognitive Theory of Multimedia Learning [2] is an elegibile cognitive psychological approach for creating dynamic multimedia in chemistry education.

4. Outlook

In further research, it will now be investigated whether and to what extent the expected differences in learning with dynamic multimedia and static monomedia can be measured. The learning content will also be a mechanistically demanding learning content of higher organic chemistry, which, just like electrophilic aromatic substitution, requires high visualization [9]. In this context, the questionnaire of the preliminary work shall serve as a starting point for the creation of measuring instruments for further work.

In a control group design, it will be investigated whether retention and transfer performance of both groups differ. In addition, the level of prior knowledge will be surveyed to investigate whether students with little or high prior knowledge benefit from the dynamic multimedia treatment. Another research interest is the influence of the spatial ability on the constructs mentioned above. It is unclear whether, under the outlined conditions, learners with low spatial imagination (ability-as-compensator hypothesis) or learners with high spatial imagination (ability-as-enhancer hypothesis) benefit more from learning with dynamic multimedia [10]. To investigate this question, the spatial imagination will also be measured.

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Reimagining Student Laboratories: Design and Evaluation of two Innovative Concepts

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Abstract

Most student laboratories organized and cared for by universities try to enrich students' interest in sciences by offering experimental courses for school classes and working closely to their school's curriculum. At the Friedrich Schiller University Jena, the working group for chemistry education is aiming to enhance this offer in two ways by intertwining the existing classical student laboratory with digital media elements and providing it with a learning-to-teach-approach.
Learning-to-teach-laboratories are defined as a special organizational form of teacher education. By supervising students during the experimental courses of student laboratories, student teachers can gather teaching experience, thus combining learning activities of students with job-related qualifications of student teachers. Applying this approach to the student laboratory in Jena, chemistry student teachers can experience a change of perspective from the role of a student to a chemistry teacher.
Furthermore, in all stage's digital media such as iPads and Whiteboards will be used to improve students' experience of the course. Following the SAMR-model for the integration of learning technology these technical augmentations are aiming to enhance and transform the learning culture of the student laboratory through expansion of the experimental courses by new innovative modules, which will be evaluated by an accompanying study.

Keywords: teaching chemistry, student laboratories, digitalisation, learning-to-teach-lab

1. Introduction

Since 2003, the student chemistry laboratory of the Friedrich Schiller University Jena has offered learning opportunities for interested learning groups of all ages. The student laboratory is funded, supported, and supervised by the working group for chemistry education and its staff. The courses, experiments and materials have been developed over the years during various research projects and are constantly updated and expanded. The provided materials include experimental instructions as well as exercises to help understand the science behind them. Due to this set up it can be qualified as a 'classical student laboratory' [1].

When looking for ways to expand this offer, two fruitful approaches were found. To include the student laboratory further in the teachers training a learning-to-teach-course was designed. Moreover, a change to the experimental course design is being made. By including digital media and expanding the experimental courses with e-learning units it is hoped that learning efficiency and motivation will increase.

2. Student laboratories and the teacher education

Combining university-based teacher education with practice elements, *learning-to-teach-laboratories* (abbreviated as “LTL” in the following), especially in the training of prospective STEM teachers, play an increasingly important role [2]. LTL is currently understood to be “[...] *a special organizational form of teacher education in which learning, or support activities of students and the job-related qualification of student teachers are meaningfully linked.*” [3]

2.1 Concept of the LTL in Jena

In a one-semester-module, chemistry student teachers in their first semester can already experience an initial shift of perspective from the role of a student to a chemistry teacher. The focus here is on reflective engagement with beliefs and motivational orientations, which is an important component of teacher professionalism [4].

The concept is based on the principle of *subject-specific instructional coaching* which includes three sections: preliminary discussion – teaching sequence – debriefing. The phases of pre- and post-discussion are designed in corresponding to a *co-constructive dialogue* [5] between the student teachers and the lecturer. The participants work in small groups, each planning and carrying out one session in the student laboratory. After an introduction, basic didactic seminars are held for all participants, in which the necessary contents are worked out together. Furthermore, the groups get to know the experiments of their student lab theme in practical courses. Simultaneously, group-related consultations are held to prepare the respective student laboratory session. Each group then carries out the previously planned teaching sequence in the student laboratory. Immediately afterwards, a debriefing session takes place to evaluate the sequence regarding the reflection criteria previously defined. In a final meeting, the group results are compiled, experiences are shared and reflected on together (Fig. 1). During the module, all results and reflections are documented in a portfolio.

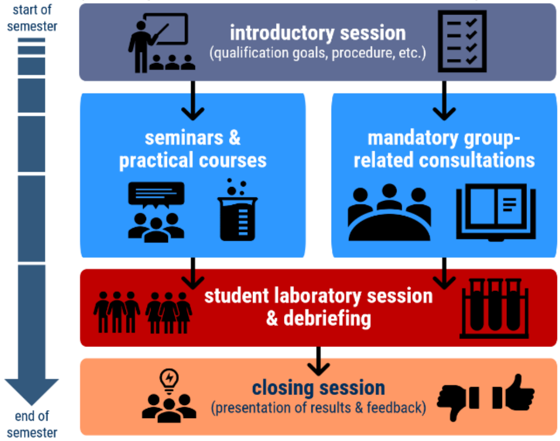

Fig. 1. Schematic semester

2.2 First evaluation results

Already from first experiences with the concept, the participants rated both the format and the early theory-practice, as profitable overall [6]. In the pilot study, a questionnaire survey in a pre-post design with a five-point Likert scale (1 = *not true* to 5 = *completely true*) was used. A total number of 19 students was surveyed. In the figures, the mean values associated with the items are shown with the respective standard deviation.

Regarding the perception of the course format, the data obtained generally indicates that student teachers evaluate the practical experience in the first semester positively.

The basic conception is also considered sensible by them. Furthermore, specific course elements, such as working in groups or the prior supervision by the lecturers, are also met with a high level of approval (Fig. 2).

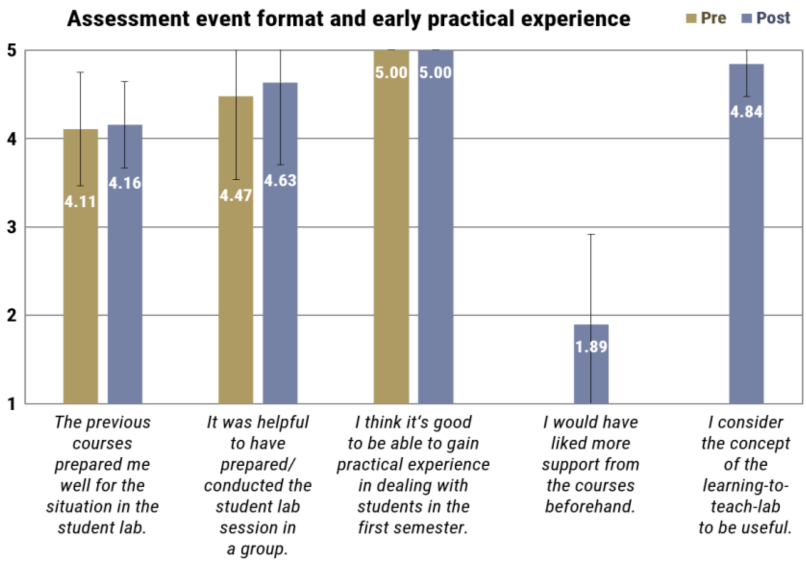

Fig. 2. Selected items on the assessment of the event format and the participants' perception of the early practical experience

Concerning the career choice motivation, the piloting results initially indicate that participants chose to study chemistry with a high level of motivation. This remains largely constant after the interaction with the students. It is also evident that the experience tends to reinforce the career aspirations rather than raising doubts about them. From this it can be concluded that an initial experience in the LTL can influence the career choice decision at the start of the study and even reinforce it (Fig. 3).

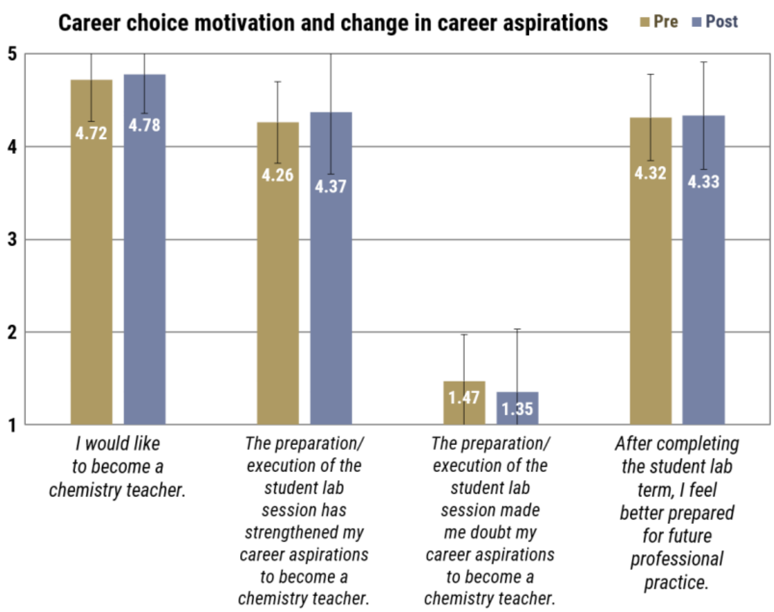

Fig. 3. Selected items on the career choice motivation and on possible changes of the wish to become a chemistry teacher

Finally, the participants assessed the quality of their student lab session and their own competencies (Fig. 4). In the area of these **self-efficacy expectations**, positive effects can be recognized regarding the effectiveness of the unit planned and carried out by the participants as well as their own competencies. These can be observed mainly in the assessment of the students' time management or the evaluation of their own professional responds to students' inquiries. However, in the context of a one-time interaction in LTL and regarding the point of time in the study, the effects are to be assessed as low. The high standard deviations for many items indicate that the evaluation by the participants seems to differ significantly on an individual level.

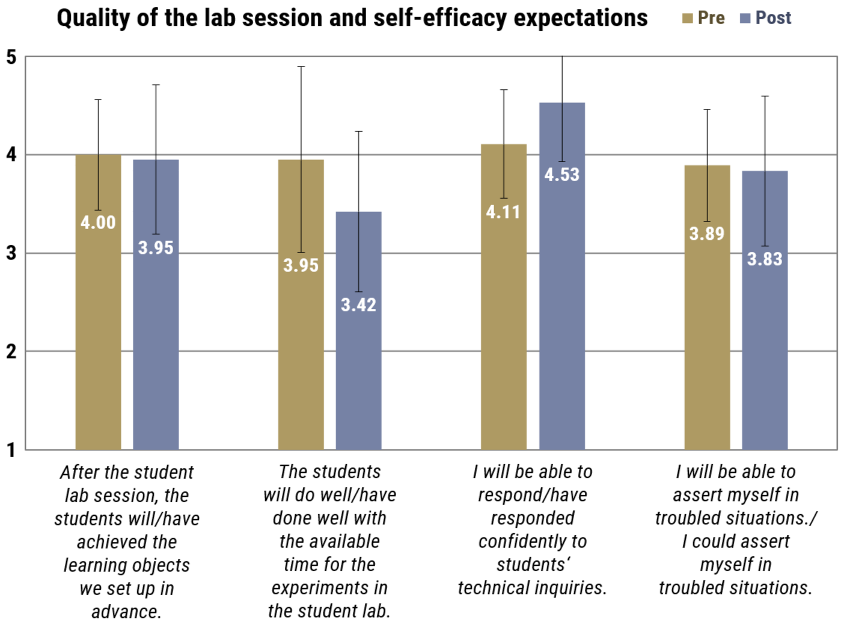

Fig. 4. Selected items on self-assessed quality of the student lab session and on aspects of self-efficacy expectations

3. Digitalisation and expansion of the student laboratory in Jena

The existing student laboratory is to be expanded at several central points with innovative modules. One aim is to link classical and well-established aspects with future-oriented possibilities of the digital world. Digital media should be used with a sense of proportion and by utilising their specific potential. Therefore, digital aspects will be integrated in the different stages of the student laboratory day to different extents.

3.1 Renewed concept of the student laboratory

The renewed concept and schedule of a student laboratory day is illustrated in the following figure:

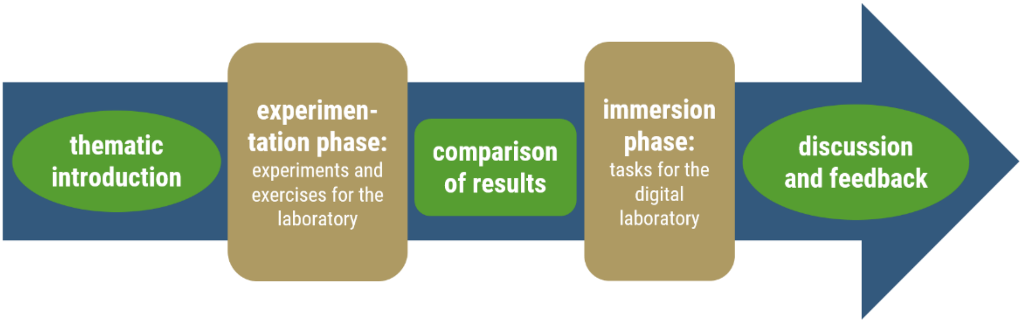

Fig. 5. Renewed sequence of the student laboratory

As preparation for the experimentation phase, a thematic introduction is planned, in which the stations and their focal points are presented to get a distinct insight into the topic and to prepare the students for the experiments accordingly. The experimentation phase itself is essentially identical to the previous contents of the classical student laboratory. Existing experiments from the student lab, which have proven themselves during regular realizations, can therefore be adopted for this phase.

Afterwards, a comparison of the results from the student laboratory should take place.

The students can compare their results for each station and can correct previous mistakes and unclarities. With the planned immersion phase, a completely new format will now find its way into the student lab day. The students will have the opportunity to apply their knowledge and deepen their understanding of the subject-related aspects of the stations. A short discussion and feedback session should conclude the day and offer the students time and space for reflection. In addition, any topics that emerge here can offer suggestions for the follow-up of the student lab day in school.

3.2 Establishing the concept of a digital student laboratory

Digital media will be integrated into the work processes in a variety of ways. First, the previous experimental instructions for the experimentation phase are gradually being converted into digital experimental scripts. In the sense of e-books these digital experimental scripts can already contain graphics or other interactive elements that extend the functionality of analogue scripts. In the sense of the SAMR model [7] analogue content will be directly replaced by digital content and its range of functions expanded. Thus, the first stage in the integration of learning technology, enhancement, is achieved.

The use of iPads also makes it possible to design tasks in a new and open way: The app *Prezi* will be used for the thematic introduction. In this app, presentations no longer correspond to a linear format but can be perceived interactively. In this way, several layers of the presentation can be incorporated, and the reader can grasp the information in a self-determined way. The software *Explain Everything* will be used in the immersion phase. This app can be used to simulate a whiteboard on any device, which can be prepared in different ways depending on the task. Thus, additional help, videos, links, etc. can be integrated, thereby transforming the learning environment. The next stage of integrating learning technology in the SAMR model, transformation, is thus achieved and the potential of digital media largely realised.

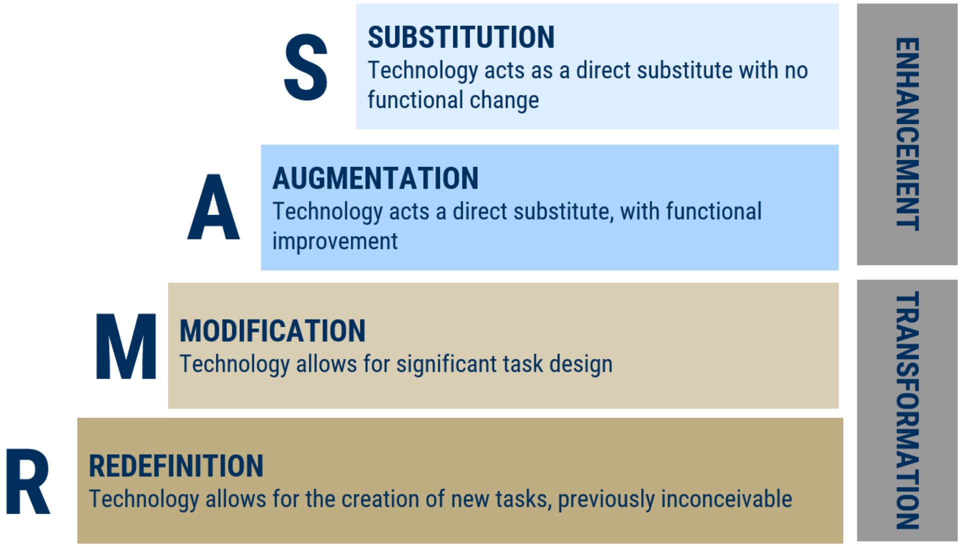

Fig. 6. Reconstruction of the SAMR model)

3.3 Evaluation and integration of the concept

The newly created concept is to be reviewed subsequently. For this purpose, a study with about 100 students is planned. The learning effectiveness will be examined by a pre-test/post-test design. In the beginning, only the immersion phase will be evaluated in comparison to groups who will instead experience the classical student laboratory schedule with more experiments. It will be investigated whether the pupils who have gone through the student laboratory with the digital immersion phase achieve better results and thus learning progress than those who have only gone through the experimentation phase. This would be a first indication that the new offer is more effective for learning than the previous offer. The results of the study will then be analysed, and conclusions drawn about further development possibilities and the future orientation of the student lab. A follow-up questionnaire is planned, examining long-term effects of the intervention.

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Science in the Spotlight: Didactic Reconstruction of Current Research for Chemistry Education

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Abstract

Fundamental scientific research and its results are very difficult to understand for the general public since they are mainly communicated between experts in the respective field and presented in a way that laypersons cannot easily understand. This leads to a separation between science and society and consequently to a lack of awareness and often a lack of mutual appreciation. The didactic reconstruction of current research results addresses this challenge by making future-oriented topics and their associated research methods accessible to society.
The field of photochemistry is currently subject of intense research and offers excellent learning opportunities. Related technologies find broad applications in everyday life, science and technology, ranging from solar collectors and photocatalytic wastewater treatment to light-emitting diodes (LEDs) and beyond. Due to their strong connection to everyday life, their great significance in the present and the future, their possibilities for interdisciplinary approaches and contexts, these topics offer just as great a potential for teaching in formal as in non-formal educational programs. From a didactic point of view, they offer a variety of interdisciplinary learning opportunities and numerous references to the basic concepts of energy (conversion and storage), chemical reaction and structural properties. In addition, there are numerous links to many classical contents and content fields of chemistry lessons at secondary level II.
In our article we present how current research results on photocatalysis can be reconstructed didactically and implemented into schools and student laboratories. In close collaboration with chemistry research groups, teaching concepts, teaching materials and (model) experiments have been developed that can be carried out with harmless chemicals and low-cost analytics.

Keywords: Chemistry Education, Didactic Reconstruction, Photocatalysis

1. Introduction

Good communication between science and society is of vital relevance and interest to both groups. This becomes particularly clear in the current exceptional situation when, for example, research processes for the development of drugs and vaccines to treat COVID-19 have to be communicated to the public in an understandable way. Strong relations to science are also of great importance for school chemistry education and vice versa: the subject of chemistry is often perceived by students as “abstract” and “lifeless” [1] and over 70% of students cannot imagine taking up a STEM profession [2].

The examination of current research results within exciting contexts and with a high level of relevance to everyday life offers a variety of opportunities to contribute to the solution of both problems. Future-oriented topics and their associated research methods can be made accessible to society through the didactic reconstruction of current research. This offers students as well as teachers not only motivating learning opportunities and contexts, but also enables participation in social discourses in the sense of a *Scientific Literacy* and reveals new career perspectives. It offers the interested public the opportunity to encounter future technologies to obtain comprehensible first-hand information and to participate in scientific and educational policy debates.

2. Photochemistry: Chemistry in the right light

Reactions driven by (solar-) light are the main focus of the German transregional collaborative research center 234 CataLight (TRR 234), hosted by Ulm University and Friedrich-Schiller-University Jena with additional project partners at Max Planck Institute for Polymer Research Mainz, Vienna University and the Institute for Photonic Technology Jena. To pave way for a broad usage of abundant solar energy, CataLight develops molecular light-driven chromophores and catalysts, and establishes concepts for their integration into soft matter matrices.

The thematic orientation of CataLight offers excellent opportunities for school chemistry education. Chemical reactions with (solar) light represent the basis of numerous processes that enable life in the biosphere. They also have broad applications in everyday life, science and technology, ranging from solar collectors over photocatalytic wastewater treatment to light-emitting diodes (LEDs) and beyond. Due to their strong connection to everyday life, their great importance in the present and future, and the possibilities for interdisciplinary considerations, they offer as much potential for teaching in formal as in non-formal educational programs. From a didactic point of view, they further provide a variety of interdisciplinary learning opportunities and numerous references to the basic concepts of *Energy*, *Chemical Reaction* and *Structure-Property-Relations*. In addition, there are numerous links to many classic contents and content areas of chemistry lessons at secondary level II [3, 4].

For these and other reasons, the topic of "chemistry with light" is the subject of research by several didactic research groups; however, the core curricula and syllabi are still mostly limited to superficial considerations and a few examples of application, such as photosynthesis or solar collectors. Current research on these objectives has rarely been taught in schools and student laboratories to any great extent, nor has the impact been considered, that such new technologies can contribute to society as a whole (e.g., energy supply, mobility, climate change).

3. CataLight: Shedding light on chemistry

Within CataLight, new photosensitizers, photocatalysts and suited soft matter matrices for the immobilization of these chemically active components are developed.

To understand the interaction between all components of the reactive systems, an interdisciplinary effort is required to generate a fundamental understanding rather than gaining specific insights into only a particular chemical system. Consequently, research activities cover the fields of theoretical, physical, organic, inorganic and analytical chemistry as well as physics and chemical engineering. Below, two selected research areas are briefly presented.

One research area within CataLight performs photochemistry in a soft matter membrane-material that is very similar to the natural material of cell membranes: phospholipid bilayers. In water, such membranes form so called vesicles, which serve as nanoscopic chemical reactors. In this project, the membrane itself is used to self-assemble chromophores to absorb several colors of the visible light and funnel the light energy from the membrane surface to the inner water interface of the nano reactor where the energy is used to convert substrate into product (see Figure 1 and 2).

With regard to chemistry education, direct links exist to the subject area of surfactants, which are typically taught in secondary level II. Since amphiphilic molecular structures and micelle formation are well known by students, these “classic contents” can easily be transferred to a current research context within CataLight.

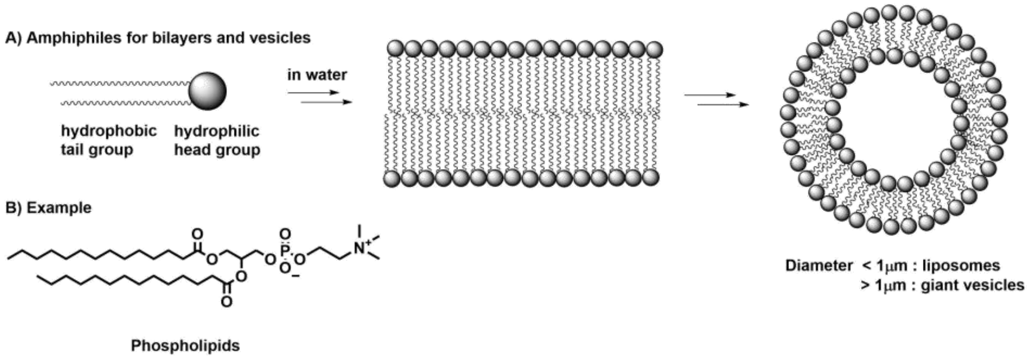

Fig. 1. A) Self-assembly of amphiphilic molecules in water into bilayers and vesicles. **B)** Example of bilayer forming amphiphiles: phospholipids

Building on experience of energy transfer within such membranes [5], this process is fine tuned to enable long range energy transfer within the membrane. The specific energy transfer mechanism is called “FRET” (Förster resonance energy transfer) and is very often used in biological and biochemical context to “measure” distances on the nanometer to sub nanometer scale in biological material such as proteins using luminescence and luminescence quenching via FRET (Nobelprize 2008) [6]. Specific chromophores are chosen based on their luminescence properties, excited state reactivity with respect to photocatalysis and their ability to co-assemble with the phospholipid bilayer.

An example of a luminescent chromophore is shown in Figure 2: A luminescent metal complex with hydrophobic alkyl tails is perfectly suited to integrate into phospholipid membrane vesicles. In combination with other chromophores, absorbing different colors of the visible spectrum, light harvesting via energy transfer is enabled, which can be monitored and used for luminescence spectroscopy and photochemical reactivity (see Figure 2).

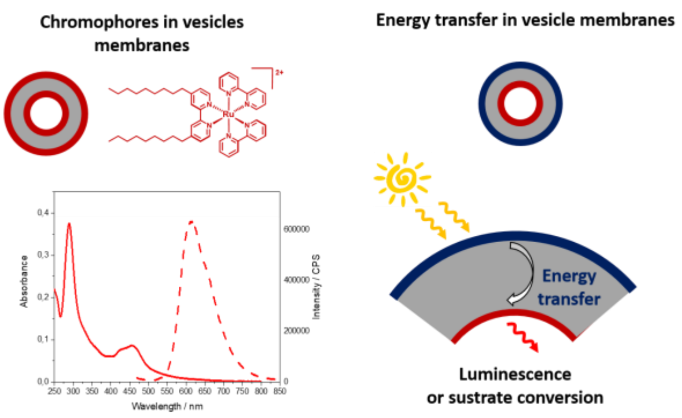

Fig. 2. Left: Chromophore in vesicle membrane including absorption and luminescence spectrum. **Right:** Scheme of targeted vesicles with chromophores absorbing different colors of light and funneling the energy to the inner vesicle compartment for photochemical oxidation of substrate to product.

Photochemical reactions heavily depend on the reaction conditions. As for thermal reactions, parameters such as temperature, concentration, pH-value, etc. influence reaction rates and selectivites. Beside this, intensity and wavelength of the light reaching the chemically active species are not only further parameters that govern the performance of the reaction but the most important [7]. During experimental work, this influence often results in poor reproducibility of experiments since conventional experimental setups are prone to slight changes of the overall arrangement. Hence, the irradiation conditions and consequently the most important reaction parameter, the light intensity, randomly changes. To minimize this experimental error, rapid prototyping and additive manufacturing are applied within CataLight to develop and distribute experimental setups that prevent changes of the irradiation conditions (see Figure 3).

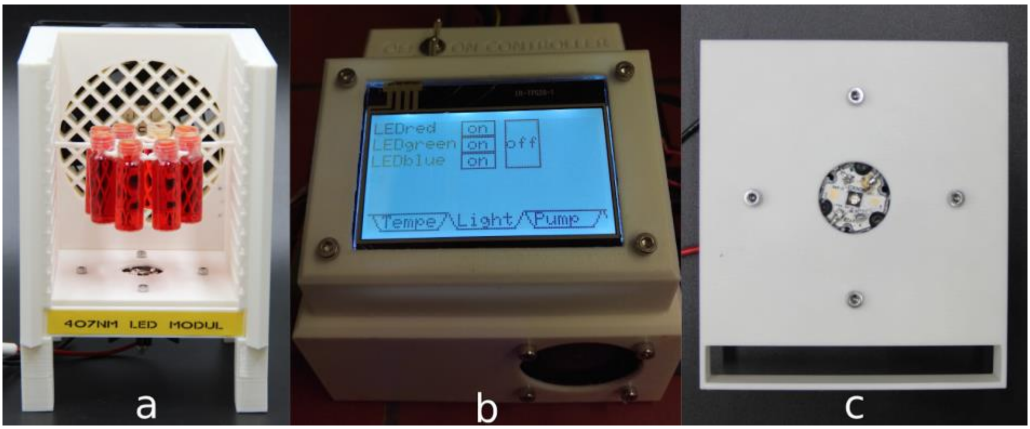

Fig. 3. A) Experimental setup for screening of photocatalytic systems, **B)** control unit for light sources and other devices, **C)** modular LED cartridge, available with different light sources

The flexibility that is gained by additive manufacturing allows for an easy adaptation to particular experimental requirements of the various photocatalytic systems that are investigated within the TRR234. Furthermore, manufacturing costs are low and processing times for individual adaptations short. This allows for the necessary wide distribution across the different projects and swift response to practical experiences and new scientific insides. This concept is well suited for transfer to school education since it covers aspects of physics, physical chemistry, photocatalysis as well as analytics, statistics and planning of experiments. It further introduces engineering aspects like design of reactors and experimental setups on the basis of modern and also popular and easily available 3D-printing techniques.

4. Reconstruction for School Chemistry Education

For a successful transfer of these contents from CataLight to schools and the public, there are three central challenges in particular:

1. **Didactic reconstruction:** Due to its high specialization, current (fundamental) research is usually very demanding and difficult for learners to comprehend. Especially for the understanding of light, there are inaccurate preconceptions or misconceptions on the part of the learners [3], which have to be addressed.
2. **Experiments and analytics:** Standard equipment and chemicals in research cannot be used in schools due to their high costs and/or hazard potential. In addition, schools and student laboratories typically do not have access to analytical methods.
3. **Instructional approaches and in-service training:** Many teachers are motivated to teach new subject areas in their classes, but often perceive multiple barriers to teaching new subject areas in their classes. These include, in particular, lack of subject knowledge, lack of teaching materials, and lack of teaching time.

This results in three fields of action in which the above-mentioned challenges are to be addressed, new impulses for chemistry teaching are to be developed and the dialogue with the public is to be promoted.

Field of action 1: didactic reconstruction

For the research process, the model of didactic transfer research [8] is used as a foundation, which opens a structuring framework for the scientific development of the contents. Figure 4 visualizes the three sections, which include (1) the didactic reconstruction of the contents in cooperation with scientists, (2) the development of teaching materials in a cyclical process of conception, testing, evaluation, and optimisation and (3) the final dissemination of the tested materials into science and teaching practice. An example of a practical implementation of the model can be found at [9].

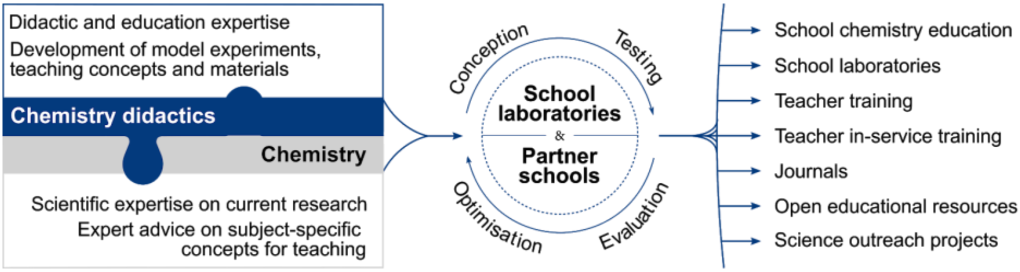

Fig. 4. Model of didactic transfer research [8]

Field of action 2: digital low-cost analytics

One challenge for the development of meaningful model experiments is the lack of possibilities for measurement data acquisition in the classroom. However, this represents a central aspect of scientific-experimental investigations, which is rarely reflected in teaching for a multitude of reasons. Schools often lack the funds to purchase and maintain the measuring instruments. In addition, many existing devices are not designed for use in the classroom.

This challenge is met by using the digital low-cost measuring station LabPi with the aim of opening up new experimental possibilities for STEM teaching [10]. Instead of individual solutions for each unit, LabPi represents an open platform on which up to five measuring variables can be recorded simultaneously. This is achieved by combining single-board computers (Raspberry Pi) with powerful (miniature) sensors, which are widely available and sometimes cost only single-digit euros. With an adapter board and the corresponding software, measurements of pH, temperature, conductivity as well as photometric investigations are currently possible, providing basic analytics for chemistry teaching.

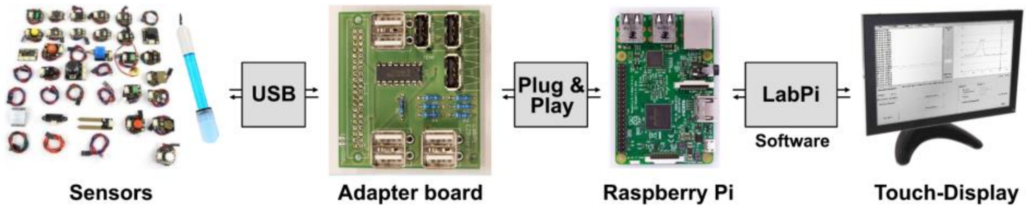

Fig. 5. Components and schematic representation of the LabPi build

Field of action 3: dissemination and outreach

The developed and tested teaching materials (see Figure 4) will be made accessible to students, particularly via regular teaching in upper secondary schools; by integrating them into formal education, learners can benefit from the offerings both regionally and nationally. In addition, we will also develop materials and courses for student laboratories, so that interested learners can get to know this offer on their own initiative.

To enable or facilitate the teaching of the subject area to motivated teachers (as multipliers), we provide the developed materials (experiments, worksheets and sample solutions) as Open Educational Resources. At the same time, a teaching sequence is created on this basis, which can be used in regular lessons with the associated handouts. Thus, teachers are relieved in the preparation of lessons, but retain the flexibility to adapt the unit depending on the learning group, time and interests.

5. Conclusion and outlook

The subject area of photochemistry offers excellent learning opportunities for consideration in chemistry classes. In addition to numerous everyday connections, challenges facing society as a whole can also be discussed and evaluated in a context-oriented manner. The research work in the transregional collaborative research center CataLight offers an ideal environment for this and will be didactically reconstructed for schools and student laboratories in the coming years.

Acknowledgements

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Teaching Entropy at Bachelor Level in a Conceptual Change Perspective

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Abstract

In the framework of conceptual change theories in the learning sciences, identification of pre- or misconceptions and their replacement by scientifically validated conceptions is a central aspect of any teaching. Recent neuroscientific explorations brought new dimensions to the problem by showing the importance of inhibitory processes. Physical chemistry at the undergraduate level is known for being a difficult topic, due to its abstract character and the need to combine physical insight with a mathematical toolkit. Entropy and the second law of thermodynamics is a central topic in the physical chemistry curriculum, upon which most STEM students step during their first year at university. Specific difficulties linked with these concepts include the existence of two possible approaches, a macroscopic and a molecular one, whose interconnections are seldom made explicit. In this study, we present and discuss results of misconception identification for first-year bachelor students in chemistry, pharmacy and geology in a French-speaking Belgian university, using a pre- and post-test about entropy and the second law, before and after a one-semester course using the most common macroscopic teaching method. The questions of this test have been developed based on a detailed analysis of the approaches of standard physical chemistry textbooks. In addition, the investigation of remaining misconceptions of more advanced students (2nd and 3rd bachelor year, 1st and 2nd master year, not presented here) completed the study. Some of the identified misconceptions are comparable to those already published in the literature, and new ones are detected. Some misconceptions are rather of ontological nature whereas other ones result from inappropriate interpretation of analogies. As far as 1st year bachelor students are concerned, the results indicate that most erroneous conceptions remained after the one-semester course and that some were even aggravated. The obtained results will be a guide to develop new teaching approaches, involving a better link between experimental situations and the conceptual framework and including discovery learning as well as numerical simulations.

Keywords: Conceptual change, misconceptions, entropy, second law of thermodynamics

1. Introduction

The existence of student misconceptions is recognized as one of the key elements to be considered in any didactic approach [1]. Concepts and approaches in physical chemistry frequently exhibit a high degree of abstraction, which is partly related to the associated mathematical formalism. This is the source of many of the didactic hurdles typical of abstract subjects [2]. Among the major themes of physical chemistry, our research focuses on one of the fundamental aspects of thermodynamics: entropy and the second law. This topic presents, among others, two didactic characteristics worth of interest: (i) physically speaking, entropy emerges from events at the atomic and molecular level, what we call the microscopic scale, but, historically, it has first been addressed at the macroscopic scale, which leads to two distinct teaching approaches; this is a source of cognitive conflicts that tend to remain even after an introductory course; (ii) it is a cross-cutting subject, addressed in physics, chemistry, biology, engineering and information science, with each branch having its specificities and complementarities [3].

Johnstone's triangle [4] is a key to analysing the problem posed by the appropriation of the concept of entropy. The interconnection of three points of view – macroscopic, microscopic and representational – generates cognitive obstacles specific to chemistry.

The present work also fits into the theoretical framework of conceptual change, for which several currents or sensibilities exist, represented among others by Vosniadou [5] or diSessa [6]. These theories conceptualize how students evolve from alternative, naïve, false or incomplete conceptions to scientifically founded ones.

The work presented here is the first step in the development of new methods for teaching entropy and the second law, at the undergraduate level, supported by research in didactics. The first step is to identify the misconceptions of a population of students in their 1st year of chemistry, geology and pharmacy in a French-speaking Belgian university (University of Liège) at the end of a basic general chemistry course (autumn semester) and to analyze the impact on these misconceptions of a more in-depth one-semester course (spring semester) using the conventional macroscopic approach. The pre- and post-tests invite students to develop reasonings that question the metaphor of disorder [7].

2. Method

A questionnaire was submitted to N=181 students in the following sections, following common courses: Chemistry, N=27; Geology, N=12; Pharmacy, N=142. Five closed-ended questions aimed at probing expected misconceptions, in light of the literature and the analysis of recognized textbooks. Five semi-open-ended questions (multiple choice and request for justification) seek to elicit cognitive conflict by confronting students with paradoxes related to alternative misconceptions. The questionnaires were validated by 20 experts. The pre-test was organized face-to-face, while the post-test was offered online and without obligation, resulting in a significantly lower answer rate (N=49). The comparison of the two tests was limited to the common respondent population. A system of identifiers makes it possible to monitor the individual progress of the participants.

3. Results and Discussion

We shall focus here on one question of each above-mentioned category to illustrate two aspects of identified preconceptions: ontology and analogy.

3.1 Closed question analysis: example of entropy definition

Figure 1 presents the results of the first question, which attempts to identify the concepts that students consider as ontologically related to entropy.

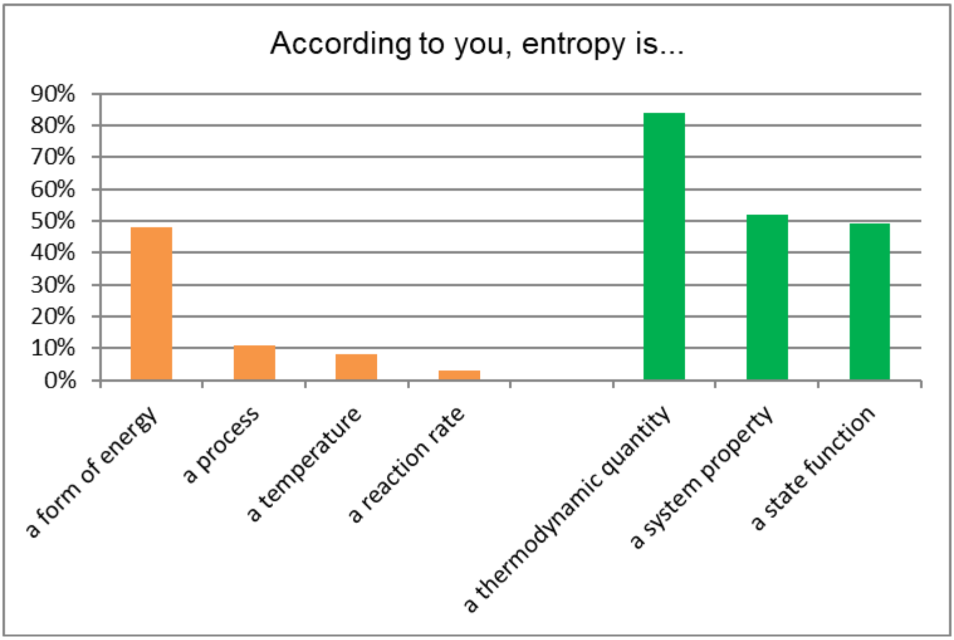

Fig. 1. Percentage of choices for the different statements related to the definition of entropy. Pretest data (N=181). Multiple answers are possible. Green: correct choices. Orange: incorrect choices

The assimilation of the concepts of energy and entropy is a misconception that is significantly present (48%), even though the two concepts are distinct: energy is the capacity of a system to perform work, whereas entropy represents the degree of energy dispersion over the accessible states. Energy is conserved, unlike entropy, which increases during a spontaneous process. While more than 80% of the students recognize entropy as a thermodynamic quantity, only half of them perceive it as a property of a system (52%) or as a state function (49%). This may be related to the fact that the macroscopic approach focuses on the entropy change, in line with Clausius' equation, therefore obscuring the fact that entropy is a property of a system. The notion of state function remains very formal and is only touched upon in a basic course.

Figure 2 compares the pre-test and post-test results for the items we have just discussed. The other statements have similar answer rates for the pre- and post-test.

We recall that the respondent population is significantly lower for the posttest (N=49 out of N=181 on the pre-test). It can be assumed that the posttest results come from the most motivated students.

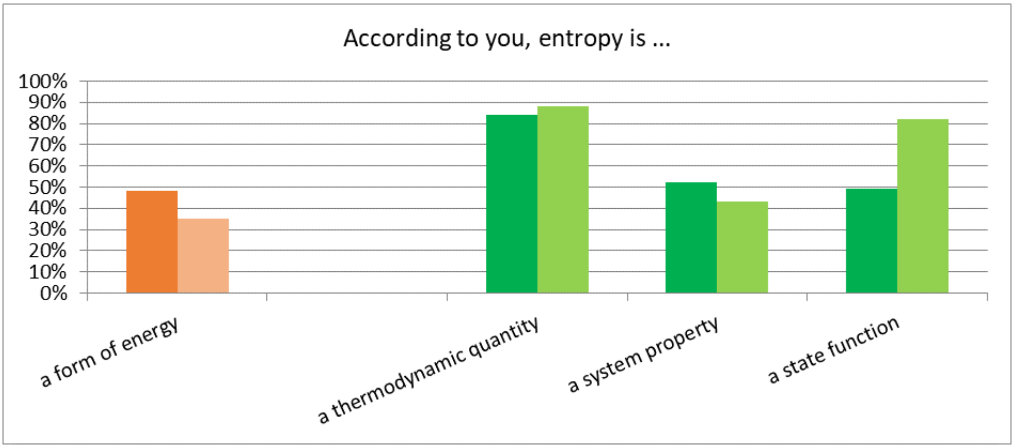

Fig. 2. Percentage of choices of statements related to the definition of entropy. Data obtained before and after the spring semester course. N=49 common participants to both tests. Dark colours: pre-test; light colours: post-test

Figure 2 highlights the following aspects.

- The misconception "entropy is energy" is receding but remains present for more than one third of the students.
- The correct statement "entropy is a state function" progresses significantly. This seems to be consistent with the macroscopic approach, which emphasizes "entropy as a function of state" for use in classical thermodynamic procedures to calculate entropy variations. However, the concept of state function seems only partially understood, since only 43% of the students recognize the link with the item "property of a system".

3.2 Open Question: Example of overcooling

The following open-ended question is adapted from Sözbilir and Bennett [7] and simplified to remove some ambiguities.

Water, when it is very pure, can be kept in a supercooled state down to -10°C at atmospheric pressure, which means it's still liquid when it should be solid. When an ice crystal is added to this sample of water, crystallization starts immediately. This phase change is exothermic.

To study this process in detail, a known quantity of water is placed in a supercooled state, in a Styrofoam box (thermal insulation): there is therefore no possible heat exchange with the environment. Then, a small ice crystal is added through a hole in the cap, which is immediately closed, triggering spontaneous crystallization. The mass of the added crystal is small enough for its contribution to entropy to be neglected. How does the entropy of the system change after the ice crystal is added?

◯ It increases.
◯ It decreases.
◯ It remains constant.
◯ None of the above three answers is correct.

Fig. 3. Open-ended question about supercooling

This question addresses the misconception "the variation in entropy is determined by the visually observable change in spatial disorder". Although the order increases during the transition from a liquid to a solid at constant temperature, the entropy must nevertheless increase here: it is indeed a spontaneous evolution in an isolated system.

The process is indeed accompanied by a temperature increase. 58% of the students seem to follow the misconception and consider that entropy will decrease. In addition, the post-test shows that the distribution does not change after the spring semester course, showing the resistance of this alternative design to change.

In Figure 5, we can observe the distribution of the student justification categories.

More than 20% of the students who provide the correct answer do not justify it correctly or not completely. For example, some students state that the addition of a crystal increases the entropy of the system, in contradiction with the provided information (Fig. 3).

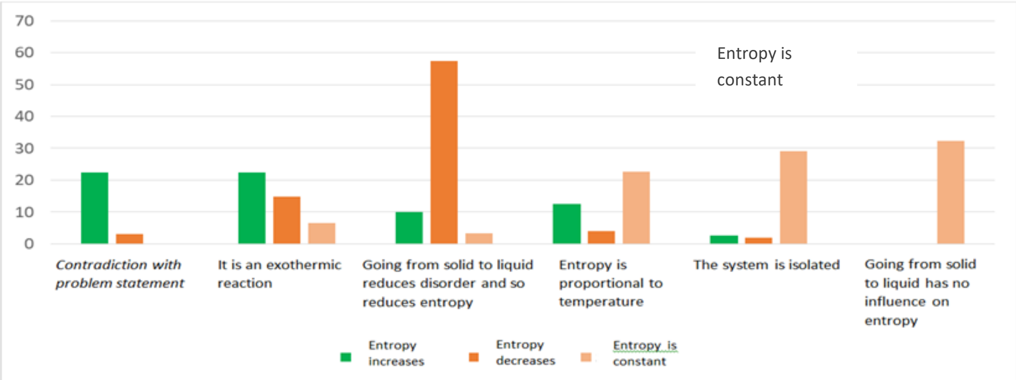

Fig. 3. Percentages of occurrences of typical justifications for the question on undercooling. Pretest: N=181. Some answers provide several different justifications

4. Conclusion

Entropy and the second law of thermodynamics, because of the involved degree of physical and mathematical abstraction, the difficulty to make a link between the macroscopic and the microscopic scale, and the cognitive conflicts they generate, represent a didactic challenge. In this paper, we show that first-year students present many misconceptions of the concept of entropy and its use through the second law, and that a traditional thermodynamics course does not necessarily correct or even aggravate them. Some misconceptions are ontological in nature, such as the assimilation of energy and entropy, others seem to be related to a superficial understanding, and thus misuse, of a metaphor ("entropy = disorder") already introduced at the birth of Boltzmann's statistical thermodynamics.

These results, supplemented by ongoing analyses of other first-year student populations, will constitute a basis for the development of didactic approaches aimed at enabling students to make appropriate connections between various experimental situations and the conceptual framework, either through investigative learning or the development of numerical simulations.

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Transitions in University Lab Teaching in an Age of Pandemic

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Abstract

No sooner had I completed a full review and revision of my first-year Chemistry lab course at the University of Sheffield, with a focus on more intelligently managing the transition from A-level and other university-precursor studies, than the global coronavirus pandemic hit. Suddenly, like thousands more academics across the world, I was thrust into a new reality full of new challenges. Choices had to be made rapidly, about what could move online and what was essential to teach in person with appropriate risk management. As I was already conducting pedagogic research into how my new course had been received, though time was short, I chose to continue surveys and discussions with my new year group of students as we faced these challenges together. The result: the safe and successful delivery of eight full lab days of face-to-face practical teaching with each student in their first semester, informed by regular student feedback and discussion. Here, I will share my experiences with what worked and what did not, as well as some preliminary findings from my ongoing pedagogic research with the students.

Keywords: pandemic, chemistry, practical, lab, challenge, teaching

1. Introduction

"…the most useful designation I have found for them is *Digital Natives*. Our students today are all "native speakers" of the digital language of computers, video games and the internet."

- Marc Prensky, 2001 [1]

"I could use more help with this [assignment] … I've never really used a computer before"

- A current first-year UK home student from an average economic background, born in 2002 [2]

This implied disconnect between what we think our students' life experiences may be like according to generational stereotype, and the reality, is nothing new – but it has serious implications for how we teach. I begin this paper with the high-profile example of the debate over 'digital natives' [3] as delivering digital distance learning has grown even more important since the outbreak of the COVID-19 pandemic. [4] However, there are many other examples, some less universal but no less fundamental for an individual student experience, of how lack of teacher understanding of the student experience can undermine student confidence in the educational process. Such confidence is vital to retain student engagement. A simple example of this is that many disciplines will require repetitive practice at basic techniques to demonstrate mastery before the end goal is in sight [5] – and a student must have confidence in the teacher's assurance that that end goal exists, and is worth his or her time and effort at work that might otherwise be perceived as tedious.

I was inspired to conduct this research by an example of such a disconnect in my own student life, back in 2003. I was a member of only the second cohort to complete A-levels (England's primary pre-university qualification) after a significant reform by the UK's (then) Department for Education and Employment. Though I was studying at a storied institution under some of the finest minds in science, it was clear that the course design had not taken these recent changes to A-levels into account, or perhaps sought to be inclusive of different educational backgrounds by not assuming knowledge they included by default. This became clear in the important chemistry field of Nuclear Magnetic Resonance (NMR) spectroscopy, in which the course was designed under the assumption new students lacked familiarity with it; the first year only covered carbon NMR, with the more complex and useful proton NMR relegated to second year. In fact, my Chemistry A-level qualification had already covered the latter to a significant depth.

This had two negative consequences; firstly, it implicitly dented my confidence in my lecturers as said above, and secondly it gave me a sense of complacency and false confidence in my own existing knowledge in general.

2. Redesigning my Lab Course

Mindful of this life experience, when the A-level syllabus changed again in the late 2010s, I was keen to avoid giving my own students a similar experience of disconnect. I worked closely with the AQA A-level exam board through their Higher Education Stakeholders programme to ensure I had a good theoretical understanding of the changes to the Chemistry A-level. [6] The primary change was the addition of a 'practical endorsement' which, simplifying for space reasons, essentially requires schools to give pupils a minimum of 12 practical experiments as part of the curriculum, with an inspection regime to enforce this. While there remains a disparity between different schools *beyond* the 12, this change creates a minimum baseline of practical experience.

As I had just taken responsibility for the University of Sheffield's first-year Chemistry lab course, it was clear to me that the course needed to change to take this into account.

There was no time to do so for the first cohort of students to have taken the new A-levels, but (via the Student Observation of Teaching scheme operated by Tim Herrick) [7] I was therefore able to gain new student responses to the existing course to inform my reforms. I also consulted with my postgraduate lab teachers for their experiences teaching the students. Some findings were predictable – the students displayed more confidence in working with basic equipment and there were fewer elementary questions, allowing a change to a less 'recipe-based' or 'hand-holding' approach in the lab manual guidance for a better pedagogic experience. Other findings were less predictable – for alleged 'digital natives' the students displayed an increasing lack of familiarity with spreadsheet work compared to previous cohorts, perhaps reflecting a shift in emphasis.

The students also supported my proposal to divide practical techniques into a generic skills manual separate from the introductory protocols for individual experiments – making it easier for them to look back on the former the next time they used that technique. The emphasis on different techniques also shifted; a consequence of the new A-levels was that 100% of home UK students had all already performed a recrystallisation before, for example, allowing me to add in extra techniques previously relegated to second year. (It was, however, always important to remember those students from non-A-level backgrounds who might need additional support).

In the 2019-20 academic year I rolled out my new course and conducted surveys of the new cohort of students (the second to have completed the new A-levels). It was my intention to have the survey findings discussed by student focus groups after the course was over. However, the pandemic then intervened.

3. Response to the COVID-19 pandemic

The pandemic hit almost at the end of my 2019-20 lab programme; students therefore did not miss out on much remaining course material (which, like colleagues around the world, I taught online in an initially *ad hoc* manner). However, it did mean that my planned focus groups sadly did not happen, leaving me only with the initial survey data. My focus was then on preparing to teach in the 2020-21 academic year. Following committee discussions about online lab alternatives, it was concluded that a majority of the learning outcomes could not be completed except with face-to-face lab teaching, albeit supported by interactive simulations (the setup of which was driven by student feedback).

Under normal circumstances, a student year group is divided into cohorts of perhaps 40 students, a pair sharing a fume cupboard, and is taught by a single academic and two or three postgraduate lab teachers supported by a technician. This was clearly non-viable under pandemic conditions. However, the size of our teaching lab and spacing of fume cupboards meant that single fume cupboard occupancy was safely possible with 2m social distancing (as deduced thanks to work by the technical staff). A risk assessment and Standard Operating Procedure was drawn up by myself and my Head of Department. By dividing the year group into more, smaller groups (18 students) with each having 4 days a week in the lab, it became possible to deliver the lab course with relatively minimal changes. Each student had a set of equipment, a single rotary evaporator and a single computer assigned to their sole use, etc., meaning there was no need for cleaning procedures mid-week. Viral matter was therefore allowed to decay over the weekend before the next class group would come in for their four days, supported by additional cleaning before and after for a ‘belt-and-braces’ approach.

The remarkable result of these changes was that (at time of writing), half our lab course (48 contact hours) has been successfully delivered to the students with only minor alterations to procedure, and there have been no cases of COVID-19 transmission in the lab. Indeed, the more significant issue from my perspective was of post-lab written assessment, which I naturally shifted online to avoid contamination issues. Once again, for ‘digital natives’ there was a substantial variance in students’ ability to scan and create PDFs, use Google Forms and so on! In consequence of this I created resources to talk students through the submission steps required. A key concern with online teaching is students losing a sense of community and the experience feeling impersonal. [8] I and my postgraduate lab teachers noted how much our students seemed to benefit just from the (distanced!) human contact of in-lab teaching. Reflecting this, I took the decision to write personalised feedback emails for each weekly student lab report, a significant time investment but one which was appreciated by students; “…seeing those grades and constructive feedback has helped me so much.” [9]

4. Continuing research and preliminary findings

Despite time constraints, this was an obvious opportunity to continue my existing pedagogic research – at time of writing I am carrying out the same surveys of this group, exploring online solutions for focus groups. As these are presently incomplete, I hear present selected findings from the survey of the 2019-20 pre-pandemic group. [10]

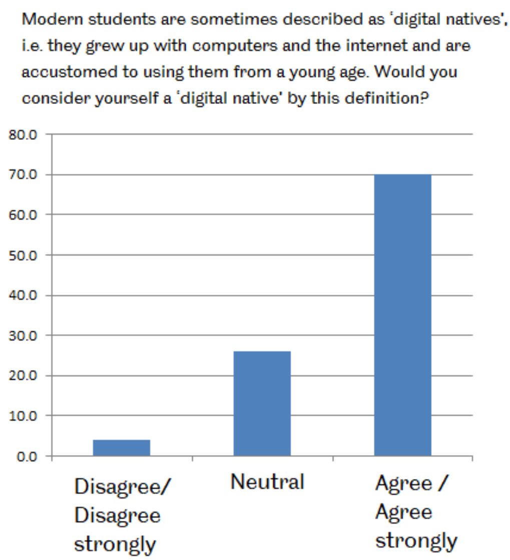

Fig. 1. Are you a digital native?

In Figure 1, we see that most (though not all) students do agree they qualify for the definition of 'digital native' given here. However, it is also clear that the details of how some teachers may translate this description to reality may vary from the student experience.

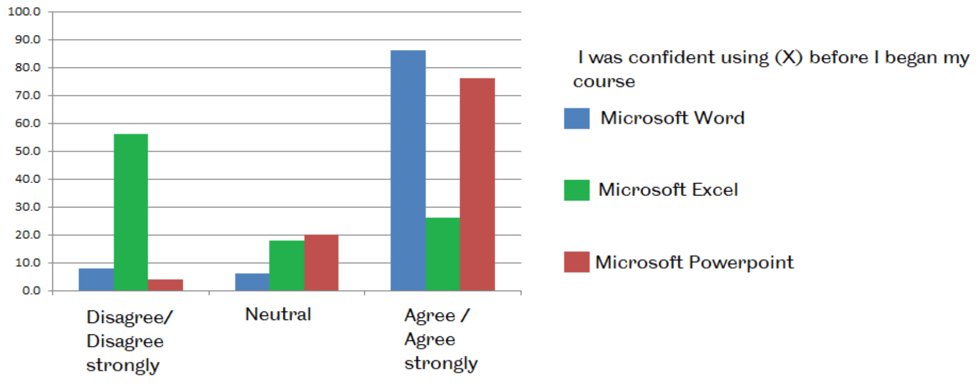

Fig. 2. Familiarity with different Microsoft Office programs

Figure 2 illustrates that the anecdotally noted lack of student familiarity with, specifically, spreadsheet programs is supported by survey data. Some students, consulted more directly, report never using spreadsheets in A-level Chemistry *at all* (I hope to back this up with more rigorous focus group data in future). I have fed this back to my contacts on the A-level exam boards and it was a surprise to their representatives, who felt use of spreadsheet software was implicitly required by the Chemistry syllabus.

This indicates the importance of managing the A-level to university transition as a two-way process, avoiding the perceived disconnects in the student experience I discussed at the beginning of this paper.

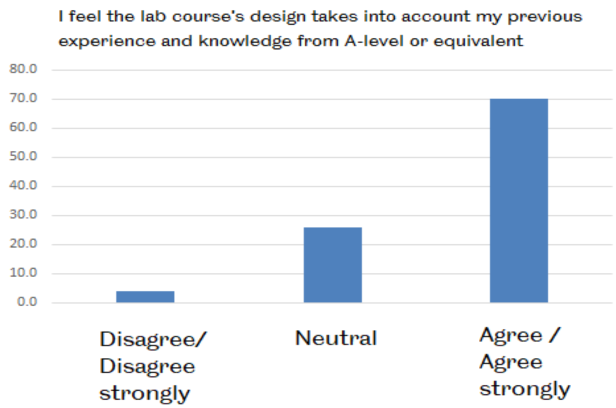

Fig. 3. Does the course design take previous experience and knowledge into account?

I conclude with the results of a survey question explicitly asking the students about how the course manages this transition (Figure 3). Given the students were not afraid to give more critical responses to other specific questions in the anonymised survey, I feel this 70% approval justifies the course I took in prioritising the management of the impact of reforms to the A-levels on lab teaching. However, there is more work to be done in further understanding the student experience.

4. Conclusion

The student experience cannot be reduced to stereotypes. Close consultation with and survey of the student population not only informed my reforms to manage the transition from the altered A-level course; it was also a vital tool in building a Covid-safe lab course. This illustrates the importance of pedagogic research-led teaching in the modern university.

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2019, pp. 132-145 (Although note that Fawns rightly critiques an overly simplistic division between digital and face-to-face learning in this characterisation).
[9] Quoted from an unsolicited email from a student to myself, reproduced with permission.
[10] N=63 (97% response rate), using an anonymised paper survey approved by the University of Sheffield's ethics approval process. Further details available on request.

Workshop on Friction Connecting School Students' Everyday Life to Recent Fundamental Research

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Abstract

The Collaborative Research Centre (CRC) 1073 "Atomic Scale Control of Energy Conversion" at the University of Göttingen aims to contribute to a sustainable energy future by providing guidelines for technical innovations which allow a clean, efficient, and sustainable generation and storage of electric energy. Since a large proportion of e.g., wind energy is converted into heat by friction occurring in bearings of wind turbines, the CRC project A01 tries to disentangle the process of converting kinetic energy into heat in a sliding contact. It has already contributed to a better understanding and thus to the discovery of control tactics of dry friction at the atomic scale. Nevertheless, the fundamental causes of friction are still not fully understood, even though it is all around us. At the macroscopic scale, friction is often described by simple empirical laws, but those cannot be applied at the atomic scale. The CRC enables high school students to discover this scale dependency themselves experimentally during the "Hands-On Energy Science Workshop" presented here. The workshop starts with everyday life friction phenomena. Afterwards, the students apply normal forces F_N and measure the corresponding friction forces F_R between two materials at the macroscopic scale. By using the Atomic Force Microscope of the CRC, students can then perform an analog experiment at the nanoscale, but the plot of the nanoscale friction forces vs. the nanoscale normal forces shows that the simple law $F_R = \mu \cdot F_N$ taught in school does not fit. This creates a cognitive conflict. When comparing this plot with the one of the forces they measured at the macroscopic scale they recognize that they do not have to change their pre-conceptions of friction, but that they need to extend it: Size must be considered. They finally understand why CRCs energy conversion studies at the atomic scale are required, in particular because components of technical innovations become smaller and smaller.

Keywords: friction, energy science, fundamental research

1. Introduction

Europe targets a cleaner and more sustainable energy future [1]. Therefore, physicists and chemists in the Collaborative Research Center (CRC) 1073 work together on tactics to control elementary steps of energy conversion at the atomic scale. In this way, the CRC researchers contribute to appropriate answers to central questions of our future energy supply: How can energy losses be reduced? (Researcher group A) How can the enormous power of the sun be efficiently converted into electric power? (Researcher group B) Since power is also needed when the sun is not shining: How can power be stored? (Researcher group C)

Researchers in project A01 aim to control friction losses in order to increase the efficiency of energy conversion processes, by relating the frictional losses measured at the surface to the physical properties of the underlying material. Friction is an everyday phenomenon, since it occurs always when two materials slide against each other, e.g., during walking between our shoes and the floor or in motors. A closer look at the contact area between the materials reveals very rough surfaces at the nano scale. It consequently consists of many nanoscale contacts. Moreover, components of technical innovations become smaller and smaller. That is why, the project A01 investigates friction at the nano down to the atomic scale by using an Atomic Force Microscope (AFM). Here, we present a workshop on friction addressing school students which reveals that the simple laws used to describe friction at the macroscopic scale cannot be applied at the nanometer scale. It shows the great value of research at small scales.

Therefore, the main educational goals of the workshop are to pass an appreciation and understanding of research on to school students and to arouse their interest in energy science.

The friction workshop developed within the scope of a Bachelor project is one of a few workshops the CRC offers to school students [2]. Further public outreach activities [3] aim to encourage everybody to contribute to a sustainable energy future by an active participation in discussions about the future energy supply and by using energy consciously.

2. Workshop concept

The one-day workshop targets high school students, because the used measuring methods of the AFM require advanced cognitive capabilities. The first unit of the workshop deals with friction at the macroscopic scale and the second with friction on the nanometer scale. An additional unit about using friction losses to generate electric energy [4] is optional. As an introduction into the topic, simple questions are raised: Do you know friction from your everyday life? Why is it important for energy conversion processes? Since the students do not know us and the Göttingen University Campus, the questions act as ice breakers and activate the students, but they also evaluate their pre-knowledge about friction which gives us the opportunity to adapt the first unit to it.

In the first unit, school students apply the simple law which describes the proportional correlation between the friction force and the normal force. Based on their everyday life knowledge about friction they acquire the law experimentally using the inductive approach. Thus, students construct their knowledge according to the constructivist learning theory. If the students know the law already, the deductive approach is used instead. In this case, the only intention of the first unit is to ensure that every participant has the basic knowledge about friction needed to understand the main message of the workshop.

First, students are divided in groups of two to four students and each group is asked to develop an appropriate experiment to measure friction and its dependencies based on their everyday life experiences with friction. If they e.g., want to stop their bicycles faster than usually, they increase the friction force by applying a stronger normal force on the brake blocks. According to that, they usually have the idea to test in their experiments how the friction force depends on the normal force. They might also investigate, if friction depends on the size or roughness of the surface area or the material itself. The experiment students usually develop will be described in the following section 3.1. One group which plotted their measured friction forces F_R against the different applied normal forces F_N and which thereby figured the law $F_R = \mu \cdot F_N$ out (μ: friction coefficient), presents its results to the other groups.

In the second unit, the school students gain insights into the research topic and methods of the CRC project A01. We show them an animation film, in which the surfaces of the bearings of a wind turbine are slowly magnified until one can see that the contact area is in fact composed of many nanoscale contacts. This gives a first idea why the project A01 investigates friction at the nanoscale. Students might wonder: How can friction be measured at a scale we cannot see with our eyes or with the light microscope in school? Researchers use an AFM. In the workshop, students learn how the AFM friction measurements work by performing a model experiment described in section 3.2.

Afterwards, they mount the sample & the cantilever which are only a few millimeters in size and measure the sample topography & friction under supervision (s. Fig. 1 and section 3.3). Then, they use the AFM friction data to plot the friction forces vs. the normal forces again. Comparing this plot with the plot from the macroscopic measurements of the first unit creates a cognitive conflict, because the fit line does not meet the zero-point.

This means that the observations on the macroscopic scale cannot simply be transferred to the nano scale. Instead, the experimental results at the nano scale reveal the following equation: $F_R = \mu \cdot F_N + F_A$. F_A is caused by adhesion forces. Adhesion forces can be neglected at the macroscopic scale, but they cannot at the nano scale.

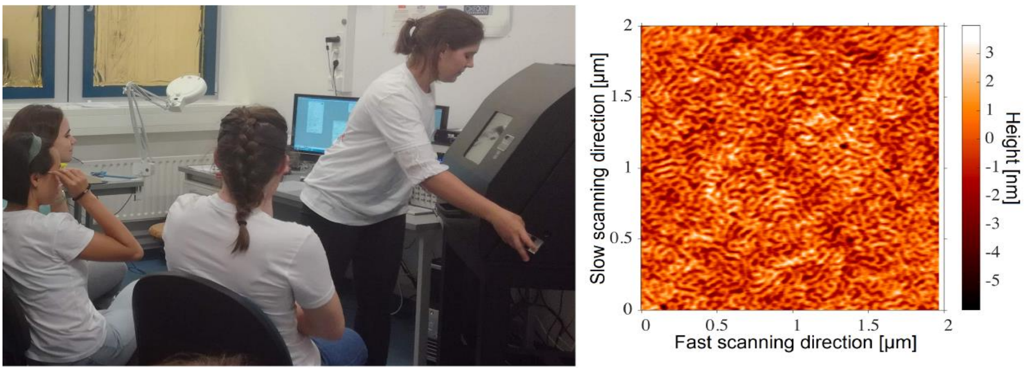

Fig. 1. School students at the AFM (left)
and AFM image of polymer composite PS-b-PMMA (right)

3. Hands-On Experiments

In the workshop, friction is measured at the macroscopic scale and at the nano scale using an AFM. To help students understand how the AFM measurements work, they perform them with an AFM model first.

Students work with the exact same AFM instrument & the measuring mode the CRC researchers in the project A01 use. Additionally, they have the chance to ask the PhD student of this project questions to his project and the work as a researcher.

The main learning objective of the experiments is that the school students work like an experimental scientist measuring and comparing friction at different scales to understand how size affects friction.

3.1 Measuring friction at the macroscopic scale

Two materials lay on top of each other (e.g., a box made of an arbitrary material on a table surface) and a force gauge is fixed to the upper material. By moving the force gauge parallel to the contact area, the upper material is slid against the other material.

Thereby, the friction force F_R is measured with the force gauge. This process is repeated with different weights laying on top of the upper material. Finally, the friction force is plotted against the normal force.

3.2 Measuring friction with an AFM model

Height measurements: The topography of a material surface (sample) containing e.g., a few bumps are measured with an AFM model. The model consists of the basic AFM components (s. Fig. 2): A cantilever connected with a tip reflects laser light onto a screen. To measure the material surface in the contact mode, the cantilever tip needs to touch the surface. Then, the material is moved parallel to the length of the cantilever.

Depending on the local sample height, the cantilever is bent and the laser point on the screen moves up and down (vertical movement).

Friction measurements: To measure friction, the cantilever pressed onto the sample with a constant force F_N is moved perpendicular to the cantilever length. The Friction between the cantilever tip and the underlying sample leads to a torsion of the cantilever visible on the screen by the horizontal movement of the laser point.

3.3 Measuring friction at the nano scale using an AFM

An AFM height profile/topography of a sample is measured in the same manner as in the model experiment (s. section 3.2). To obtain the heights of an area, the cantilever tip, scans the area line by line.

The friction measurement in the AFM is analogous to the macroscopic experiment in section 3.1: The cantilever tip slides against the sample surface. The friction force is measured by the torsion of the cantilever as it is done in the model experiment (s. section 3.2). After every scanned line, the normal force is increased. After the AFM experiment, the measured friction force is plotted against the applied normal force.

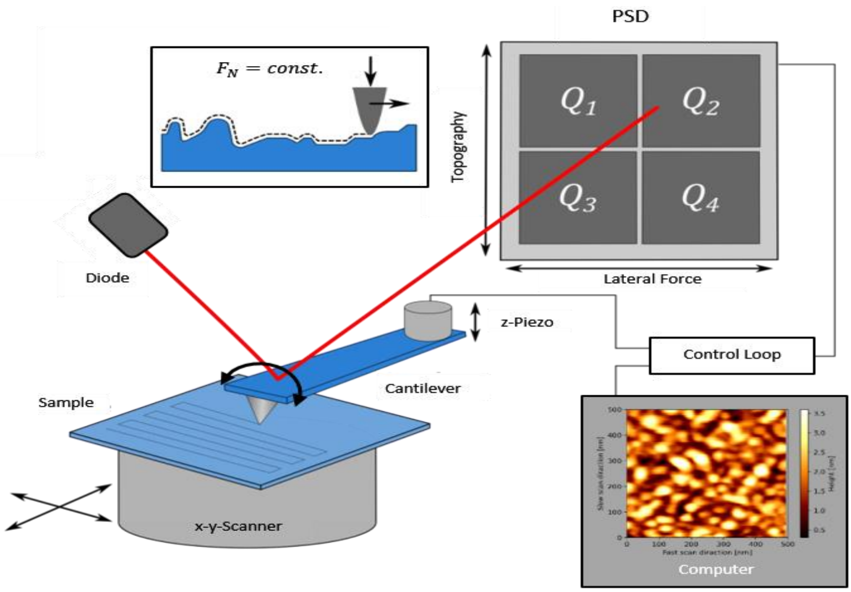

Fig. 2. Schematic picture illustrating the basic operation principle of an AFM [5]

4. Summary

We presented a workshop in which students work like researcher in the CRC project A01. They use the same equipment and reproduce the experimental approach by which researchers understood that size affects friction and material behavior/properties in general. These findings are especially important for technical innovations whose components become smaller and smaller.

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Enhancing Students' Motivation

BYOD to Enhance Students Motivation in STEM Learning

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Abstract

During more than 20 years of my professional carrier as teacher and pedagogical advisor, it has become clear to me that classes should be made more colourful, attractive and interactive, independently of the teaching level (higher education or lower educational level [1]), and of the type of the subjects. Analysing students' attitude to work in details, I also concluded that students' motivation in STEM learning and teaching should be enhanced. Students need more fun, more attractive and interactive activities, where they can be involved and take part with pleasure. Members of this generation should be prepared to be active learners; they should follow the general path and steps of inquiry and research: make observations, form hypotheses, do a test or experiment and make reflections and conclusions. In order to improve our students' key competencies, we should let them bring their devices [1] (BYOD), and use them for educational activities (assessments, hands-on experiments, measurements, simulation, etc.). During the pandemic period another method had to be introduced: teleconferencing, performed with MS TEAMS or ZOOM (delivering lectures and talking about simulated events, explaining a physical phenomenon). The aim of this work is to share some good examples, resources and methods to enhance students' motivation, or present different types of educational methods like cooperation, project method, IBL or flip classroom [2]. Each example has already been used by me, or will be used shortly in high school and college BSc level. Some activities include gamification ("Escape room") and group-work activities, contain students' and teachers' guides and self-evaluation tools, like multiple choice questions, interactive exercises with simulation, theoretical exercises etc. All examples are related to study of the basic laws of Physics with more fun and enthusiasm. Students should leave high schools, universities and colleges with an adequate knowledge and with applicable skills in STEM, therefore we should help them to achieve this.

Keywords: hands-on experiments, BYOD, ICT, multimedia, interactive activities

1. Introduction

In the beginning of lockdown period of COVID-19 many new questions raised up, which had to be solved immediately. It was a real challenge for both students and educators.

In this paper some selected, adaptable examples, with different methods applied will be presented, which were used in Physics teaching to increase the students' motivation and to develop their learning and innovation skills, digital literacy skills, and career and life skills [3].

2. Target, participants

The following implementations have been done in the past and will be done again with my students from high school and college BSc level who are enrolled to compulsory Physics classes.

3. Teaching methods used

The main teaching theories can be divided into two categories: teacher-centred and student-centred learning. Every teacher can decide which method is more appropriate in his/her educational environment, and especially in online courses. During this period, I used different types of methods.

3.1 Cooperation method

Participants involved in the cooperation method are expected to be engaged in group work, where the classroom is transformed into an attractive environment. Students enrolled to the activity usually have very different background knowledge [4].

Unfortunately, during the lockdown period of COVID-19 the method had to be transformed online. In this sense this activity was kind of a pilot project that tested the solutions involving aspects of motivation, collaboration, creativity and confidence as well as self-paced and personalised learning.

I used this method to make students to understand better the physical properties of the **pressure**, and its types and laws. Some students were involved in performing the hands-on experiments, some have prepared some fun quiz questions, and some others were working out some problem-solving exercises.

Before starting the experimental activity, the students had to make some predictions, collect the requested materials and set-up the experiment.

1st experiment

This experiment (Fig. 1), required a balloon, two pieces of wood plates and approximately 30 iron nails with the same size.

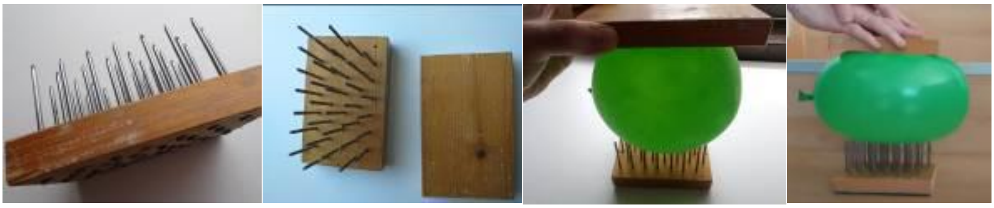

Fig. 1. exploring the meaning of pressure

Students had to press down the balloon, applying a force on the wood plate at the top and observe, what was going on. After the experiment students started their online conversation for developing and improving their critical-thinking and argumentum skills.

Students finally concluded, that the balloon was not burst because the applied force was equally distributed on many nails, they also have learned the definition of the pressure.

$$p = \frac{F}{A} \qquad [p]_{SI} = 1Pa = 1\frac{N}{m^2}$$

2nd experiment

Another group studied the dependence of the pressure of a gas on the temperature.

This experiment required an egg and Erlenmeyer flask or milk bottle preheated by some boiling water. After that a peeled hardboiled egg was quickly placed on the top of the Erlenmeyer flask (Fig. 2).

Fig. 2. Egg in the Bottle, in the Erlenmeyer flask or milk bottle

After a short time, the egg was "sucked inside" the flask (the students' words). In the discussion of the experiment the conclusion was that the preheated air inside the flask cooled down, and therefore its pressure decreased, and the larger pressure of the outside air pushed the egg inside the flask. (Additionally, when the flask cools down, some remnants of the water vapour from the boiling water condenses, which also contributes to the decrease of the pressure inside the flask).

In addition to discussing the general concept of pressure and the effects of pressure change, this experiment can also be applied when one is teaching Gay-Lussac laws.

3rd experiment

A group of students studied the hydrostatic pressure with the third experiment at home using only a PET bottle. They had to predict, and observe what happens, when they made holes at three different heights.

Fig. 3. exploring the dependence of the hydrostatic pressure

With a simple tape they even could measure the largest distance.

After analysing and discussing students concluded that the hydrostatic pressure depends on the height.

$$p = \frac{F}{A} = \frac{m \cdot g}{A} = \frac{V \cdot \rho \cdot g}{A} = \frac{A \cdot h \cdot \rho \cdot g}{A} = \rho \cdot g \cdot h$$

When the atmospheric pressure acts on the surface of the liquid, it should also be taken into account.

$$p = p_0 + \rho \cdot g \cdot h$$

4th experiment

Aim of this experiment was to understand Bernoulli's equation. The students needed to have a hair dryer and a ping pong ball.

Observing the movement of the ping pong ball students concluded that the ball usually was trying to escape from the vertical airflow but was directed back into the airflow by the higher pressure of the surrounding dormant air.

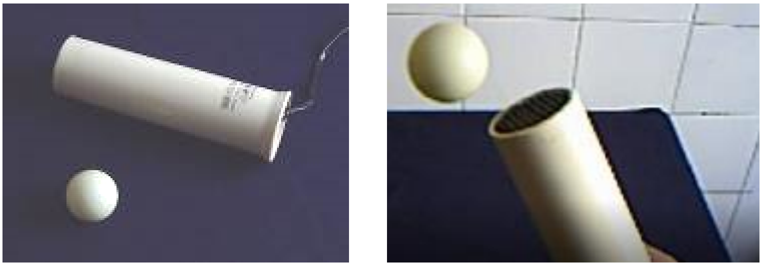

Fig. 4. exploring Bernoulli's principle with hair dryer

A funny experiment was also done at home, which requires only a ping pong ball, and a funnel from the kitchen. The aim is to blow out the ball from the vertically held funnel.

At first one usually tries to blow out the ball from the bottom of the funnel, but one should realize that it is not possible. However, when blown sideways over the funnel (Fig. 5.), the ball gets "lifted" and easily removed.

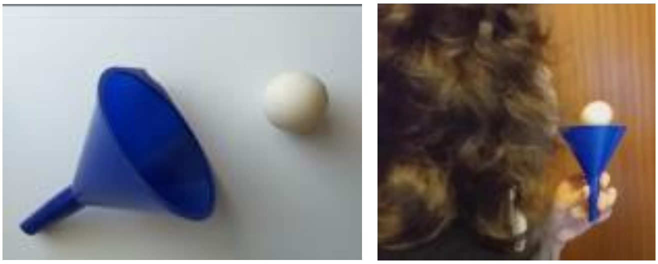

Fig. 5. Ping Pong Funnel Experiment

As a result of the experiments presented, students concluded that the pressure in liquids (and gases) depends on the flow rate as well as the hydrostatic pressure. They better understand now the Bernoulli law:

$$p + \frac{1}{2}\rho \cdot v^2 + \rho \cdot g \cdot h = const$$

During these exciting and successful activities students learned to make observations, formed hypotheses, made their fun experiments, discussed the topic and deduced their conclusions. They were involved in teaching and learning procedure through the camera, using their own devices, and own tools for experiments.

3.2 Project method

In the project method students solve a practical problem over a period of several days or weeks. This method has many advantages because it can be used even online, and participating students can carry out activities according to their interests. I have been using the project method with my students already for a long time. All measurements have already been published in details in a conference proceeding [5]. The novelty in this semester lies in the fact that we will do everything online.

The goal of each of the suggested experimental methods is to determine the value of the gravitational acceleration. Students can choose one of these:

- recording and analysing the sound of a ball rolling and free falling
- video recording and analysing the movement of a free-falling ball
- use the Phyphox free apps designed by Aachen University

For all methods, students have to determine the value of the gravity acceleration (g) and estimate the uncertainty of their measurement.

I hope that all students will find a task that suits their interests, but will also learn mastering their own tools, learn about error calculation, and be able to compare the measured results with the value published in the literature.

3.3 Inquiry-based learning

IBL is based on the constructivist conception of learning, which involves the followings: developing questions, making observations, find out what information is already known, outlining possible explanations and creating predictions for future study.

All these expectations are embedded in the activity performed with the students.

During one of my Physics courses my students offered voluntary their participation in this method. IBL was used for understanding the “Plum pudding model of atom” proposed by J. J. Thomson in 1904.

A simple experimental tool was constructed by the students, so that the “Thomson’s atomic model” could be more easily understood.

Thomson supposed that the atom is made of a positively charged bulk (like a pudding), and it contains electrons scattered (like some raisins inside the pudding).

Although the electrons repel each-other, the positively charged bulk holds the whole thing together.

The students constructed a model from the following components:

30 cm diameter glass bowl,
10 cork plugs with a diameter of 4 cm,
10 pieces of 3 * 30 mm strong neodymium magnet,
30 m Teflon coated coil of copper wire,
9 V battery,
glue gum

Fig. 6. Use of Inquiry-based learning to study the plum pudding model proposed by J. J. Thomson

The magnetized needles represent the electron- “raisins”, because they repel each other. The particles swim as far apart as possible. The attractive force of the “pudding” is provided by the magnetic field of the coil. It should be noted that here we use magnetic forces, whereas in the Thomson model electrostatic forces are in play! Discussing the experiment students observed that the particles always were arranged in the most symmetric way, even after their movement towards the centre of the vessel. The students informed me about their feelings and their worries. They felt that constructing this experimental equipment was a huge experience in their life. They will never forget this material.

4. Conclusion

Students in my Physics courses gave me very positive feedbacks. Based on the results and on personal interviews I conclude that they became better motivated because they were required to do an experiment, to start discussing, observing and predicting about a phenomenon.

I hope that their enthusiasm will not disappear after returning to normal education system, and they will still be motivated enough to make similar experiments also in the classroom.

I am confident that these attractive and understandable lectures can better attract our students to the course and their motivation for measurements can be enhanced by using their own devices.

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Development of a Virtual Wetland Ecological System Using VR 360 for Applications in Environmental Education

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Abstract

The purpose of this study is to develop the "Cardboard VR Game-based Virtual Wetland Ecology System" learning software using virtual reality technology, displaying the image of the real wetland environment, designing the exploratory missions and challenging level stages by adding the digital game-based learning concept, to initiate students' interest and motivation. Finally, the effectiveness of the students' learning achievement and motivation in environmental education was investigated. This system used the wetland ecology of Hsinchu as the environmental educational teaching theme. The learning contents of the wetland ecologies and creatures of the "Chin Cheng Hu watching bird area", "Hsiang Shan wetland" and "Shin Feng mangrove forest area" provided students with the knowledge of the wetland creatures and importance of the wetland environment. This study adopted 42 students from 1th grade of county junior high school in Pingtung County as the research participants. The quasi-experiment design was employed. They were divided into two groups. A half of students in the experimental group used this system to conduct learning activities with exploratory missions, and the other half of students in the control group received regular teaching materials. The teaching time was 135 minutes covering three lessons. The measuring tools of this study included: (1) the questionnaire of satisfaction towards this system, (2) the wetland ecology environmental education learning achievement test, and (3) the questionnaire of wetland ecology learning motivation.
The experimental results in this study indicated: (1) Using "Cardboard VR Game-based Virtual Wetland Ecology System", the learners showed a high degree of satisfaction of the overall experience perception (2) Using "Cardboard VR Game-based Virtual Wetland Ecology System", the students' learning achievement in environmental education was significantly higher than that of regular teaching. (3) Using "Cardboard VR Game-based Virtual Wetland Ecology System", the students' learning motivation in environmental education was significantly higher than that of regular teaching.

Keywords: Cardboard VR, wetland ecology, environmental education, digital game-based learning, learning achievement, learning motivation

1. Introduction

With the development of science and technology, the mobile technology and wearable devices such as AR (Augmented Reality) and VR (Virtual Reality), and they have been widely applied in learning activities. The students are not restricted by time or space when immersed in the VR environment [1]. The VR technology is often referred to as an immersive multimedia, and the objective is to recreate human sensory experiences to create a computer-generated environment that simulate physical presence in virtual world [2].

This study adopted simple headset mounted VR device, it provides panoramic images in real world to make students can watch around the environment through Cardboard VR viewer and smartphone. Therefore, the students are not limited by time, space, traffic cost, and the problem of the personal safety will not happen either. Oigara [3] indicated that students considered Google Cardboard VR device as an effective tool which provided an immersive and active experience for learning, and they agreed that Cardboard VR could provide a new way of learning helping them to clearly understand the complicated concepts and increased their interest and concentration. In this study, we developed the "Cardboard VR Game-based Virtual Wetland Ecology System" using virtual reality technology, and the related research indicated the students used the VR learning tools to learn and operate and it could help students to establish their spatial perception [4].

Furthermore, we introduced the digital game-based learning conception to integrate wetland ecology learning contents into this system, making students complete effectively the learning targets and initiate their interest and motivation [5], understanding knowledge of the wetland beings and importance of wetland environments. Finally, we investigated the effectiveness of the students' learning achievement and motivation in environmental education.

2. Cardboard VR Game-based Virtual Wetland Ecology System

This study adopted the Google's Cardboard VR headset where the smartphone is inserted into the cardboard viewer. It is a mobile, inexpensive, and convenient device and the whole system is referred to as "Cardboard VR" [2]. Cardboard VR Game-based Virtual Wetland Ecology System is a smart phone application. It contains the learning contents of the wetland ecologies and creatures of the "Chin Cheng Hu watching bird area", "Hsiang Shan wetland" and "Shin Feng mangrove forest area". Students can use the application to explore and observe real wetland ecology environment and beings via the cardboard viewer headset by themself, as shown in Fig. 1.

Fig. 1. Screen view of the smartphone application

In addition, this system is developed by Unity 3D game engine software, introducing digital game-based learning conception to design wetland ecology exploratory missions and challenging level stages, so they can initiate students' learning motivation and enable them acquire the sense of accomplishment, and it can also enhance their learning achievement.

3. Experimental design and results

In order to analyze the effectiveness of the students' learning achievement, motivation and the satisfaction by using the Cardboard VR Game-based Virtual Wetland Ecology System after the VR learning activity, a teaching experiment was conducted.

3.1 Participants

A total of 42 students from 1th grade of junior high school were used as the research participants. Among them, 21 students were in the experimental group using the system to receive teaching with exploring mission worksheet, and the other 21 students were in the control group receiving regular teaching materials. Both groups were taught by the same teacher in the teaching activities to avoid the impact of the different instructors on the experimental results.

3.2 Experimental process

Before teaching activity of the wetland ecology environmental education was started, both groups were required to complete the pre-test of wetland ecology environmental education achievement test. The instructor spent 20 minutes explaining the function and operation of the Cardboard VR Game-based Virtual Wetland Ecology System to the students in the experimental group. They were guided sequentially via the instructor to use this system and then explored and learned the wetland ecology by themselves. After that they were asked to complete the wetland ecology game-based exploratory mission with the worksheet, as shown in Fig. 2 and Fig. 3.

Fig. 2. Student using the Cardboard VR to explore Hsinchu Wetland ecology

Fig. 3. Student completing the wetland ecology exploratory mission worksheet

On the other hand, the students in the control group had received regular teaching materials with the PowerPoint learning contents, and they were guided sequentially by the instructor to learn knowledge of the wetland ecological environment and creatures.

After the 135-minute teaching activity, both groups had taken the post-test and filled out the questionnaire of learning motivation, and the students in experimental group were requested to complete the questionnaire of satisfaction toward this system. The experimental procedure is as shown in Fig. 4.

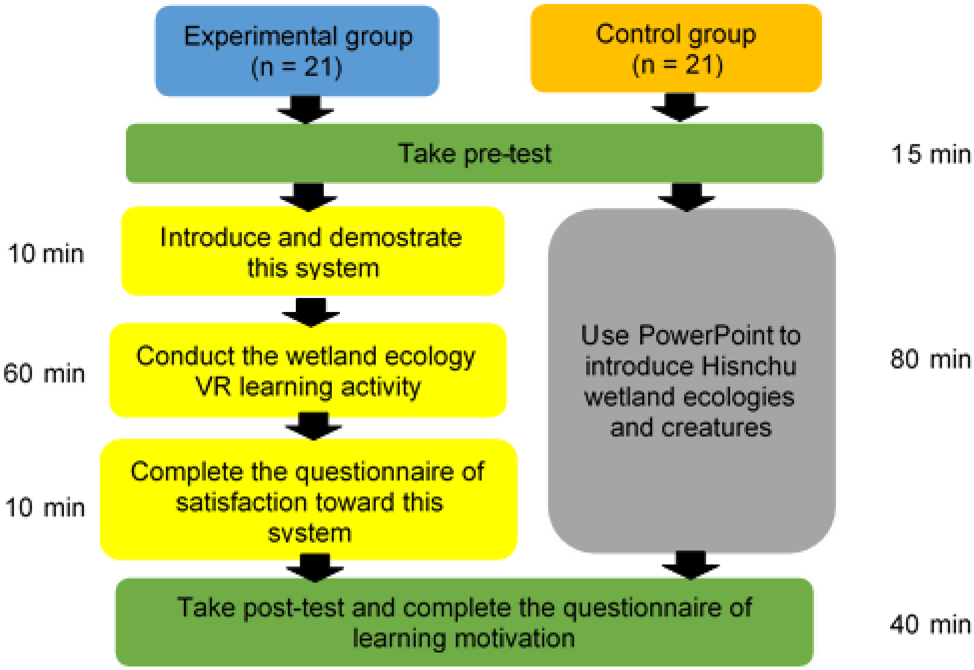

Fig. 4. Experimental procedure of the wetland ecology learning activity

3.3 Measuring tools

The measuring tools of this study include: questionnaire of satisfaction towards this system, learning achievement test of the wetland ecology environmental education, and questionnaire of wetland ecology learning motivation. The questionnaire of satisfaction for this system was designed by the advised professor, and it contains fifteen items (e.g., "I can clearly observe the outline and feature of the wetland animals and plants"), divided into three dimensions, "VR system interface design", "VR system learning contents", and "VR system operating sensibility". The questionnaire used 5-point Likert scale ranging from 1 (very disagree) to 5 (very agree), and the Cronbach's alpha value of this questionnaire was 0.88, implying this questionnaire is reliable.

The questions of wetland ecology environmental education learning achievement test in both pre- and post-test were designed by three experienced natural science teachers.

The purpose of this test was to understand the students' knowledge of the wetland ecology environment. The test consists of twenty items, adopted from three Hsinchu wetland ecology contents.

The questionnaire of wetland ecology learning motivation was designed by the advisor, and it was used to measure the students' learning motivation about learning wetland ecology contents. It consists of thirteen items (e.g., "I am very curious about wetland animals and plants, and want to learn more") and uses 5-point Likert scale ranging from 1 (very disagree) to 5 (very agree), and the value of Cronbach's alpha for this questionnaire is 0.93, implying this questionnaire is reliable.

3.4 Results

This study used descriptive statistics to analyze learners' overall and three dimensions satisfaction toward this system, adopting one-way ANCOVA to analyze the learning achievement, and applying independent sample t-test to evaluate the learning motivation.

First, the analysis of the satisfaction toward this system indicates: (1) the mean value and standard error of the overall satisfaction are 4.27 and 0.96, (2) the mean value and standard error of the "VR system interface design" satisfaction is 4.36 and 0.95, (3) the mean value and standard error of the "VR system learning content" satisfaction is 4.31 and 0.93, (4) the mean value and standard error of the "VR system operating sensibility" satisfaction is 4.15 and 1.01. Therefore, the learners showed a high degree satisfaction by using this system.

Secondly, we performed the homogeneity test before analyzing the learning achievement of both groups. The homogeneity test result showed that ANCOVA ($F=0.70$ and $p>0.05$). Therefore, we can analyze the post-learning achievement scores of the both group students. As shown in Table 1, the adjusted mean value of the learning achievement was 88.04 for the experimental group and 73.85 for the control group.

According to the one-way ANCOVA result ($F=14.448$ and $p<0.001$), which shows the students' learning achievement in experimental group was significantly higher than control group.

Table 1. The ANCOVA result of the students' learning achievement

Group	n	mean	SD	Adjusted mean	F	η^2
Experimental group	21	87.14	10.79	88.04	14.448	0.27
Control group	21	74.76	13.46	73.85		

*p<.05, **p<.01, ***p<.001

Third, the analysis of the wetland ecology learning motivation was performed by independent sample t-test, the mean value was 53.24 for the experimental group and 43.24 for control group ($t=-3.209$, $p<0.01$), as shown in Table 2. Therefore, it indicated the students' learning motivation in experimental group was significantly higher than control group.

Table 2. The independent sample t-test result of the learning motivation

Group	n	mean	SD	t-test	p
Experimental group	21	53.24	9.85	-3.209	0.003**
Control group	21	43.24	10.33		

*p<.05, **p<.01, ***p<.001

4. Conclusions

From the analysis of the experimental results, it was found that the students using the Cardboard VR Game-based Virtual Wetland Ecology System could enhance students' learning achievement and initiate students' learning motivation significantly. In addition, the students showed high degree of satisfaction toward this system, and they thought it was a good and effective learning tool to learn the knowledge of wetland ecology in environmental education.

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Does the Organization of Study Groups into Different Knowledge Levels Improve the Performance in a Bachelor Degree Course?

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Abstract

Organising students into groups for studying is widespread and being done with an increasing frequency world-wide. However, there is little knowledge available on how to organise and run the student study groups in the most efficient manner. To provide insights and guidelines for the best practices if the study group organisation, the paper describes a case study conducted with 74 Bachelor students at a university in Austria. Various effects of the group splitting by the knowledge level are shown, particularly, the performance successes in the study (the teachers' perspective), as well as the satisfaction from the study groups, work load assessment, fairness, leadership and other competences gained, study journal usage (the students' perspective). Overall, the organisation of the study groups with the size of 3 students at homogeneous knowledge levels has been well accepted by the students and led to a higher study performance at all knowledge levels. Combining the approach with further teaching methods and performance evaluation approach emphasising both the group as well as the individual learning gains can bring further improvements.

Keywords: Study groups, study performance, university, bachelor course

1. Introduction

With numerous study materials available online, the trend of students staying away from the classrooms is on the rise. Attending the classes in person actively can be seen as the highest level of the study engagement. While still a lot of study success can be achieved with learning outside of the classroom, successive lowering of the level of engagement may end up with the students becoming completely disengaged, disconnected, and eventually unfollowing the study.

One of the features typical for and only possible at with the studies in the class is a high degree of communication and group work among the students, compared e.g., to the online study mode where the interaction and group work is weakened, and can take place only via the means of technology. Group work has been recognized as successful for engaging the students, and for the facilitation of the study for the students (better study successes are confirmed e.g., by Liang *et al*., [1]) as well for facilitation of teaching for the course leaders. However, the question on how to organize the study groups most efficiently remains open, and there has been no literature covering exactly this research question. The question is in particular not trivial in the settings where the classes are composed of the students with varying levels of prior knowledge and study abilities.

Some of the challenges include cases when the students distribute the work among themselves and learn less individually, or when more advanced students are placed in a mixed group with weaker students: they are demotivated to such extent that they start to dis-engage.

2. Case Study

The case study has been made in the lecture and exercise university Bachelor degree course "Booking and Yield Management". The course has had the volume of 2 weekly hours during the semester, and has been held from 13th to 28th of May 2019 in a blocked form in Landeck, Austria. The course audience has comprised 74 students, split in 3 groups (27, 24 and 23 students), led by two course instructors: each instructor had an own group, and one group was taught by both instructors.

For the evaluation, first, "the learning journal" (or, what the students should learn from the course) is to be defined, followed by the assessment/exam's mode definition. The latter is to be based on the points accumulation system, with points accumulated during the whole course – for the group tasks, as well as for individual tasks. As communicated to the students from the start of the course, they have been able to collect points for:

a) group work (60% of the grade),
b) individual work, including the final test (40% of the grade),
c) extra "bonus" points: for placing questions in the forum (one has to post one question and vote for three good ones of colleagues – the best question is to be answered/discussed), and for solving the exercises of "extra" difficulty (supposedly is to be managed only by "stronger" groups).

3. Aim of the Case Study – Testing of Two New Didactic Strategies

New settings of study groups. The first strategy of the case study evaluates the effect of working in various study groups. The students are to be doing course exercises in a group of 3 persons each, with settings requiring both autonomy and structure [2].

The course exercises would, apart from learning, enable demonstration of the autonomy and leadership development. Further, structured ways to get involved with the contents of the course and the means to cut off better at the course evaluations have been provided e.g., possibilities to receive extra points towards the exams grade, particularly for asking questions about the course online and voting/commenting on them.

Approach in the case study. A study mix is elaborated to be heterogeneous and address various student study groups and personality types. The direction here is to split the students in the subgroups of various expertise levels (for the given 3 study groups of ca. 25 students each):

1. mix of "stronger" and "weaker",
2. the students with the similar level of skills together – so there are to be "weak" groups and "strong" study groups,
3. allowing students to mix themselves, to observe which performance takes place naturally.

Then it can be observed which of the set-ups are bringing better learning and engagement results.

At the start of the course, the student prior knowledge is to be tested, with a test consisting of a mix of course-relevant questions, a mix of self-assessment questions, and questions about their personality/typical attitudes/levels of engagement. The points which the students have scored have been calculated, and the split into the study groups have taken place already on the first day, with the group work starting from the second day of the course. An additional strategy to be tested here is making the students self-accountable for their study progress with the construction and the maintenance of the "learning journal" i.e., conduction of the diary containing the details of what the students have learned in the course.

4. Research Questions, Hypotheses and Evaluation Design

This work investigates various settings of the study group work to conduct teaching and to increase the study engagement, and eventually identify their added value for the study in the classroom as well as the extent with which they should be applied.The main research question to address is as follows: ***Will the organization of the study groups according to the students' competence levels, i.e., students with similar competence levels joined into the same study group versus other ways to form a study group, lead to better learning outcomes for all students at a Bachelor degree course?***

Further, the following, secondary, research question is to be addressed and answered: ***Does construction and maintenance of the learning journal (or a diary, representing the learned knowledge or skills in the course) by the students lead to a more positive attitude and better learning outcomes in the course?***

The basic hypothesis/assumption here is that there are different types of learners/personality profiles, and the currently deployed in education "one-size-fits-all" methods – such as study group work where "stronger" in the subject students teach the "weaker" ones, as well as just one "typical" combination of methods are inevitably not matching well or addressing poorly certain learner groups on every course. In the worst-case scenario, the "wrong" mix can cause the students, for example, the "stronger" ones, to disengage and eventually unfollow the course. While user segmentation and personalized addressing is very common in such fields as marketing or gaming (e.g., see existing categories for user gamification types [3]), the studies for similar directions in eLearning/education domain are just appearing (see Gil *et al*., [4]), and are generally not applied in practice.

The approach is to be evaluated from the perspectives of the lecturer and of the students.

Lecturer's perspective. The data collected in order to reflect the lecturers' perspective is as follows:

a) observation notes about students' engagement in learning activities, such as study group work and individual work.
b) results from the (final) exams, as assessed by the course instructors. Here, these are the grades for study group exercises and individual tests.

Students' perspective. The evaluation of the case study includes:

a) feedback from the students in which kinds of study groups they were more productive in learning and found most engagement as self-assessment
b) their actual demonstrated productivity/study success, which can be represented as the students' education progress on the "learning journal" (as self-assessment).

The students' general perception of the success of the study group work is partly estimated with questionnaires already present in the literature: such as Table 1 is mirrowing the work by Burdett [5].

5. Presentation and Interpretation of Results

The study has been running as planned, and the students have been formed in 22 study groups, on the basis of the individual scores in the initial test (see Appendix A for the test); all Appendices mentioned in this paper are available via https://doi.org/10.13140/RG.2.2.17908.68485.

We use the following notation for the study groups: A – "stronger" study groups, B – "average" study groups, C – "weaker" study groups, M – mixed study groups (have 1 "weaker" student, 1 "average" student, and 1 "stronger" student), N – study groups created in a natural way, by the students themselves.

Correspondingly, 3 A study groups, 5 B study groups, 2 C study groups, 4 M study groups and 8 study groups N have been formed.

The study groups A, B, C and M have been formed on the answers of the questionnaire, with the students getting between 6 and 9 points on this test classified as A students, students gaining between 4 and 5,5 points classified as B students, and students gaining between 1,5 and 3,5 points were classified as C students (see Appendix A). Further, we present the evaluation in terms of different perspectives (lecturers, students).

Perspective of the lecturers. One key criterion is an observation of the study performance (individual and study group work, final individual test, forum questions, bonus exercises and learning journal). *Another criterion to observe is the students' performance on the individual final test (see the final test in Appendix D). The study performance is evaluated with the group and individual study progress, including the final individual test.*

In A study groups 7 out of 9 students, in B study groups 14 out of 17, took the final test. In study groups C, M and N everyone took the test. It is likely be the case because compared to the study groups A and B they were less active in other exercises or assumed that they performed weakly, and thus assumed they still need more points.

The results for this criterion (including the grades, bonus exercise activity and the average score for the individual test) are shown in Table 1.

The final average grades presented in Table 1 are calculated with the summing of the final grades received by the students in the all types of the groups (A to N) and dividing these grades by the number of the students in the corresponding study group category (n).

For the grading of individual students, the usually applied in Austria grading system was employed i.e., between 1 and 5, where 1 is the best (excellent), and 5 is the worst (fail). The scores for the bonus exercise activity participation, as well as for the individual final tests are also average values, calculated in a similar manner.

The overall evaluation of the work of the students show that homogeneous study groups (A, B, C) have managed to achieve better academic grades than the heterogeneous study groups (M and N). On the other hand, in the individual final tests, the A and B study groups have scored the worst – with 8 and 8,6 points on average out of 20 points, while the study groups C, M and N scored better: 10,75, 10,54, and 11,75 points on average out of 20 points (the questions and the points awarded for them are shown in Appendix D). In A and B study groups the performance of the students has been different: there were "strong" and "weak" cases, so this is not a monotonous drop for all.

Table 1. Study performance of the students of various study groups

Study group type	Final average grade	Active in bonus activities, in %	Average score in the individual final test (when taken)
A (n=9)	1,89	87,5	8,00
B (n=17)	1,94	50,0	8,60
C (n=6)	2,00	66,7	10,75
M (n=13)	2,30	69,2	10,54
N (n=24)	2,30	77,3	11,75

Table 2. Students' feedback on group work in various study groups

Questions	**A** (n=8)	**B** (n=15)	**C** (n=6)	**M** (n=13)	**N** (n=23)
1. My experiences with formal, assessed group work have been positive.	1	1	0,83	1	1
2. I felt comfortable working in my group.	1	1	1	1	1
3. Overall, my group worked well.	1	1	1	1	1
4. I did not enjoy working on group assignments.	0	0,07	0,5	0,15	0,44
5. I often assumed a leadership role.	0,29	0,5	0,2	0,15	0,57
6. Overall, I did most of the work.	0,25	0,07	0,5	0,17	0,26
7. Working in a group required less work for myself.	0,63	0,48	0,4	0,77	0,83
8. Overall, the grades for our group work were fair.	1	1	1	1	0,95
9. Problems that arose were solved by the group.	0,88	0,93	0,33	0,85	1
10. I achieved better outcomes working alone.	0	0,2	0,6	0,23	0,55
11. Marks awarded were generally fair.	1	1	1	0,92	0,90
12. Peer assessment was generally fair.	1	0,93	1	1	1
13. I learned to negotiate with other group members.	1	0,8	1	0,92	0,91
14. I learned to build positive relationships in my group.	1	1	0,83	0,92	0,91
15. I learned to manage tasks effectively.	1	0,8	0,83	1	0,91
16. I learned to share responsibility.	1	0,93	0,83	0,85	0,91
17. I learned to use rational argument to persuade others.	0,63	0,87	1	0,67	0,82
18. I learned to solve complex problems.	0,75	0,67	0,83	0,92	0,70
19. I learned to resolve conflicts.	0,63	0,27	0,5	0,73	0,70
20. I ran the study journal largely throughout the course.	0,88	0,5	0,67	0,69	0,78
21. The study journal was helpful for my learning process.	5 out of 5	4 out of 8	2 out of 3	4 out of 10	7 out of 14
22. The study journal was helpful for my learning outcomes.	4 out of 4	4 out of 9	2 out of 3	3 out of 8	9 out of 12

So, for the individual learning success, one recommendation may be to collect people in C study groups. Though they will report a lot of pressure, and won't report that they enjoy the study group work, they will learn the most. Also, N study group have done well, and interestingly – they also have been reporting that they had issues with the study group work, compared to the others. It is possible that the study groups such as A and B were too good in splitting the work among themselves and avoiding studying the basics on their own, therefore having worse results on the individual tests.

What in any case is also dissatisfactory for the A students is when they are placed in a mixed study group with weaker students? Also, here "stronger" students, which have been placed in an M groups construction, have been reporting dissatisfaction.

Overall, though, the activity on the course of the students have been good, and the methods have found their followers. As also seen later in Table 2, a fair number of the students have been following the learning journal, as well there was enough activity on the course forum.

Perspective of the students. The evaluation of the students' perspective of the study group work has been performed by the questionnaire distributed to the students (see Appendix B). Table 2 presents the scores from this questionnaire, presenting the average scores received per each question per each of the study groups, where the answer "agree" has counted with 1 point, and the answer "disagree" with 0 points.

6. Summary of findings in the light of research questions

The findings of the study can be outlined as follows:

1) **The study groups as a method are verified as appropriate.** *The students are in favor of the study group work in principle*, and are considerably more in favor of it and are satisfied with it compared to another similar study in the past that has been measuring the same metrics [5]. This may be caused by the fact that the study groups in this study were efficient i.e., consisted only of 3 people, in the contrary to the settings of the other experiment [5], which had between 2 and 10 people per group.
2) **Homogeneous groups function better than heterogeneous groups only according to some performance criteria.** Whether to recommend one or other type of the study groups, also appears to depend on what the learning and study group work goals are, as the feedback varies. *Homogeneous study groups are better at achieving the goals* (such as getting better grades) than the heterogeneous ones, however, still not necessarily better at learning individually. *The study group work more enjoyable in stronger, homogeneous study groups. Creating study groups "with issues"* (e.g., weak study groups, or naturally formed study groups) *typically leads to less enjoyment from a study group work, but better individual learning outcomes*.
3) **Different students are responsive to different methods.** *The learning journal technique have been found useful by a limited number of students only.* So, it can be recommendable for a segment of students, but not for all. Such diversification could be facilitated by online methods [6].

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Effectiveness of Learning Assistants on Student's Active Learning in College STEAM Courses

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Abstract

In this study we identified the effectiveness of Learning Assistants in enhancing college students' active learning in STEAM and other courses. A learning assistant is an undergraduate student who supports and facilitates students' learning in the assigned course through the guidance of a course instructor. More universities in Japan have been introducing own learning assistant programs, and they had been uniquely developed in the last twenty years. But the effectiveness of Japanese LA program had not been researched in detail yet. To analyze that, we conducted a common student survey at three universities to ask students who took courses with LAs and received more than 860 answers. We found major supports from LAs were giving advice for group discussions and group activities. And students highly evaluated the existence of LAs in classes because LAs made themselves easy to ask questions and participating in activities during class time made easier. They would feel easier to ask questions to LAs rather than to course instructors. In conclusion, our survey revealed the value of the LA program in all three university courses with active learning.

Keywords: Learning Assistant, STEAM Education, Active Learning, Student Survey

1. Introduction

The program of learning support by undergraduate student assistants has developed uniquely in Japan. When Keio University opened a new campus in the suburbs in 1990, there were only first-year students and Keio were not able to hire graduate students for TA. The university therefore decided to hire a good undergraduate as an assistant and named it Student Assistant (SA). SA was a paid job and the role was to support teachers and students in class. This was a program that embodied Keio founder Yukichi Fukuzawa[1]'s concept of *hangaku hankyo* (learning while teaching, teaching while learning). Fukuzawa thought that it was important for those who had learned earlier to teach those just beginning to learn. Keio University had another reason to hire undergraduate SA students in 1990. The new campus was the first campus in Japan to fully introduce computers and the Internet, and the number of faculty was not enough to teach computer operation to more than 1,000 freshmen students. SA at this time was

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[1] Fukuzawa founded a school for western studies in 1858 in Edo (Tokyo), which became the oldest institute of modern higher education in Japan, Keio University.

not specially trained. Only high-performing students were nominated by faculty to become SAs, and they supported other students' assignments.

In 2000, the Higher Education Bureau of Japanese Ministry of Education published a report, "Measures to Enhance Student Life at Universities-Aiming to Create Universities from the Standpoint of Students". In this report, it was desirable that, not only graduate students but also senior undergraduate students should be actively given opportunities to be learning assistants in education. Also, from the 2000s, Japanese universities have made an effort to qualitatively shift from education that teaches knowledge to education that focuses on growing competencies. With this shift, Japanese university education has begun to change. It aimed not only at academic skills but also transferrable generic skills through active learning such as group work, discussion, and project-based learning. However traditional college professors who accustomed to one-way lectures are not good at teaching this type of classes. Therefore, some universities have started to hire high competent undergraduate students as in-class facilitator, supporter and assistant. In this paper, undergraduate students who fulfill such roles are referred to as learning assistants (LA). Especially departments that don't have a graduate course have to hire LAs.

The learning assistants have brought various benefits to students, faculties, departments, and themselves. However, there is few studies in Japan yet that measured these benefits quantitatively. As LA program costs money, university management demands to show its effectiveness. The purpose of this study is to clarify the educational effects of supports by undergraduate Las in active learning classes and to compare STEAM and other courses.

2. Related Researches

Stade organizes the benefits of introducing LA into classes by classifying them into four groups: faculty, students, LA themselves, and Institution as shown in table 1 [1].

Table 1. Benefits of LA Program at the University of Colorado Boulder

1. Benefits to faculty who use LAs	2. Benefits to students in courses that use LAs
□ LAs can help faculty learn and understand about active learning and other evidence-based teaching "best practices." □ LAs can help faculty design tasks and activities. □ Faculty can use LAs as "virtual students. (Faculty can test lesson plans and ideas on LAs.) □ LA program connects faculty from different departments, encourages collaboration and sharing of ideas.	□ LAs facilitate active learning, which has been shown to improve grades, retention, confidence, etc. □ LAs have learned the course material quite recently, so they are often better able to relate to students' difficulties in learning. □ LAs provide extra help (they have office hours in a "help lab," they can run review sessions, and so on). □ Students in classes with LAs generally do better and learn more.
3. Benefits to the LAs themselves	**4. Benefit s to departments and institutions**
□ The best way to learn a subject is to teach it! LAs have the opportunity to learn a subject more deeply. □ LAs get experience teaching. Some are inspired by the LA experience to become teachers. □ By reflecting on teaching and learning, LAs learn more about themselves and their own education. □ LAs make important connections with faculty. □ LAs get course credit for their content and pedagogy courses. □ LAs get paid. □ LAs have an impressive experience to put on their resumes.	□ An LA Program can transform departmental culture. □ By having an LA program, departments are engaging more actively and thoughtfully in teaching their undergraduates. □ Teaching becomes more respected. □ Faculty see that some of their best students become LAs, and this helps faculty recognize the value and intellectual merit of teaching.

The Colorado learning Assistant Program began in 2001 at the University of Colorado Boulder. Their Learning Assistants are undergraduate students, too. LAs facilitate discussions among groups of students in various classes thorough the guidance of weekly preparation sessions with faculty. To become LAs, they need to take pedagogy course. The program implemented mostly in STEM departments and is focused to improving the quality of education. Otero and Finkelstein showed that the LA Program has significantly increased the number of STEM majors earning secondary teaching certifications [2]. Moreover, Gray, Webb and Otero compared K-12 teachers who served as learning assistants (LAs) as undergraduates to colleagues that were certified through the same teacher certification program but did not serve as LAs. The former LAs used significantly more reformed teaching techniques than their colleagues who were no LAs [3]. Alzen, Langdon and Otero indicate that "exposure to LA support in any STEM gateway course is associated with a 63% reduction in odds of failure for males and a 55% reduction in odds of failure for females in subsequent STEM gateway courses" [4].

The University of Colorado is a key member of the Learning Assistant Alliance (LAA), and their LA program's purpose seems to focus STEM education and teacher training pedagogy.

Kansai University in Osaka is a large private university with 30,000 students. In 2006, the Center for Teaching & Learning provided 138 SAs to support faculty members in various classes in all 10 departments. There were 623 faculty members using SA in the fall semester of 2007. Iwasaki *et al.*, conducted a questionnaire survey with faculties and SAs about the status of SA utilization, the effects of SA, and effects and challenges of SA program. As a result, 89% of faculties satisfied with the use of SA and students who worked as SAs felt that their media literacy and business manners had improved [5].

Kawachi and Sugimori also conducted the student survey at Kanazawa University.

The survey target is the students in courses that use Active Learning Advisors (ALAs).

ALAs are graduated students and undergraduate students over sophomore. They support and facilitate students' learning in the assigned undergraduate course under the guidance of a course instructor. The survey result showed more than half of the students consider ALAs' supports effective for enhancing their learning [6].

3. Method

These studies all described the effects of LA program at one university. So, in this study, we conducted a common student survey at multiple universities, University A, B and C in Japan, in ordered to examine the differences between programs at different universities and the differences between STEAM courses and other courses.

University A has introduced the LA program in the first-year seminar, the sophomore seminar and information literacy for freshmen course in its commerce department. Those two seminar courses are mainly PBL with a small group work, and the number of students in one seminar is about 30 and one teacher and two LAs are assigned. The information literacy course covers subjects ranging from the introduction of computer operation to quantitative data analysis. The number and composition of teacher and LAs are the same as the seminar courses. University B also use LAs for their first-year seminar courses in the business department. The number of students of the course is less than 30, and only one LA is assigned to each seminar. In the survey, class size information could not be obtained. University C introduced one LA to each of the art expression classes for freshmen in its art department.

What all three universities have in common is that LA Program is introduced mainly for courses for freshmen students. Those courses are divided into several classes, in each class one faculty member teaches common contents of the course with one or two undergraduate LA students. The pedagogy lessons for LA held at the three universities would be different. Table 2 showed the outline of the survey.

Table 2. Student Survey

	Course Title	*year*	*# of classes*	*# of students*
	Information Literacy	Freshman	11	256
University A	Freshmen Seminar	Sophomore	11	243
	Sophomore Seminar	Freshman	11	236
University B	First-Year Seminar	Freshman	Unknown (1)	84
University C	Art Expression	Freshman	3	48
Total			37	867

4. Results

In the survey results, we focused on the level of LA activities and educational effectiveness of LA supports, which students in the courses subjectify answered. Fig. 1 showed the differences of level of LA activities in each course.

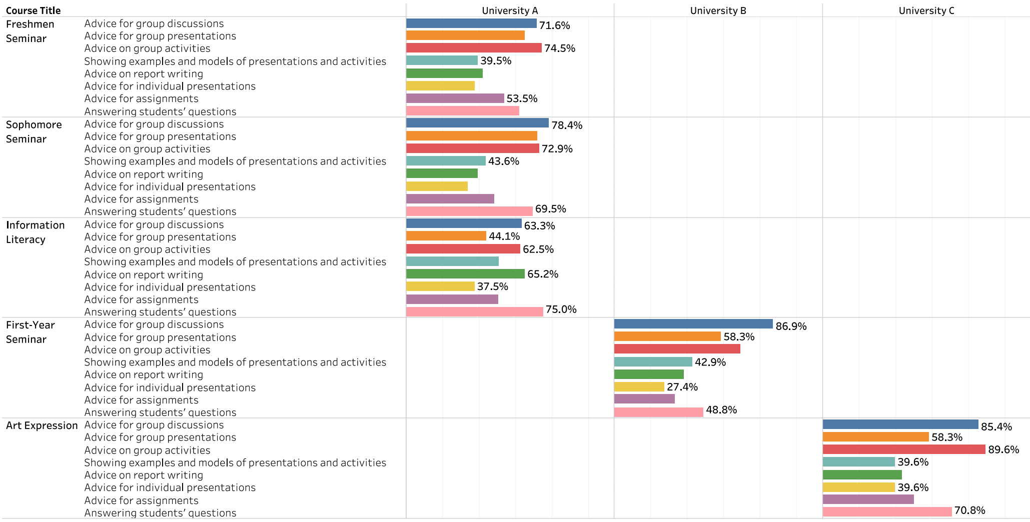

Fig. 1. Level of LA activities

The major LA supports common to the three universities are giving advice for group discussions and group activities. Giving advice for group presentations and answering students' questions are next highest. Therefore, from this survey it turned out that the main role of LAs at these three universities was to support and facilitate group activities in these entry level courses. However, the information literacy in University A showed a different tendency that advice on report writing was much higher than other.

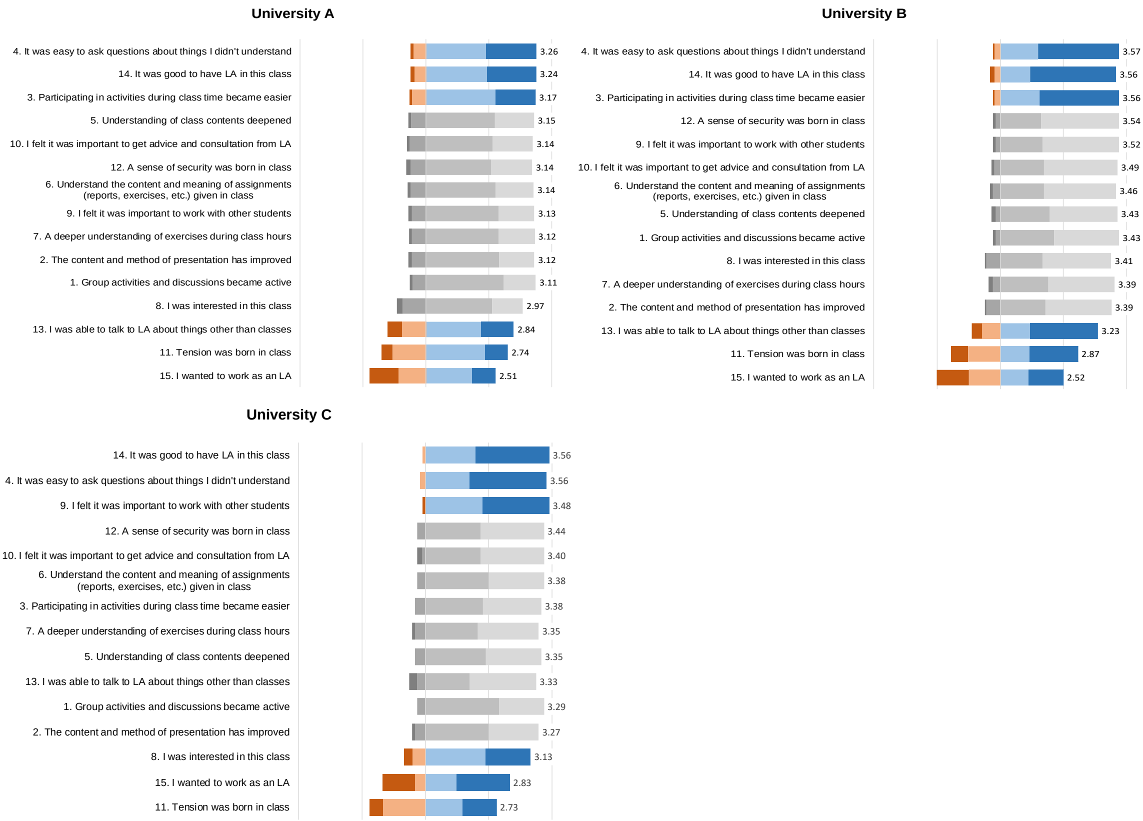

Fig. 2. Effects of LA

In Fig. 2, the educational effects of LA supports were showed. Students responded with a five-point scale for each effect LA provided. The top three effects of University A and B are same; "4. It was easy to ask questions about things I didn't understand", "14. It was good to have LA in this class" and "3. Participating in activities during class time became easier". In University C, "9. I felt it was important to work with other students ranked third. On the other hand, students gave the least value to these effects; "15. I wanted to work as an LA", "11. Tension was born in class" and "13. I was able to talk to LA about things other than classes". It turns out that recognizing the positive effects of LA are different from wanting to be LA or having a personal relationship with LA.

5. Discussion

The results of this survey are limited to these three universities. But we have shown from the survey that the effectiveness of the LA program is quite common, regardless of the university or course content. LA Program works effectively in active learning in introductory courses. However, factors such as how to increase its effectiveness could not be clarified from this survey.

Acknowledgment

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How Can Students Explore Critical Thinking as an Academic Practice?

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Abstract

Critical thinking is one of the most important skills imparted by scientific education. It enables students to assess, evaluate and interpret different theories and topics, making up their own minds and coming to their own conclusions.[1,2] Especially the ability to acknowledge that there might be other ways of understanding the very same information, gains ever more importance as students come face-to-face with new technological developments, such as Artificial Intelligence (AI) or the acquisition of knowledge via Big Data Analysis. However, critical thinking as a practice student needs to be introduced to and experiment with, is often neglected by university teachers – in STEM subjects most of all.[3] In this paper, the resulting lack of critical thinking is addressed from a developmental perspective on education. We present the prototype of an interactive video which confronts students with puzzling situations based on philosophical ideas and encourages them to approach these conundrums by means of critical thinking. Using three nicknames of the philosopher Socrates – the gradly,[4] the midwife,[5] and the electric ray[6] – as a starting point, students independently explore the theory and practice of critical thinking. Afterwards, educators will initiate a discussion on why critical thinking is important for higher education. In our project, we explore critical thinking from philosophical and educational perspectives, iteratively refining the interactive video. This paper presents the results of our first iteration.

Keywords: critical thinking, interactive videos, Platonic dialogues, philosophical approaches, Design-Based-Research

1. Introduction

Critical thinking can be described as “the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action.”[7] Critical thinking is considered crucial by both teachers and tutors in higher education – as a skill, it is equally appreciated in all academic disciplines.[1] This, in turn, also impacts the students’ perspective on critical thinking. In a representative survey conducted across German universities by the German Centre for Higher Education Research and Science Studies in 2018, 91.2% of all participating students consider critical thinking very important in regard to their studies. Especially in the Humanities (95.7%), Social Sciences (94.7%) and Legal Sciences (96.6%), students rank the ability to think critically as essential. In contrast, students in the natural and technical sciences consider critical thinking to be far less relevant. 23.1% of the surveyed students of natural sciences and 29% of the students enrolled in technical sciences state that in their studies they are not encouraged to think critically.[8]

This might just be the tip of the proverbial iceberg. On an international level, Richard Arum and Jospia Roksa created a stir as they presented a mixed-methods analysis of more than 2.300 undergraduate students enrolled in 24 different universities.[9] The authors concluded that 45% of undergraduates showed no significant improvement in their critical thinking skills while attending college. The results of this analysis have been confirmed by a replication study in 2011, using data taken from students enrolled in different schools and even including another statistical test in order to measure the participants' overall intellectual development.[10] Recently, however, the methodology of Arum and Roksa's original study has been criticized again.[11]

2. The Project

Our project centers around an interactive video meant to encourage students (especially in the STEM subjects) to engage in critical and independent thinking. This paper presents the first results of an ongoing inquiry using design-based research (DBR). The term DBR refers to a research framework characterized by methodological diversity which aims at developing a specific research-based solution to a real-life problem. Once a solution has been found and applied, it provides data which – in turn – leads to new theoretical insights. As the research for theoretical knowledge and the development of a concrete design object depend on each other, each DBR projects tries to achieve both a development goal and a knowledge goal.[12] Our development goal is to create a prototype for an interactive video helping students explore the theory and practice of critical thinking, while our knowledge goal is to collect data on the improvement of critical thinking in this specific educational setting.

According to McKenney and Reeves, DBR projects can be divided into three interconnected phases: *Analysis and Exploration, Design and Construction, Evaluation and Reflection.*[13] To complete a project, several iterations of these three phases are necessary. Each repetition forms a so-called "DBR cycle" in which a prototype (e.g., the video script or a software mock-up) and theoretical educational hypotheses are developed, adapted and revised. In the following paragraphs, we outline the methods and results of our first DBR-cycle.

2.1 Phase: Analysis and Exploration

In the first phase, we created the theoretical groundwork for our prototype. In order to encourage students to engage in critical thinking, it is necessary to first introduce them to the characteristics of *thinking*. In his writings, the Greek philosopher Plato uses three nicknames of his fellow philosopher Socrates – the gadfly,[4] the midwife,[5] and the electric ray[6] – to explain what thinking might entail. We decided to base our interactive video on these metaphors. In Plato's writings, these nicknames indicate that critical thinking is an exhausting activity which destroys supposed knowledge, dissolves conventions and often turns out to be at least partially inconclusive. A perfect approach to making students in STEM subjects reconsider their thinking habits: In their studies, these students often differentiate correct answers from incorrect ones – which is why it is so important for them to start questioning theories and concepts and to accept the fact that sometimes there is no clear-cut solution.

Following Plato's idea of presenting philosophical concept as metaphors, we investigated the use of metaphors in education. Metaphors can be understood as cognitive patterns.[14] In our DBR project, the nicknames of Socrates form a connection between the Platonic hypotheses of thinking and students' conception of their own thought process. Those metaphors, in fact, have a theory-constitutive effect because they help students visualize the activity of thinking, highlighting specific aspects of critical thinking and allowing students to explore them in a theoretical context.[14,15]

2.2 Phase: Design and Construction

Based on Plato's descriptions of thought and our research into metaphors in education, three pictures are created to represent the gadfly,[4] the midwife,[5] and the electric ray.[6] In the interactive video itself, which is created with the software H5P, these images will be animated and presented one after another. Following each animation, the video will provide tasks and a user interface with a text box for students to type their results. In accordance with the educational postulate of thinking from the known to the unknown,[15] the students will start interacting with the video by associating the profession of the midwife, the hunting method of the electric ray or experiences with gadflies.

Fig. 1. Images by Andrea Wandinger used for the interactive video

To demonstrate how the interactive video shapes this thought process, here is an excerpt taken from the questions about the gadfly:

1) Imagine being the horse in the picture. Gadflies are buzzing around your head. What spontaneous thoughts come to your mind when you imagine this and what adjectives would you use to describe the gadflies? Write down your thoughts.

2) Could you put your spontaneous ideas into context with the activity of thinking? To what extent can the gadfly be a metaphor for thinking?

Write down your thoughts and try to always start your explanations with the following sentence: "Thinking is / means / leads to ..."

As their next task, the students will be asked to link their ruminations to the activity of thinking. Once the students have answered the first questions by associating what they know, a short excerpt from Plato's writings will appear to provide further information about one of the nicknames of Socrates. Based on this new information, the students will once again be asked to contribute their own ideas about the activity of thinking:

1) Read the passage from Plato's "Apology" in which he compares Socrates to a gadfly.

2) Afterwards, consider and discuss whether you have reached similar reflections in connection with the metaphor of the gadfly and the activity of thinking. How do you interpret Plato's use of the gadfly in the text?

At the end of the video, the students will be asked to apply these thoughts to their academic subjects: In which contexts might critical and independent thinking impact their studies and, later in life, their work?

2.3 Phase: Evaluation and Reflection

To prepare for video production, we tested the concept (including pictures and tasks) in a 4-hour online seminar with 60 students from the course Mediendidaktik (*media education*) in the subject Media Production at OWL Technical University of Applied Sciences and Arts. The students used a video conferencing tool to work in groups, jointly solving the tasks and discussing the material as well as reflecting individually on what the video asked of them.

Applying the method of *conjecture mapping*, we used the data obtained in this seminar to test both the design of the interactive video and our theoretical hypotheses.

Based on this analysis, modifications were also made to the specific learning material. As a result, the students will be provided with a short introduction to Socrates in the interactive video and will be invited to brainstorm about the activity of thinking. To increase access to Plato’s texts, we will also change the excerpts of the platonic dialogues and will use a simple and modern language.

2.4 The Next Steps

As a next step, we will design and develop the actual interactive video. This prototype will be tested by students enrolled in technical and scientific subjects at OWL Technical University of Applied Sciences and Arts. The answers of these participants will be evaluated. Based on this analysis, we will improve the prototype of the interactive video while using the data collected in this DBR cycle to further explore students’ stance on and theoretical knowledge of critical thinking in engineering and scientific subjects.

3. Conclusion

We hope that our interactive video will help students in STEM subjects to engage in critical thinking and discover its importance for their field of studies. Furthermore, we would like to make the video available to other target groups and create an interdisciplinary workshop during which students from different subjects would be able to express and exchange their ideas on critical thinking. A workshop such as this would allow us to gather more data on the application of critical thinking in different fields of academia. At this point, however, we should also point out the limitations of our project.

Naturally, our video only creates an impulse: It gets students to casually think about critical thinking, but it does not and cannot lead to an in-depth examination of the activity of thinking. The aim is rather to find an entry point to the topic – and to take it from there in later projects.

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New Approach to Teach Product Development in the Area of Smart Textiles

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Abstract

This paper deals with the challenges to teach how to develop so called Smart Textiles – these are textile-based products with extended functionalities that will contribute to the next revolution in textile and clothing technology and they have a high market potential. Therefore, it is important to prepare students for this task. So far there are only a few approaches in teaching this interdisciplinary field especially in the area of product development. Accordingly, this project aims for the development, piloting and evaluation of an innovative didactic tool in the field of Smart Textiles for engineering degree programs especially in the field of textiles and clothing. Thus, an application-oriented construction kit is developed that should help to extend the frontiers of knowledge, stimulate creativity, and give students the ability to solve real-world problems. As added benefit it will accelerate the understanding of innovation and interdisciplinary challenges. The project aims to prepare students to think interdisciplinary, broadly, deeply, and last but not least critically. The whole approach is tested in a on scene learning concept as well as in a blended learning concept. Her you get an overview on the didactical approach, the learning tool kit and first experiences.

Keywords: Smart Textiles, Engineering, Learning tool kit, Didactical approach, E-Textiles

1. Introduction

What are Smart Textiles? Why is a new didactic tool needed and how is it created?

How can aspects of design thinking and gameful design be integrated in the development? What are the benefits of different teaching-learning approaches and what do learn reflections and participatory observation contribute to optimize those set-ups?

1.1 The textile and clothing industries

The textile and clothing industries are traditional, but at the same time innovative businesses that have to face the challenge of systematically developing new knowledge in order to remain market leaders. This is especially true for Baden-Württemberg, which is the strongest textile location in Germany according to the textile industry association Südwestextil [1, p. 3] and where our university is based. Many companies are already developing and working with high-tech materials and products that will be further used in other industries and will, for example, bring even more safety, sustainability, energy efficiency and comfort into everyday life in the future. One of the most important challenges in the textile and clothing industries will be Smart Textiles – products with extended functionalities. [2]

1.2 The interdisciplinary sector of Smart Textiles

Smart Textiles Products will contribute to the next revolution in textile and clothing technology and have a high market potential [3]. These are textile products with an additional benefit – often in combination with electronic components. This can be clothing such as heated gloves, a shirt for monitoring vital parameters or another textile product, such as an anti-theft luggage item or a smart carpet. Although the development of smart textiles has been going on for decades, everyday use is still in its infancy. In the following, Smart Textiles are defined as textile products that interact with their environment and can thus actively support users. The following Fig. **3** illustrates the different levels of Smart Textile products. This work focuses on so-called E-textiles, which are textiles with integrated electronic components.

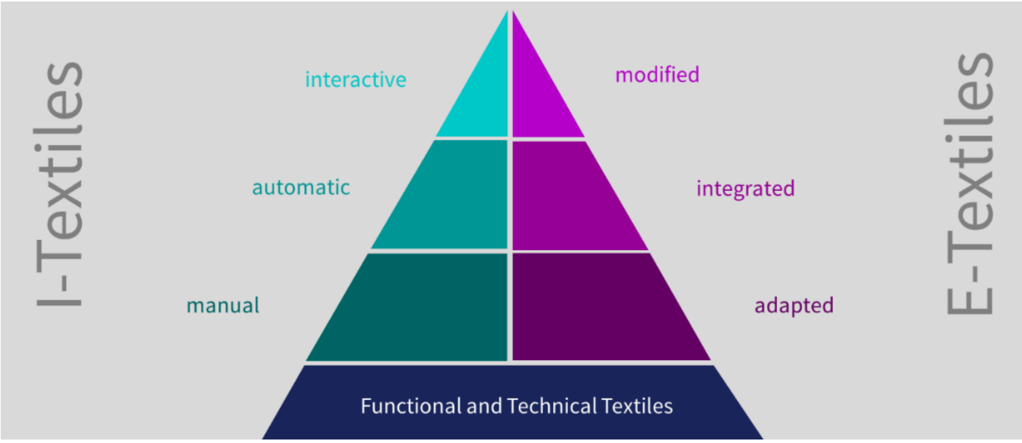

Fig. 3. Smart Textiles definition [4]

The area of smart textiles is one of the core competences of future engineers, as this market also addresses the current megatrends of our society, such as digitalization, mobility, health, individualization or silver society [5]. However, there are only a few approaches in teaching this interdisciplinary field especially in the area of product development. Yet what specific competences are needed for product development and how can we foster them?

2. Models behind the didactical approaches

This project is situated in the field of constructivist learning theory, which assumes that knowledge cannot be transferred from a teacher to a learner, but that knowledge is individually constructed by each learner. In this process, prior knowledge is actively included and the learner must take responsibility for his or her own learning process. [6, p. 4f]

2.1 Construction Kits

The idea of stimulating users to think and learn via constructive W-questions is also pursued by so-called learning and construction kits. In contrast to the pure transmission of knowledge, complex topics are conveyed in a playful way in these kits. Among other things, motivation, creativity and cognitive abilities are positively influenced. When conducting a market research with regard to modular construction systems, in particular construction kits, which are also used in education in schools and universities, first and foremost well-known brands such as LEGO® Education or Fischertechnik and less well-known brands such as Tinkerbots or littleBits are encountered. What do all these systems have in common? They are construction kits that playfully allow the user to easily construct a variety of different objects using prefabricated elements. These kits use the approach of gamification of learning and promote the joy of learning through their design. At the same time, they provide scientific or technical background knowledge. [7], [8], [9], [10]. A special kind of construction kits are so-called experimental kits. The pioneer in this field is the KOSMOS brand, which introduced its first experimental kit to the market in 1922. [11] In a study commissioned by LEGO Education, it was also found that "hands-on learning", i.e., working with the construction kits, significantly boosts learners' confidence in dealing with STEM topics and motivates them to tackle new subjects [12, p. 8 & 27]. All types of construction kits give their users the chance to experiment and to experience learning by doing and trial and error. This is according to Hüther and Quarch" [13, p. 86] the key factor for learning.

2.2 Gameful Design and Design Thinking

The biggest crowd puller in the world is a game, namely soccer. So why is a game so fascinating to us humans? It's often the combination of fun, social interaction, and a way to satisfy oneself and one's curiosity. Focusing on the user's needs leads to increased motivation. Playful elements should enrich the user experience and thus have a positive impact on the learning experience. In addition, the playful approach provides a way to deal with failure in a positive way. [14] But what is the difference between Gamification and Gameful Design? Gameful design, explains Fischer, can be understood as a design strategy that can help create motivational and participatory learning environments at universities where students can build professional competencies individually or collaboratively. [15, p. 141] Nicholson recaps the principle of gameful design as follows: "Instead of using game design elements to increase external motivation through rewards, designers can use game design elements to increase internal motivation." [16, p. 3]

The design thinking method is a human-centered problem-solving method in which problems are solved from end-user perspective and therefore the product development process is focused and most of the times accelerated in comparison with other methods.

The entire development process of the new kit is therefore based on the clearly structured process and the high user orientation of design thinking and runs through the three phases of the problem and subsequently the solution space in a sequential manner. So, it can be summarized that both the design thinking method and gameful design are focused on the needs of the user.

3. Experiences – the difference between idea, prototype and reality

Whilst teaching smart textiles in the past the Wearic Smart Textiles Kit [17] was used to bring students in contact with this innovative new field of combining textiles and electronics. The Wearic Kit is intended to help people to discover the potential of Smart Textiles. Therefore, the set includes textile-based sensors for pressure and wetness, heating, push-buttons, sewable LEDs, and as core piece an expansion board with an Arduino nano-controller. The board and actors are easily connected by conductive snap fasteners. The following Fig. **4** shows the WEARIC Smart Textiles Kit with attached sewed on LEDs, a pressure sensor and a push-button.

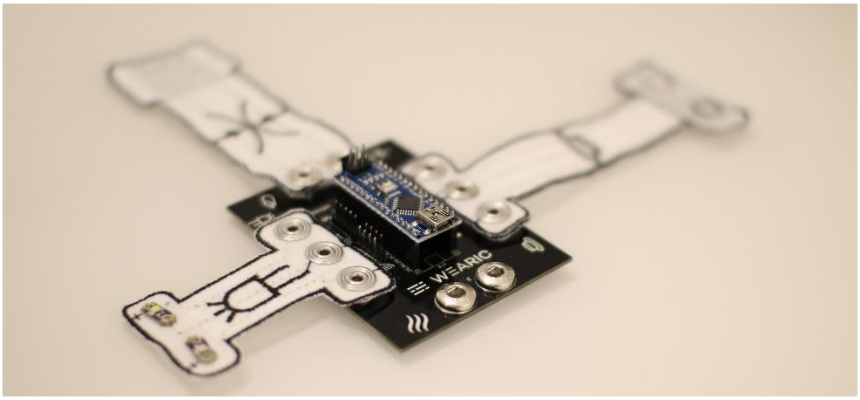

Fig. 4. Wearic Smart Textiles Kit

Unfortunately, this kit has a number of disadvantages. The experiences in using the Wearic Kit were initially documented in the form of participant observation. Since the summer semester 2020, my observations have been completed by individual learning reflections of students and evaluated by a content analysis. Students rated working with this kit as a good entry point to the topic of smart textiles, but as soon as they wanted to realize their own products based on their new experiences, they found the limits of the system. However, they were subsequently unable to transfer this knowledge to real-life problems such as product development. This goal or the fostering of the competence to act is the focus of the new development.

4. Plans – the new concept

The new concept is structured in the following phases, where these phases are already completed:

- Survey of the requirements for quality teaching in the field of product development for smart textiles incl. research in relation to other teaching programs and construction kits Implementation of a face-to-face course with the Wearic kit and the evaluation tool of participant observation,
- Implementation of an online course with the Wearic kit and the evaluation tool of individual learning reflection,
- Evaluation of the participant observations and learning reflections,
- Development of the new kit (Flex-STEx) using methods from design thinking and considering gameful design aspects.

The following steps are planned for the next year

- Piloting of the kit with a student working group,
- Revision and duplication of the construction kit,
- Implementation of the new kit in a face-to-face course as well as in a blended learning course in order to evaluate the integration into the teaching-learning arrangement.

4.1 The Flex-STEx Kit

The new kit is called the Flexible Smart Textiles Experience Kit, abbreviated Flex-STEx. The Flex-STEx should enable my students to make their own experiences with the construction kit and, after an initial introduction, also to develop their own ideas and implement them directly in prototypes. The construction of a product prototype should thus be facilitated and it should be possible to make mistakes when working with the construction kit in order to learn from these and avoid this when realizing the products.

At the moment the new kit is being optimized - it is now mounted on a textile carrier and uses a Lilypad Arduino as controller and some components ae enlarging the Flex-STEx kit.

Fig. 5. Flex-STEx Prototype

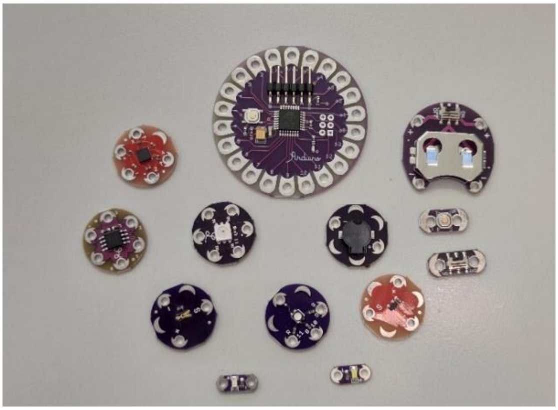

Fig. 6. Lilypad Components to enlarge the Flex-STEx Kit

The next steps include on the one hand the optimization of the prototype and on the other hand the implementation in a student working group. If necessary, this phase will be followed by iterative improvement of the prototype before it is subsequently multiplied.

The theoretical and practical exploration of the Flex-STEx learning kit will take place didactically and methodologically in parallel in a face-to-face course and in a blended learning course from the summer semester of 2021. These two methodological approaches are chosen in order to do equal attention to the existing teaching concept of the course as well as future planning with digitized teaching and to be able to compare the extent to which the kit is suitable for use in both teaching-learning arrangements.

Conclusion

In the field of smart textiles, interdisciplinary cooperation between specialists from the textile and clothing industry, as well as information technology and electrical engineering, is one of the most important key factors. Therefore, students have to be prepared to work in this way. The Flex-STEx application-oriented construction kit is intended to help to extend the frontiers of knowledge, stimulate creativity, and give students the ability to solve real-world problems. As added benefit it will accelerate the understanding of innovation and interdisciplinary challenges. A content-analytical evaluation of the data resulting from the work with two student groups each in presence and after the blended learning approach with the two construction kits will be carried out. Finally, by comparing these results, experiences and learning reflections, it can be determined whether the students have acquired professional competence through the innovations in the interdisciplinary field of smart textiles and are subsequently able to develop products independently or to optimize existing products in a targeted manner. Students will be ready to contribute to the development of new products and face the challenges of structural change along their working life if they are teached in the proposed concept.

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Why Students' Interest in Science Declined? On Focus Group of Japanese Undergraduate Students

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Abstract

Students' declining interest in science is internationally problematic, especially in developed countries. Despite efforts aimed at making science appealing to students, this problem persists. There is a shortage of studies that have applied fine-grained qualitative methods to examine how Japanese students' views have shifted toward a dislike of science. This qualitative study aimed at elucidating how and why undergraduate students in Japan experienced disliking science during their lives. A total of 22 freshman and sophomore students attending a Japanese public university described how their dislike of science came about within small focus group discussions (3-4 participants per group). Data sources comprised participants' interview data and written papers about life events associated with their attitudes toward science. A grounded theory approach was applied for coding the qualitative data. The analysis revealed 14 sub-categories under the following six categories: comprehension, hands-on activity, teacher and teaching, autonomy of learning, perceived relevance of science, and engagement. The study's findings demonstrated inter-relations among the sub-categories that influenced students' attitudes toward school science. The results emphasized the practical importance of hands-on activities for fostering students' understanding of abstract scientific concepts and the influence of teachers' personalities in shaping students' attitudes toward school science. The dynamics among these factors require further exploration to advance understanding of such complex attitudinal changes toward science.

Keywords: Science Interest, Focus Group, Grounded Theory

1. Introduction

Students' declining attitude towards school science in early adolescence have been a big issue in science education [1-3]. The TIMSS 2019 results reveal this continuing trend. Accordingly, in 2019, the percentage of Japanese students who 'do not like learning science' is 9% among 4th graders while 35% among 8th graders. Findings for other developed countries, including the United States, England, and Australia were similar [4].

Previous studies have shown that some factors such as gender, early experiences, and teaching quality affect students' attitudes toward school science [1, 5, 6]. Moreover, many interventions, such as summer camps and hands-on activities have been developed, all of which have demonstrably positive effects on students' attitudes [7].

Nevertheless, we are still facing a students' declining attitudes problem.

One of the possible reasons is that there is a shortage of studies that have examined detailed processes of swinging away from science. In fact, in Japan, no studies have applied a fine-grained qualitative method to examine how and why students' science interests shift to a dislike of science [8]. Some studies used qualitative methods [9-10], which focused on the emerging interest process and did not reveal the process toward disliking of science. A comprehensive examination of how students disliked science would be beneficial to tackle this problem. Therefore, this study sought to elucidate how undergraduate students came to dislike science in their life using a qualitative research method.

2. Methods

2.1 Participants

In July, 2020, 22 freshman and sophomore students (11 male and 11 female students) at a Japanese public university, who experienced disliking of science, participated in focus groups comprising three to four students. The participants represented all departments at the university, ranging from natural science disciplines to social sciences and humanities.

2.2 Data Collection

Before the focus group discussions took place, participants were asked to complete a pre-assignment (Fig. 1). Specifically, they were asked to plot attitudinal changes to school science during the course of the four schooling phases (lower elementary, upper elementary, junior high, and high school) and to note any events that explained their attitudinal changes on a worksheet. Focus group discussions were subsequently conducted, during which the pre-assignment worksheets were used to facilitate participants' active engagement with each other, supplementing each other's memory gaps and stimulating their personal memories. All interviews were videotaped and analyzed.

2.3 Coding

A constructivist grounded theory approach [11] was applied, which included at least two coding steps: initial coding and focused coding. MAX QDA software was used for the coding process. An event mentioned by more than two participants when explaining their attitudinal change regarding school science constituted a sub-category. If only one participant mentioned an event, it was treated as an exception.

3. Results

The analysis generated six categories and 14 sub-categories that explained how they came to "dislike" science. Table 1 shows some illustrative quotes for some of the categories. The numbers in brackets after each sub-category name denotes the number of participants who mentioned it.

3.1 Comprehension

3.1.1 Increased memorization (12)

With ascending grades, the contents taught in science classes generally increase.

Twelve students attributed their dislike of science to the need for increased memorization. In addition, the students increasingly tended to memorize contents without fully understanding them because they prioritized memorization in the limited time available, which did not facilitate the development of their understanding.

3.1.2 Content invisibility (5)

With ascending grades, the main activities in science classes entailed learning abstract concepts, such as force, energy, and electricity, rather than practical activities such as growing plants and craft making. These concepts, unlike the previously learned content are difficult to see or touch directly.

3.1.3 Mathematical operations (4)

The use of mathematical formulas and the need to perform calculations in science classes increases with advancing grades. Four students mentioned that these mathematical operations hindered their ability to follow science lessons.

3.1.4 Poor understanding (20)

Increased memorization, invisibility of content, and mathematical operations, along with decreased hands-on opportunities, disengagement from science learning (see 3.6.1). and poor teaching quality (see 3.3.1) contributed to a poor understanding of scientific content. Of the 22 participants, a substantial majority identified poor understanding as the cause of their dislike of school science.

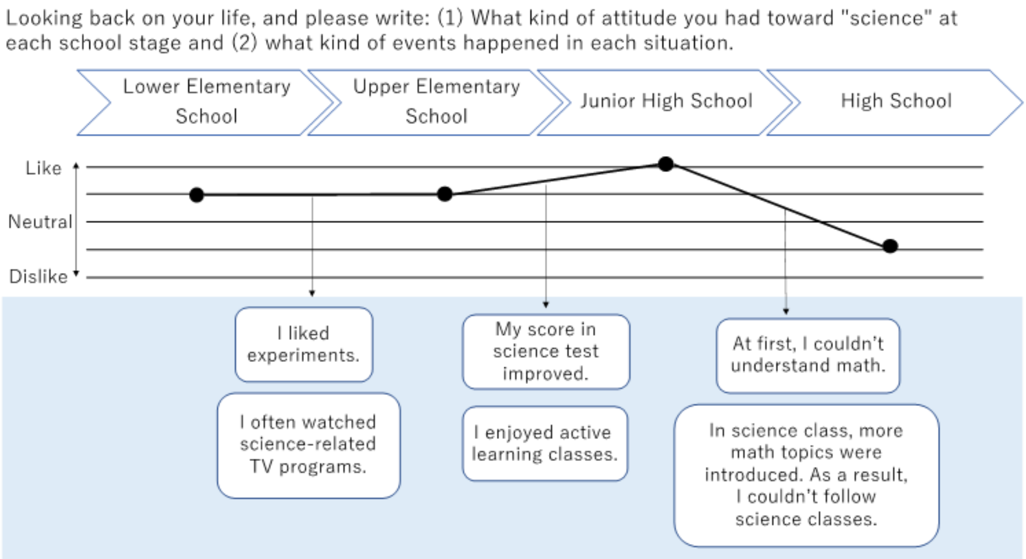

Fig. 1. Quotes (translated from Japanese) in a Student's Worksheet

Table 1. Some Categories, Sub-categories, and Illustrative Quotes

Category Sub-category	Illustrative quote
Comprehension	
Poor Understanding	"At first, I couldn't understand the equation ma = F in physics at all. I got stuck there. I couldn't visualize it at all. Even if I drew it in a diagram, I couldn't understand it."
Increased Memorization	"There was so much to memorize in inorganic chemistry that I gave up trying to remember it, and because chemistry is a subject where everything is connected, my understanding of the theory part went down, and I didn't even know where to restart."
Hands-on Activity	
Decreased hands-on opportunities	"The number of experiments was reduced, and it became more difficult to understand the concepts and content, even though high school students were doing things that were more invisible and difficult to imagine."
Teacher and Teaching	
Negative perceptions of teachers' personalities	"I asked a lot of questions, but I was rebuffed. So, I had a negative feeling toward my teacher, and I didn't want to study anymore."
Autonomy of learning	
Studying for the entrance exam	"I felt as if science had become nothing more than a subject for [passing] entrance exams."
Perceived relevance	
Relevance to life	"I didn't think I would get into science course at all, and I wasn't interested in science at all."
Engagement	
Disengagement	"I didn't like him/her, so I didn't even want to ask about it."

3.1.5 Poor test scores and grades (11)

Tests reveals the level of their understanding. When students' scores were below the class average or when they compared their scores with those in other subjects, or with their past scores in the same subject, they recognized their science ability were poor.

Eleven participants mentioned this factor.

3.2 Hands-on activity

3.2.1 Decreased hands-on chances (9)

Decreased opportunities to engage in hands-on activity (e.g., observations and experiments) negatively influenced attitudes toward school science both directly and indirectly. Indirectly, it deprived learners of opportunities to understand abstract science concepts. Nine participants mentioned this factor.

3.2.2 Independent research (2)

Elementary school students in Japan are commonly assigned homework during the summer vacation called independent research. Two participants mentioned that one of the reasons why they disliked school science was the requirement of conducting independent research.

3.3 Teacher and teaching

3.3.1 Poor teaching quality (3)

Poor teaching quality led to negative attitudes toward school science in two ways. In the first, poor teaching quality led to poor understanding, which in turn led to a negative attitude toward school science. The second pathway was via formation of a negative attitude toward the teacher, which in turn led to a negative attitude toward school science.

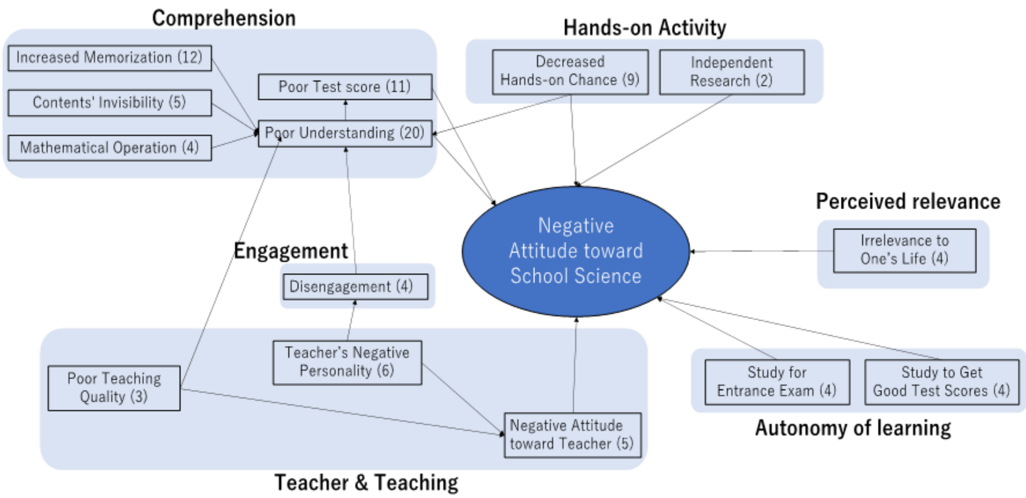

Fig. 2. Relationships between Category and Sub-category
Note. The numbers in brackets denotes the number of participants who mentioned each sub-category

3.3.2 Teachers' unfavorable personalities (6)

Teachers' unfavorable personalities induced negative attitudes toward school science in two ways. The first way entailed discouraging students' active engagement in learning science, which constrained their understanding. The second way entailed the transference of a student's dislike of an individual science teacher to the science subject that they taught.

3.3.3 Negative perceptions of teachers (5)

The above points show that the development of students' negative perceptions of teachers is brought about by poor teaching quality and teachers' negative personalities.

The difference is that while the "Poor teaching quality" simply refers to teaching methods, the "Negative perceptions of teachers" refers to teacher's personality.

3.4 Autonomy of learning

3.4.1 Studying for entrance exams (4)

The first sub-category was related to entrance exams. Before they recognize that science is a preparation subject for entrance exam, they could enjoy science classes.

However, after they recognized that science is a subject for entrance exam, their learning will come to be forced beyond their own will of studying.

3.4.2 Studying to attain good test scores (4)

The second sub-category was related to tests. Even though they initially started their science learning with their own intellectual curiosity, they came to worry about evaluations and test scores after they recognized science is an important subject for their future.

3.5 Perceived relevance

3.5.1 Irrelevance of class content to students' lives (4)

Four students mentioned that their negative attitudes toward school science developed when they began to perceive school science as being irrelevant to their lives.

3.6 Engagement

3.6.1 Disengagement from science learning (4)

There are many reasons for disengagement from learning science, such as being busy with club activities and illness. During the focus group discussions, students mentioned that teachers' negative personality caused them to disengage.

3.7 Dynamic interrelations among factors

Fig. 2 illustrates the interrelationships among the above-described sub-categories.

When at least one student mentioned the causal link between the two sub-categories, we drew an arrow. It reveals that there were five categories (except for Engagement) that directly influenced negative attitudes toward school science. In addition, some sub-categories also indirectly influenced negative attitudes toward school science. For example, the decrease in hands-on opportunities directly fostered negative attitudes toward school science and also indirectly reduced understanding, which led to negative attitudes.

4. Discussion

While the findings of this study are consistent with Self-Determination Theory [12], the influence and relevance of hands-on activities appears to be unique to science education. However, the negative impact of independent research on students' attitudes contrasts with the finding of a previous study that open inquiry positively influences interest in science [13]. This study's findings emphasized the practical importance of hands-on activities for students' understanding of abstract science concepts and of teachers' personalities in shaping students' attitudes toward school science. The dynamics among factors require further exploration to grasp complex attitudinal changes toward school science.

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Engineering Education

"Si(n)Ce You Are a driver": a PCTO Experience about Semiconductor Physics in Italy

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Abstract

Electronic devices are found as enabling technology in many objects of daily use. Some show a clear usage of electronic components, such as mobile phones and PCs, whereas in many objects, electronic control reliance is less evident. This is the case with the most recent domestic appliances. The use of the so-called "inverter technology" allows for smarter use of electricity and electric cars, where the inverter is defined as the motor's brain. The inverter is an electronic device that commutes current from continuous to alternate. Though silicon is the most common material employed in electronic device fabrication, the high power absorbed by electric cars requires inverters able to withstand high currents and voltages. The most suitable material for high power devices is silicon carbide, a semiconductor whose improvement is the aim of several research projects. "Challenge" is a project funded under Horizon 2020, coordinated by the National Research Council of Italy (CNR). Its dissemination strategy includes actions to make youngsters aware of the progress in the application of semiconductor technology. This work describes a pathway for transversal skills and orientation carried out by two high schools in Italy. We followed an ideal route from innovation to market for power electronic devices applied in e-mobility. Two whole classes attended thematic seminars on silicon carbide, and one on the European Framework Programs for research and innovation. The practical activity dealt with science dissemination activities towards different types of public. We observed that linking scientific issues with actual objects such as electric cars attract youngsters' attention towards an extracurricular scientific theme. Simultaneously, communication activities can deepen the level of insight while promoting pupils' critical thinking about the transfer of research findings to the market.

Keywords: Semiconductor physics, silicon carbide, electric motor, PCTO, science communication

1. Introduction

Electronic devices are found as enabling technology in many objects of daily use.

Some show a clear usage of electronic components, such as mobile phones and PCs, whereas electronic control reliance is less evident in many objects. This is the case with the most recent domestic appliances. The use of the so-called "inverter technology" allows a smarter use of electricity and, in electric cars, the inverter is defined as the motor's brain. The inverter is an electronic device that commutes current from continuous to alternate. Though silicon is the most common material employed in electronic device fabrication, the high power absorbed by electric cars requires inverters able to withstand high currents and voltages. The most suitable material for high power devices is silicon carbide (SiC) [1], a semiconductor whose improvement is the aim of several research projects worldwide. “Challenge” [2] is a project funded under Horizon 2020, coordinated by the National Research Council of Italy (CNR) with the cooperation of 13 European and 1 Japanese partner. The work carried out in “Challenge” can contribute to SDG9 (industry, innovation and infrastructures) and SDG11 (sustainable cities and communities) and, through science and innovation, it aims at promoting high-quality education (SDG4) decent work and economic growth (SDG8). Its dissemination strategy includes actions to make youngsters aware of the progress in the application of semiconductor technology. This work describes a pathway for transversal skills, and orientation (PCTO) carried out by two high schools in Italy.

2. Methodology

The learning pathways have a modular scheme following the methodology developed in the project RM@Schools [3]. This methodology allows tailoring contents and activities to different schools. Fig. 1 summarizes the activities carried out by the two classes.

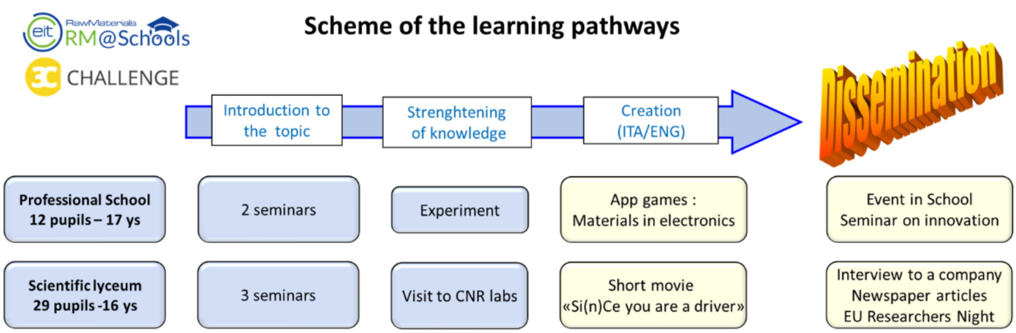

Fig. 1. Scheme (arrow) and details (boxes) of the learning pathways proposed to the Professional School and to the Scientific Lyceum. The blue boxes represent the guided activities, the yellow boxes the communication activities.

The pathways followed an ideal route from innovation to market for power electronic devices applied in e-mobility. The pathways involved: i) 12 pupils, 17-year-old, attending a Technical Professional School, named Class A; ii) 29 pupils, 16-year-old, attending a Scientific Lyceum, named Class B. The proposed topic was extracurricular for both schools.

The classes attended three thematic seminars. A scientist with expertise in processing technologies for electronic devices, held the first two. An introductory seminar explained the use of new materials in emerging electronic technologies and the need to further research in this field; a second seminar focused on the scientific topic faced in “Challenge” and dealt with physics and processing techniques of semiconductor devices made up of SiC and their application in automotive. The third was presented by an SME leading the Challenge communication activities. The seminar focused on Horizon 2020, the European Framework Program financing collaborative research and innovation. The accent was on the strategic role of public funds to sustain new ideas, researchers and economy in the fields of the enabling technologies and innovative solutions for the benefit of the society. In Class A, this seminar was given in the frame of a public event organized in the School, whereas in Class B, it was presented as the learning pathway introduction.

As a practical activity, Class A fabricated a printed circuit board as a practical activity by employing soldering, drilling, and bromographic lithography techniques. The circuit, developed in the frame of the project RM@Schools, incorporated battery, LEDs, and resistors and can be used to provide a visual comparison between the electrical resistivities of quartz slides either uncoated or covered by different transparent conductive materials (indium tin oxide and graphene). We focused on the materials constituting the devices incorporated in the circuit: silicon, the primary semiconductor material in electronic devices; gallium arsenide and gallium nitride as direct band gap semiconductors in LEDs; silicon dioxide as electrical insulator; copper and indium tin oxide as electrical conductors. The bromographic lithography served as a cue to introduce photolithography as a mean to fabricate planar electronic devices with 1-2 µm resolution. Though not directly related to SiC, this experience is suitable for a PCTO because it links the relatively new content about semiconductor physics and processing and the students' background in device integration.

The practical activity proposed to Class B was a visit to the laboratories of the Institute of Microelectronics and Microsystem of CNR in Bologna. They visited a class 100 cleanroom equipped with the technologies for electronic device fabrication: photolithography, silicon dioxide growth, metal deposition, and doping. The specific SiC temperature resistance requires dedicated equipment for the doping step. In this visit, the students could appreciate the need to develop SiC processing technologies.

The next steps of the pathway, i.e., the creation of dissemination products and the participation in a dissemination event, reinforces the link between the new contents about research in the field of electronics and the transversal skills of the students: communication, synthesis, fluency in English, use of technological devices to create multimedia contents.

3. Results and discussion

As a result of this "training" the students created dissemination products by re-elaborating in groups the scientific contents treated in the seminars.

Class A created three digital games: a quiz named "semiconductor or insulator?" where the player has to assign materials to the right category [4]; a "hangman game" where the player has to guess the name of a material, processing technique or device by suggesting letters within a certain number of guesses [5]; a puzzle whose pieces are uncovered by assigning materials to the right category [6]. Fig. 2 shows some screenshots of the games. This set of games focuses on materials and techniques used in electronic device fabrication. These games help students summarize names and electrical properties of materials.

These games served as a playful final during the open event organized in the Professional School, where 80 pupils and teachers of different schools attended seminars on innovation in electronics.

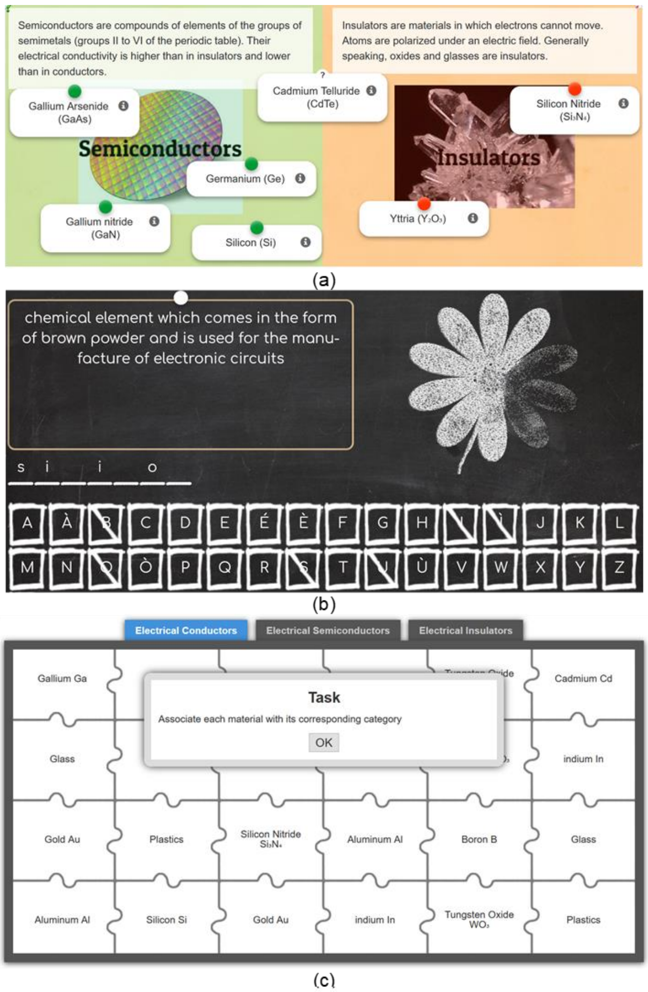

Fig. 2. Screenshots of the games realized by Class A: semiconductor or insulator? (a); hangman game of electronics (b); puzzle of materials (c).

Class B realized a short movie named “SiCcome guidi”, in English “Si(n)Ce you are a driver”, explaining the advantages of using SiC inverters in automotive and the barriers to their widespread use. They could show the need for research through nice images (some drawn by themselves) and witty use of the language, culminating in the title’s pun.

Instead of loading the speech, the use of specialist terminology resulted in a clear and precise description. This movie is published on the “Challenge” website and YouTube channel [7] and is part of the Gallery of RM@Schools.

This class made science dissemination experiences addressing different types of public. A selected group of 5 students visited a local company that produces electric vehicles, and they discussed the advantages and limitations of introducing SiC inverters in their production. The cost and reliability of components turned out to be the key elements guiding companies’ choice, highlighting the need for further research to improve the SiC material quality and processing technology.

The whole experience was published in a local newspaper [8], where the class did an intership for a different PCTO. Under the guidance of the editorial officers, the articles about SiC in automotive, the pictures of the company visited, and the interviews with researchers offered a fresh image of a topic that usually requires scientific background knowledge.

Finally, they were the protagonist in the European Researchers Night held in Bologna on Sept 27th, 2019 [9]. “Challenge” set up a stand where people could gather information, ask questions or play games. The pupils, divided into four shifts to cover the whole event, assisted the public in playing and answering questions about scientific issues with the help of a poster and their movie. As the students commented [10], the experience was exciting and engaging.

We observed that linking scientific issues with actual objects such as electric cars attract attention towards a scientific topic that requires extracurricular knowledge for a deep understanding. The students of the different schools appreciated different aspects of the pathway. The students of Professional Schools found the circuit’s realization and the hints to semiconductor processing most appealing. The Scientific Lyceum students were interested in the environmental benefits of using SiC inverters in electric cars. All the students showed a deep engagement in the live dissemination activity, testified by the intense communication with the tutors the week before the events. The realization of a dissemination product turned out to be a slender way to recollect the seminars’ content and deepen the insight acquired by the independent search. It also allowed to identify the most complex contents and find convenient strategies to tackle the issue. For example, though the band gap concept was considered awkward, its implications in high-temperature operation of SiC devices were clear. Together with the seminar on innovation, the company visit promoted pupils’ critical thinking about the transfer of research findings to the market.

4. Conclusions

This experience shows a successful practice for science dissemination in European research projects and PCTOs based on extracurricular scientific topics. By adopting the methodology developed in RM@Schools, pathways centred on the research carried out in “Challenge” could be adapted to different requirements. We find that the key to interest pupils lies in showing the social relevance of a research issue while involving them in live communication events is both engaging and rewarding.

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Didactic Example of Physics Applied to Jurisprudence

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Abstract

The teaching of physics is a very important social task even if it concerns only basic physics.
The case of a real trial in which a bad knowledge of physics laws led a monocratic judge to issue a judgment based on erroneous physical conclusions is reported. The relevant thing is that the monocratic judge was misled by a technical report prepared by an alleged expert.
In the trial, the defendant, Mr. D.S. (Defendant for Slander), was accused of slander; in particular, Mr. D.S. would have falsely accused, by means of a summons, his neighbor, Mr. O.P. (Offended Party), of having caused him a damage for which he would have demanded undue compensation. The harm would have been caused by external plaster pieces that would have detached from mr. O.P.'s property and would have reached mr. D.S. in his garden, more than a meter away from the O.P.'s building facade, injuring him in his head. The technical report should have contained the calculations or the estimate of the possible trajectories of the detached external plaster pieces, while it expresses only qualitative conclusions based on totally wrong physical considerations.
The analysis of the errors can be a useful help to identify some physics concepts that could be misunderstood by students and that should be explored in depth. In addition, this article could be a useful and interesting reading for students of basic physics courses so that they can appreciate even more the real importance of what they study and can better understand the principles of basic physics.

Keywords: Projectile motion, Physics Teaching, Restitution Coefficients, Action-Reaction Pair

1. Introduction

In this article, the case of a real trial in which a bad knowledge of physics laws led a monocratic judge to issue a judgment based on erroneous physical conclusions is reported. The monocratic judge was misled by a technical report prepared by an alleged expert. Both the technical report and the judgment are parts of official legal documents published and filed at the court of Nola – Italy (sentence n. 1010/2020 issued on June the 15th 2020 at the Nola Court – Single Judge of first instance in monocratic composition – and filed on June the 19th 2020). In the trial, the defendant, Mr. D.S. (Defendant for Slander), was accused of slander; in particular, Mr. D.S. would have falsely accused, by means of a summons, his neighbor, Mr. O.P. (Offended Party), of having caused him a damage for which he would have demanded undue compensation. The harm would have been caused by an external plaster piece that would have detached from Mr. O.P.'s property and would have reached Mr. D.S. in his garden, more than a meter away from the O.P.'s building facade, injuring him in his head. In order to understand the dispute and the physical problem, in Fig. 1 the physical situation is represented. Furthermore, in order to highlight the errors contained in the technical report, the physical solution of the problem, proposed by the authors, will be presented in the next section.

2. The physical solution

On the day of the alleged accident there was no wind and therefore its possible effects can be neglected. Furthermore, friction with air can be neglected, because in any case it has a braking effect and therefore a shortening of the horizontal range. Therefore, the only force acting on an external plaster piece during its motion is the weight force, a conservative force. The equations of motion of the plaster piece will be:

1) $\overrightarrow{F_g} = \mathrm{m}\vec{g} = \mathrm{m}\overrightarrow{a_c}$, where $\overrightarrow{a_c}$ is the center of mass acceleration.
2) $\overrightarrow{\tau_e} = 0 = I_u \frac{d\vec{\omega}}{dt}$, where $\overrightarrow{\tau_e} = 0$ is the $\overrightarrow{F_g}$ moment relative to the center of mass *C*, I_u is the moment of inertia relative to an axis *u* passing through *C*, and $\vec{\omega}$ is the angular velocity around the *u* axis.

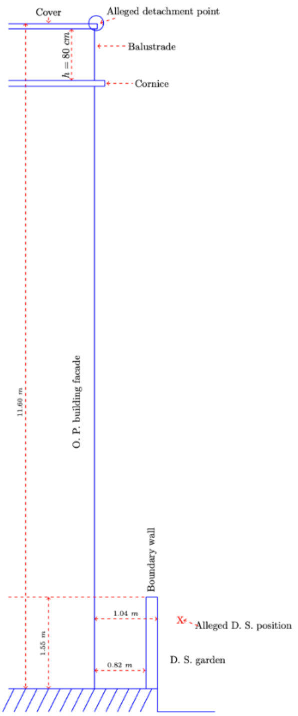

Fig. 1. P.O.'s building profile at the minimum distance from the boundary wall. A red X indicates the point where Mr. D.S. would have been hit by the plaster piece, point which is not on the same plane. This point is horizontally well over 1.30 m from the building wall from which the plaster pieces would have come off.

Equation 1) describes the motion of the center of mass *C*, that is where the plaster pieces may arrive, while equation 2) rotations about the center of mass *C*, and in particular tells us that the rotation speed remains constant. In order to establish if external plaster pieces might have reached mr. D.S. in his garden, one has to consider only equation 1), which allows to estimate the distance that they might have travelled.

In Fig. 2, all calculations about the center of mass motion are reported. In particular, a detached external plaster piece, subject only to the weight force, travels, with a projectile motion, until it collides with the cornice. Taking a very conservative assumption, it will be assumed that the external plaster piece hits a point of the cornice other than the foot of the perpendicular to the point of contact (that is a point of coordinate other then $x_i = \delta$ in Fig. 2). In that case, the plaster piece must have, at the moment of detachment, a small horizontal component of the velocity, v_{0x}, that can be determined kinematically according to the point of collision coordinate.

During the collision, the force of reaction due to the plane of the cornice, an impulsive force of contact, acts. The effect of the collision is described by Newton's coefficients of restitution (COR) [1, 2]. After the collision, the plaster resumes its motion of a projectile subject only to the weight force.

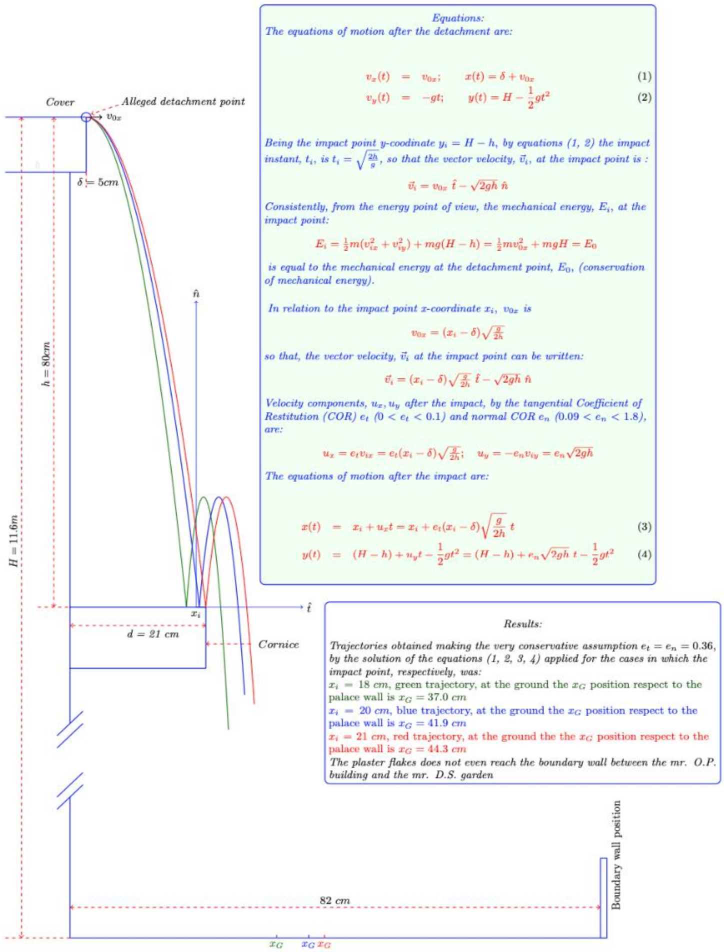

Fig. 2. Physical solution

3. The technical report

Contrary to the solution of the equations of motion, the technical report states that the external plaster piece may have reached the garden of Mr. D.S. and they may have hit him. In the following, the contents of the technical report in quotes and in italics style is reported.

"…Once the detachment points of the material "(reported by a circle in Fig. 1)*" has been identified, let's analyze the possible trajectories traced by the material after detachment… In all cases, the cornice is involved, which constitutes not only the main obstacle to the falling stones but is also the one that determines the possible trajectories of the stones themselves, according to their masses and to their geometric shapes. The height of fall does not matter, …, the fundamental thing is the point of application of the reaction force, which is the force action that the cornice exerts on the stone. Therefore, in the collision between stone and cornice, a system of forces is thus generated, all applied to the mass of the falling stones* "(see Fig. 3)*". Of course, for the trajectories it is necessary to know not only the system of applied forces, but also the mass and geometry of the individual stones that hit the cornice. ... The trajectories of the fragments, on the other hand, are characterized by the set of points of application of the resultant of all the forces acting on the fragments throughout the path.*

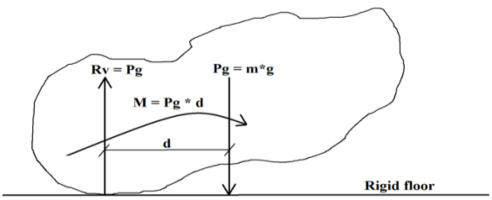

Fig. 3. Scheme of forces acting on a rigid plane according to the technical report

…the hypothesis of the discovery of materials within D.S.'s lot, appears possible and legitimate, because there is not only a system of forces acting on the bodies (stones) but also of moment solicitation that inevitably cause the onset of rotation of the mass of bodies. In fact, in our case, in addition to the gravitational force applied to the center of gravity of the mass, there is also another force that arises as a reaction to the gravitational one, and it is the force exerted by the cornice on the mass of material falling from above. The latter is equal and opposite to gravitation, and if applied in a point other than the barycenter of the mass because it is a geometrically non-definable body with uncertain shapes and of non-homogeneous material. In the statics of bodies, two forces of opposite sense which maintain the same direction, the same intensity, but which are applied in different points, give rise to a couple that gives the movement of the stone a rotary motion '(Fig. 3)'. And it is this couple of forces that, in my opinion, determined the removal of the stones until they reached the D.S.'s property."

According to the technical report, the force due to the cornice, $\mathbf{R_v}$, and the gravitational force, $\mathbf{F}_g$, are a third-law force pair and therefore are equal in magnitude and opposite in direction. If this were the case, the resultant of the forces acting on the external plaster would be zero and therefore the plaster would have no acceleration ($\mathbf{F}_g+\mathbf{R_v} = 0 = m\mathbf{a}$). Evidently, the $\mathbf{R_v}$ and $\mathbf{F}_g$ forces applied to the stones (external plaster pieces) are not a third-law force pair, because forces of third-law force pair always act on different bodies [3]; furthermore, $\mathbf{R_v}$ is a contact force, acting only during the contact, while **F**$_g$ is an action-at-a-distance force always acting.

For the same reasons, **F**$_g$ and **R**$_v$ cannot constitute a couple of forces [4, 5], so that there is no torque acting on an external plaster piece during its motion.

"*The transformation of the potential energy into the kinematic one also gives the stones an increase in forces and motion that allows them to reach even significant distances from the point of fall.*"

Forces determine the energy of a system and not the other way around. In the transformation of potential energy into kinetic energy there is no increase in forces.

"*Before finishing the technical report, I invite anyone to make the experience of dropping a small stone from his hand and checking its distance reached after the fall, he will notice that in some cases it even exceeds one meter. All this happens precisely because the mass of the stone, geometry, strength and stiffness come into play, as well as the stresses deriving from the application of the system of forces which are: Pg, Rv and M.*"

We leave the relevant considerations to the attentive readers.

4. Conclusion

In this article the case of a real trial, in which a bad knowledge of the physics laws led a monocratic judge to issue a judgment based on erroneous physical conclusions, has been analyzed (sentence n. 1010/2020 issued on June the 15th 2020 at the Nola Court – Single Judge of first instance in monocratic composition – and filed on June the 19th 2020). The relevant thing is that the monocratic judge was misled by a technical report prepared by an alleged expert. Essentially, in the technical report it is stated, mistakenly, that the horizontal range of the center of mass motion of an external plaster piece detached from a building is lengthened by the effects of a (non-existent) couple of forces and by an additional force resulting from the continuous transformation of potential and kinetic energy into a force. The technical report contains only opinions and imaginative, subjective interpretations, among other things erroneous, of some physical and non-physical laws; the contained conclusions are not the result of any mathematical model (and could not have been given the erroneous physical setting) and do not express any verifiable numerical data.

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Drop Out and Attendance in Online Pre-Study Preparatory Physics Courses

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Abstract

Offenburg university of Applied Sciences offers pre-study extracurricular preparatory courses for future engineering students in mathematics and physics. Due to pandemic restrictions, the two-week preparatory physics course preceeding winter term 2020/21 was presented as an online-only course. Students enrolled to the course attended eight online lectures of approximately 90 minutes duration followed by a group assignment. Both lectures and tutoring to the group assignment used a videoconference system with group sizes of 120 (lecture) and 6 (peer instruction and group assignments). The eight lectures focused on the high school physics curriculum of mechanics, electricity, thermodynamics and optics. Each lecture included four "peer instruction" questions to improve student activation. Student responses were collected using an audience response online tool. The "peer instruction" questions were discussed by the students in online groups of six students. These groups also received written group assignments consisting of common textbook exercises and additional problems with incomplete information. To solve these problems, groups were encouraged to discuss possible solutions. The on-line course attendance was monitored and showed a characteristic exponential "decay" curve with a half-life of approximately 18 lectures which is comparable to conventional courses: Around 73% of the students enrolled in the preparatory course attended all eight lectures. In addition to the attendance, the progress of the participants was monitored by two online tests: A pre-course online test the first course day and a post-course online test on the last day. The completion of both tests was highly recommended, but not a formal requirement for the students. The fraction of students completing the pre-course, but not the post-course test was used as an estimate for the drop-out rate of (34±3) %.

Keywords: Engineering education, STEM preparatory course, peer instruction

1. Introduction

Preparatory courses are offered by many universities before the start of the first semester to reduce the heterogeneity in introductory classes. Offenburg University offers two-week preparatory courses in mathematics, physics and informatics to all STEM-field students. Participation in the complimentary courses is voluntary, but highly recommended. The preparatory courses in mathematic focus on the repetition of pre-calculus middle-school subjects like arithmetic operations, fractions and basic algebra.

The preparatory physics course focuses on an introduction to mechanics, electricity, thermodynamics and optics defined in the requirements catalogue for STEM-field subjects at universities of applied sciences in Baden-Württemberg state [1]. In this paper, we describe the online version of the physics preparatory course (section 1.2) which was introduced due to the pandemic situation, in particular the included blended learning elements (section 2) and the effects of the online course on enrolment and participation (section 3).

1.1 Conventional physics preparatory course

To monitor the progress during the conventional preparatory course for both participants and teachers, the first and the last unit of the preparatory course consists of a 45 min pre- and post-course test with comparable difficulty. For a number of reasons, the post-test yields higher average scores: In addition to improvements in the physics skills, the drop-out probability is correlated to the pre-test score so that the students remaining in the course achieve a higher post-test score. The ratio of average post-test to average pre-test score is not a direct measure for the quality of a course.

However, the ratio can be used to compare courses if they have comparable drop-out ratios and use the same test questions. In the conventional preparatory courses, (57±5)% of the enrolled students who took the pre-test also took the the post-test (uncertainty derived from a four-year average, Fig. 1)

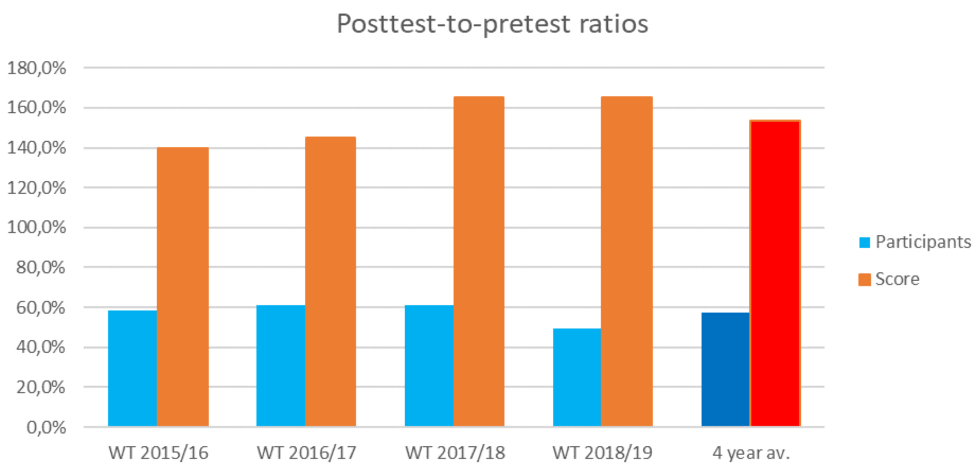

Fig. 1. Ratio of participants and average test score (post-test to pre-test) in conventional preparatory courses. Numbers below 100% indicate a loss of participants, numbers over 100% an improved average score in the post-test

1.2 Online physics preparatory course

Due to the constraints of the COVID-19 pandemic, the preparatory physics course preceeding winter term 2020/21 had to be hold on-line without any physical presence of the first-year students. Instead of the conventional combination of exercises and lectures (180 min duration) held in classes of approximately 40 students, the online lectures were presented through the zoom online platform (www.zoom.us) with 120 students in each class. Each online lecture had a duration of 90 minutes followed by half an hour break, an exercise phase of 80 minutes and a debriefing lecture of 10 minutes.

Each course days focused on a topic of the high school physics curriculum: one day focussed on units and mathematical formulas, three days on mechanics, two on electricity, and one day on thermodynamics and optics, respectively. Pre- and post-test were presented a on the moodle learning management system (LMS). The LMS also was used to distribute an electronic booklet with exercise questions and a daily letter describing the exercise phase. To maximize student activation, a number of blended learning elements was introduced into the online course.

2. Blended learning elements

Interaction from student to teacher and among students is significantly reduced in online courses as compared to conventional courses. To increase student-student interaction, we formed groups of 5-7 students with similar subject, place of residence and previous education for the mathematics and physics preparatory courses. Each group was assigned to a separate virtual classroom ("breakout room" in terms of the zoom platform) during online-lectures, especially peer instruction (section 2.1) and group assignments of the exercise phase (section 2.3).

2.1 Peer instruction lecture

In order to get a feedback on the students' understanding of the presentation, each lecture contained questions in the peer-instruction [2] format. Peer instruction requires the students to answer a single-choice question, subsequently group discussion and in a finally a re-answer of the question. If questions are well-posed, the discussion among the participants leads to an activation of the students. The monitoring of the single-choice answers also indicates the average learning level of the students. The recommendation is that questions should receive two-third correct answers in the first voting for optimum progress.

For the on-line preparatory physics course, each day used four peer-instruction questions and modified textbook [3] exercise modified for online voting. Audience responses were collected using the "peer instruction for very large groups" (pingo) web service [4]. This audience response system uses common web-browser without further client or server installation. After a first vote, participants were placed in a separate "breakout room" to discuss their choices. In the "breakout rooms", participants used video and audio to communicate in their group. After a discussion period of 5 minutes, the audience response voting was repeated. The outcome of the second vote was commented by the lecturer to correct residual ill-conceptions, if necessary.

2.2 TeachMatics App

After 90 minutes of peer instruction lecture, the groups were told to solve an exercise sheet with two types of exercises: Common textbook problems were presented for individual work and a group assignment which required additional discussion. Solution to the common textbook problems was provided through a smartphone app (TeachMatics App) [5] which has been used in the preparatory courses since 2014. The smartphone app supports students with help texts on different mathematical skills needed to solve a given textbook exercise.

2.3 Group assignments

In addition to the smartphone app, the exercise phase consisted of a daily group assignment which was not solvable alone with the information given in the exercise sheet. Instead, groups were told to discuss what additional assumptions were needed to solve the problem, to research missing data (for example, the density of air at 20°) and to sketch a possible solution to the problem relying on the assumption. Groups were told to hand in their solution. Instead of an individual feed-back on each submission, the three extraordinary submissions were presented to the semester on the next day to encourage further submissions.

3. Results

257 students enrolled in the pre-test of the physics online course, 235 of them completed the (voluntary) online pre-test. The students were divided into two groups of approximately 120 students for two online classes and the attendance in the classes was recorded through zooms server logs. The courses were given on-line by one lecturer and one student tutor to address questions from participants on the assignments and peer instruction.

3.1 Drop out

On the last course day, 163 students started the post-test and only 144 completed it.

In comparison, all students attending the last course day of the conventional preparatory course complete the post-test. The ratio derived from completed post-to-pre-tests is 144 to 235 (63%) well within the standard deviation in the conventional preparatory physics courses with a four-year average of (57±5) %. Taking into account the 19 students who started, but did not complete the post-test, the drop-out ratio is between (34±3) % where the uncertainty of 3% stems from whether participants with incomplete tests are considered or not. The drop-out rate is comparable to conventional courses (43±5) % calculated on from the four-year average.

The average test score of the students in the online post-test was 391% of the average score of the online pre-test. This number should be taken with a piece of salt due to the difference in online and written tests: It can be assumed that the students need to accustom to the online test environment whereas they already know written exams on the first course day. The online preparatory course yields a significant higher score improvement than the conventional preparatory course with a four-year average of (154±12) % even though the drop-out rate in the online course is slightly lower in the online courses.

3.2 Attendance

In addition to the drop-out rate calculated from the ratio of completed online tests, the zoom platform logs the individual attendance of the participants with a temporal resolution of minutes. For analysis, we counted all enrolled students who attended more than 50% of the duration of the online course (Fig. 2). A least-square-fit of an exponential decay indicates that 246 students attended the first day. The decay curve has a half-time of around 18 days. On day 8, 181 students attended class, although only 163 started (and 144 completed) the post-test.

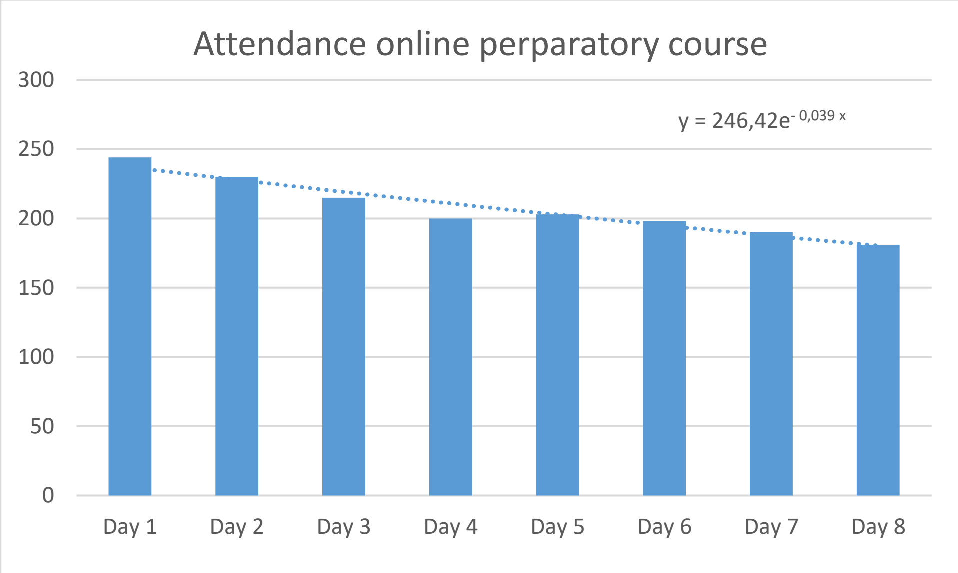

Fig. 2. Number of students attending more of 50% of the duration of the online preparatory physics course as recorded through the zoom platform logs

From the server logs, a finer analysis of the participation is in principle possible. One could, for instance, identify the fraction of students attending only in particular course activities like peer instruction lectures or group assignments. However, it is difficult to discriminate against external effects. For instance, the attendance in afternoon sessions seems to be lower than in morning sessions independently of the course activity.

4. Conclusion

In summary, the online preparatory physics course yields a drop out comparable to conventional preparatory physics courses. The online course yields a significantly higher improvement in online courses as compared to conventional courses indicted by the ratio of the average post-test score to the average pre-test score although it is not clear if the improvement might be partially caused by an adaption of the students to the online test environment. To avoid long lectures in courses, peer instruction and blended learning elements can be used to increase interaction between participants in online courses which is important to lower drop out in online courses.

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Interdisciplinary Course Smart Building Engineering: A New Approach of Teaching Freshmen in Remote Teamwork Project Under Pandemic Restrictions

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Abstract

In the context of the Corona pandemic and its impact on teaching like digital lectures and exercises a new concept especially for freshmen in demanding courses of Smart Building Engineering became necessary. As there were hardly any face-to-face events at the university, the new teaching concept should enable a good start into engineering studies under pandemic conditions anyway and should also replace the written exam at the end. The students should become active themselves in small teams instead of listening passively to a lecture broadcast online with almost no personal contact. For this purpose, a role play was developed in which the freshmen had to work out a complete solution to the realistic problem of designing, construction planning and implementing a small guesthouse. Each student of the team had to take a certain role like architect, site manager, BIM-manager, electrician and the technitian for HVAC installations. Technical specifications must be complied with, as well as documentation, time planning and cost estimate. The final project folder had to contain technical documents like circuit diagrams for electrical components, circuit diagrams for water and heating, design calculations and components lists. On the other hand, construction schedule, construction implementation plan, documentation of the construction progress and minutes of meetings between the various trades had to be submitted as well. In addition to the project folder, a model of the construction project must also be created either as a handmade model or as a digital 3D-model using Computer-aided design (CAD) software. The first steps in the field of Building information modelling (BIM) had also been taken by creating a digital model of the building showing the current planning status in real time as a digital twin. This project turned out to be an excellent training of important student competencies like teamwork, communication skills, and self-organisation and also increased motivation to work on complex technical questions. The aim of giving the student a first impression on the challenges and solutions in building projects with many different technical trades and their points of view was very well achieved and should be continued in the future.

Keywords: Freshmen, roleplay, Smart Building Engineering, BIM, remote teamwork

1. Aims of the project

For most freshmen it is a completely new period of life when they start studying: Many of them move out of home for the first time and come to new places without knowing the other students. They are suddenly responsible for themselves and have to structurize their new everyday life on their own. More than two thirds of freshmen have problems to organize themselves and prepare exams efficiently in the beginning. Many of them also struggle with performance requirements and need help with written homework [1], [3].

Corona pandemic also reinforces these problems: There is hardly any face-to-face events at the university allowed because of pandemic restrictions and many students feel lost and lonely sitting in front of their online lectures and digital exercises [2]. To provide a good start especially for freshmen anyway in demanding courses of Smart Building Engineering a new teaching concept became necessary. One of the aims was to get the students into contact with each other actively in small teams. Another aspect of the project was the training of important student competencies like teamwork, communication skills and self-organisation right at the beginning of the course. Also, the motivation to deal with complex technical questions should be increased.

For this purpose, a roleplay was developed in which the freshmen had to work out a complete solution to the realistic problem of designing, construction planning and implementing a small guesthouse in the builder's garden. Each student of the team had to take a certain role like architect, site manager, BIM-manager, electrician and the technitian for HVAC installations.

2. Requirements for the new interdisciplinary teaching concept

The freshmen should understand the interdisciplinary concept of the course "Smart Building Engineering" in general. As part of the module "Integral Planning and Building" for freshmen in the course this project should give them a first impression on the challenges and solutions in building projects with many different technical trades and their points of view. The students should get to know the different problems that arise from a construction task for the involved technical disciplines. They should understand the relevance of a good coordination of the individual contributions for the success of a construction project. Therefore, they had to recognize essential interfaces and interactions in the area of planning and execution.

The project should not just bring the students into contact with each other it also should promote their creativity. Therefore, the project had to be set up in an open way leaving enough space for creative solutions instead of resulting in a single "correct" solution. In order to be able to evaluate the project folder fairly and transparently at the end, minimum requirements had to be set for the task execution.

Because of social distancing during Corona pandemic, this project should also replace the written exam at the end. The freshmen had to submit a project folder containing technical documents, documentation, time planning, cost estimate and minutes of the meetings between the various trades.

A model of the construction project must also be created either as a handmade model or as a digital 3D-model using Computer-aided design (CAD) software. The first steps in the field of Building information modelling (BIM) had been taken by creating a digital model of the building showing the current planning status in real time as a digital twin as well.

3. Design of the new roleplay

The development of the new roleplay was challenging: On the one hand, the task should be complex enough so that all aspects of a complex building project occur realistically. On the other hand, it should leave enough room for creative solutions and not overwhelm the freshmen with its scope and complexity. The task also should be designed in such a way that it can only be solved successfully if all team members work together. Therefore, the students had to form teams of 4 to 5 members and each team member had to take a certain role. For each role a specific task was defined with just few technical restrictions to the possible solution. For each role and their tasks some simple instructions, examples and templates were given for getting an idea of how to solve the problem.

Requirements for the guest house	
Maximum floor space of the guest house	30-50 m²
Maximal height	not two full floors
Functional areas that should be included	living area
	kitchen area
	dining area
	bathroom
	sleeping area with up to 4 beds (fixed or variable)
	storage space
	terrace
	office area

Table 1. Overview of the minimum requirements for the guest house in the client's garden

In order to ensure the exchange between the team members, the students must meet regularly for digital meetings and also take minutes. In this way, joint decisions were recorded and the progress in the project was documented. These minutes were also part of the documents the students had to hand in for grading their group work.

Role	**Main tasks**
Architect	Design the guesthouse and its rooms/areas.
	Create a floor plan, views, and sections on a scale of 1:20.
	Create a model (handcrafted or digital 3D-model using CAD software).
Site Manager	Monitor and coordinate the work/elaboration of all processes.
	Plan every step using a construction schedule.
	Check the elaborations of the others and document them in minutes.
	Deal with project management, regulations and safety on the construction site.
	Cost estimation and controlling.
	As the person responsible, compile the documents for the final acceptance.
BIM-Manager	Advise the building owner about the possibilities/advantages of BIM applications.
	Monitor all planning steps.
	Define the digital planning tools and request input from all involved trades.
	"Maintain" the 3D model or the digital twin of the building.
Electrician	Plan the number and location of sockets, power lines

	and lamps.
	Create a sketch/plan on a scale of 1:50 (no expanded circuit diagram) with a legend.
	Information and communication technology.
	Alarm system.
Technician (HVAC installation)	Planning of sanitary facilities, hot water supply, ventilation (for bathroom, kitchen).
	Plan the inlet and outlet pipes.
	Dimensioning of the required components.
	Create a sketch/plan on a scale of 1:50.
	Determine the approximate material required.

Table 2. Overview of the tasks for each role in the roleplay

4. Implementation and results

The Freshmen formed 8 teams (two teams with four and six teams with five members) independently and signed up for the project via E-Mail up to a deadline. All the required specifications and the task definition were made available via the ILIAS [5] platform. All teams could start their projects at once. The students had 4 months to work on the project and to put together a project folder with the required documents at the end. The files were also submitted digitally via E-Mail or data exchange tools because of social distancing. The groups that decided to build a physical model instead of a digital 3D model were allowed to photograph their model for project folder submission and hand it in later on. Because of extended corona restrictions during lockdown in Germany at the beginning of 2021, this project replaced the final written exam in this module. The submissions were graded and all group members together received the same grade for this module.

In case of questions or problems the students had the opportunity to contact three peers. Some asked questions during the projects primarily to ensure that their solution met the requirements, but just very few teams needed further help.

Some groups faced the problem of one group member dropping out during the project. In this case, it was assured that the group can still take part in and will not be disadvantaged because of the missing parts in the grading. Some groups had that much fun with their project, that they unceremoniously divided all open tasks among themselves. In this way, these teams brought their roleplay to the next level by playing more than one role at the same time. Of course, these students got to know several different perspectives and recognized even better the importance of interdisciplinary approaches and binding agreements between the various trades.

Fig. 1. Front view of the 3D model (top left), open top view of the 3D model (top right), floor plan (bottom left) and installation plan of one of the groups [4]

5. Outlook

The Freshmen who took part in the project gave consistently positive feedback: In times of lockdown, many were grateful for a task that made it easier for them to get into contact with the others. Despite the Corona restrictions, they got a good start to their studies based on the required cooperation in their teams. Most students also found it more interesting to independently deal with typical problems during a planning and construction process than simply listening to a lecture. All this leads to a better understanding of the goals of this interdisciplinary course and have a more precise idea of their possible future professional life.

This project turned out to be an excellent training of important student competencies like teamwork, communication skills, and self-organisation and increased motivation to deal with complex technical questions. The aim of giving the student a first impression on the challenges and solutions in building projects with many different technical trades and their points of view was very well achieved and should definitely be continued in the future.

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REEdI: Rethinking Engineering Education in Ireland

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Abstract

The REEdI project offers an agile and innovative learning programme providing personalised, flexible and tailored options to diverse learner cohorts; from school leavers to graduating apprentices, to upskilling industry professionals and mature students. Building on the success of world-leading cutting-edge models of engineering pedagogy, we combine an innovative method of content delivery with new immersive technologies to deliver a transformative programme of self-directed and self-scheduled learning for the next generation of engineers. Learners will navigate an online learning map and complete subject paths, in their own time, at their own location, choosing material to suit their individual and unique needs. The framework will be truly innovative, drawing on international best practice in the field of engineering education. The programme enables a student-centred, project-centric and technologically innovative approach to undergraduate programme provision, equipping graduates with the skills and knowledge required to ensure they are capable of navigating the future challenges and disruptive technologies faced by the manufacturing sector in Ireland. In terms of structure, we have designed the framework to have three central pillars: eLearning, projects, and performance planning and review; all bracketed by innovations in pedagogies and technologies. We have modelled REEdI on a world-leading model of self-directed, project-centric learning developed by Charles Sturt University. Our novelty and additions include the use of Virtual Reality and Augmented reality (VR/AR) in supporting the education of student engineers along with student access to world class Science Foundation Ireland research centres (CONFIRM, LERO, and IMaR). This affords a wealth of advantages in undergraduate engineering education provision. It is also becoming increasingly important to involve employers in the development and provision of learning to ensure its relevance to the needs of the workplace. We have appointed Industry champions to a steering committee and industry are actively involved in curriculum design. Our approach aims to be positively disruptive and transformative, with a vision to set the agenda for engineering education nationally.

The REEdI Project is funded under the Higher Education Authorities (HEA) Human Capital Initiative Pillar 3

Keywords: Engineering education, Virtual/Augmented reality, eLearning, transversal skills

1. Introduction

This paper describes the rationale and appetite institutionally, regionally and nationally for a new way of designing, developing and delivering engineering education in Ireland, drawing on expertise and experience internationally in the field of engineering education reform. There is an increasing argument that engineering education in Ireland is risking being a barrier to economic growth in the country. Universities are coming under increasing pressure to re-invent the way that engineering is taught to students, with the ultimate aim of producing engineering graduates that are capable of meeting the skills needs of the countries industries now and into the future. A recent report by Engineers Ireland, the representative body for engineering professionals in Ireland has outlined that 91% of engineering employers identified skills shortages as a significant barrier to growth within the Industry [1]. The skills shortages identified were not only in the technical areas of engineering, but also in the areas of transversal skills. Engineering employers struggle to fill roles in the mechanical and manufacturing engineering professions, which has an annual growth rate of 16.6% [1].

Therefore, Higher Education Institutes (HEIs) in Ireland are required to become more agile and innovative in the design, development, delivery and continuous improvement of engineering education. Our REEdI initiative is to provide an alternative option for engineering education and indeed, other undergraduate disciplines across higher education in Ireland. The ultimate aim is for any HEI to be able to adopt our approach utilizing the roadmap and framework developed and tested through REEdI.

2. Engineering education frameworks – The Global context

The pressure on Universities to produce engineering graduates capable of meeting the needs of Industry is not solely an Irish problem. Many institutions across the globe have developed different frameworks and initiatives to tackle the issue. Demands placed on Universities in relation to engineering education output does not stem solely from Industry/employers. The changing demands come from a variety of different cohorts: students, society, and science [2].

Some of the most reported innovators in global engineering education and the methodologies/frameworks they have developed and proposed to meet these demands are presented here:

- Massachusetts Institute of Technology (MIT) conceived and have spear-headed the CDIO initiative (**C**onceive-**D**esign-**I**mplement-**O**perate), which is a framework that enables the systematic development of engineering programmes, with 12 standards available to guide engineering programme development [http://www.cdio.org/about]. CDIO promotes course/modular learning and project learning combined, aimed to both ensure technical skills and professional engineering skills are embedded in engineering programmes. [3]. Currently there are >120 institutes involved in the CDIO initiative globally.
- University College London (UCL) has created and driven the Integrated Engineering Program (IEP) framework [4]. This is a cross disciplinary initiative across all engineering disciplines. All programmes follow a core structure across all disciplines. Students in UCL from different engineering disciplines come together at different stages throughout the programme to work on multidisciplinary project teams. The IEP utilizes Problem Based Learning (PBL) as part of the multidisciplinary experience and this is embedded throughout engineering courses at UCL [4].

- Charles Sturt University (CSU) is a multi-campus regional University in New South Wales Australia combining on-campus project-based learning with online learning and off-campus work-based learning. CSU are seen as an emerging leader in engineering education on a global scale [5]. The CSU engineering programme was particuarlly interesting in the REEdI context, as MTU is also a regional university.

3. The Irish context

When looking at engineering education in the Irish Context, it is important to understand that manufacturing is a central pillar of Irish economy and is a high productivity growth sector [7]. According to Mulligan (2019), Ireland's manufacturing sector is facing "significant" skills shortages in engineering disciplines. Our education programmes need to be more accessible, flexible, open to diverse learner cohorts, applied and tangible. Irish HEIs therefore need to respond in order to generate the Human Capital required for our manufacturing sector. Further to undergraduate engineering skills needs, the manufatcuring industry requires flexible means for continuous professional development (CPD) for staff [7]. Irish manufacturing employers require the following transversal skills of graduates to supplement required improvements in technical engineering knowledge: creativity, innovation, entrepreneurship, critical & analytical thinking, team work, communication and business acumen [9, 10, 11]. Therefore, the manufacturing sector in Ireland was selected to pilot the REEdI framework.

4. The REEdI framework – Methodology

The pilot programme selected is a BEng/MEng in manufacturing engineering, with Industry-led content designed and developed throughout the programme.

We have designed our REEdI engineering programme to be comprised of core elements surrounded by innovations in pedagogy, technology and the REEdI Ways of Thinking (REEdI-WoTs), embedding excellence into engineering programme design.

The REEdI-WoTs are a cognitive approach which provide a framework for students on how to think and how to learn more effectively by themselves, so that they are better equipped with the transversal skills, personal effectiveness, academic and workplace competencies required once they graduate.

The following is an outline of our framework:

1. **Significant Work-Based Learning (WBL):** pedagogically based on project-centric, experiential learning. The student applies learnings from eLearning micro-modules from their learning map and performance planning, review and self-reflection to ensure the competencies WBL are met and demonstrated. A recent review by Rouvrais, S *et al*., 2017 [6] recommended the CDIO model be broadened to include more formal integrated work-based placement/learning (WBP/L) elements and frameworks. Again, the WBP/L model is particularly relevant to our work in REEdI – designing a framework in order to support students, industry partners/employers and HEIs. This activity will ensure that employers' requirements are met, that student competency, learning and professional experience is optimized, and a robust partnership is created between HEIs and industry in terms of WBP/L models.

2. **Student Performance Planning and Review:** building self-awareness and planning skills for student engineers. The purpose of this pillar is for the student (along with a core support team) to take ownership of their learning journey. This core part of our programme design enables the student to gain valuable time management skills, ability to identify individual contributions made to group projects, identify successes and spot opportunities for improvement.
3. **eLearning – Flexible and Personalised:** The REEdI e-Platform will support a flipped classroom approach. This platform will act as the students' learning map from course commencement to graduation as a professional engineer. Although students are free to complete any elements of the learning map as they wish, a number of minimum requirements will be stipulated.
4. **Bracketing the Pedagogy:** REEdI will embed emerging technologies including VR/AR simulations into undergraduate programmes. The simulations will be developed with the ability to track a student's progress as they progress through the scenarios, providing a detailed report of tasks completed successfully and those that were not. Benefits of the application of this technology include, but not limited to: practice of real world skills with rich feedback in a safe environment, mastery of a technique, behavior or method through guided rehearsals again and again, or as many times as is needed, an emotional connection of the learning event to the learner because of the realistic and immersive nature of the environment, the learning to be embedded in the proper context by providing a simulation of the actual environment and individualized instruction as a person progresses through the simulation at his/her own pace.

5. Conclusion

Our approach offers an agile and innovative learning framework for engineering education, providing flexible and tailored options to diverse learner cohorts. We will combine an innovative model of content delivery with new immersive technologies to deliver a transformative programme for the next generation of engineers. Immersive technologies such as eLearning and VR/AR are transforming how we learn with digital content. These disruptive technologies impact on academia and indeed many industries, including manufacturing. Applying these technologies to the development of a cutting-edge programme of engineering pedagogy has the potential to impact and transform engineering education across the Higher Education sector in Ireland.

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The Application of 3D Data Visualization in Education and Research

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Abstract

Visualizing scientific data can be an invaluable aid to the researcher. Each user interacts differently with the presented data. When visualizing certain results, it is very important to take into account the human factor.
The evolution of data representation can be traced back centuries, starting with Da Vinci's drawings, his students' drawings, and so on. With the development of visualization, different branches of geometry develop. Over the last 40 years, differential and descriptive geometry have made great progress in this area. Discoveries were made that radically changed the mathematical description of curves and surfaces.
In the 1980s, the visualization of three-dimensional objects was done with the help of mathematical models. With the development of computers came the need for realism. For this reason, several different disciplines such as mathematics, physics, chemistry and computer science had to be combined and a new discipline appeared – computer graphics.
It is inherently interdisciplinary. The share of computer science is very large, but without physics we will never be able to achieve realism and images close to the real ones. The initial process of creating complex three-dimensional primitives is called modeling. It can be done in two ways: by mathematical description or artificially – photogrammetry or laser scanning. The next step is to apply a texture or material. We "put" a shell on our three-dimensional object. It has certain physical properties such as transparency, light absorption coefficient, diffusion coefficient, etc. Each of these elements determines the color of the primitive, whether or not it will cast a shadow in the world coordinate system.
The purpose of this report is to present our experience in teaching computer graphics at both universities – University of Library Studies and Information Technologies and South-West University "Neofit Rilski".
The general concept we use in this article is the application of 3D models in research and the ways of presenting them in an accessible and realistic way. We will briefly present two surveys and their results on the place of computer graphics in education. The survey was conducted among students studying computer science and social sciences. The main conclusion is that students are open to the application of three-dimensional technologies in education.
In the present study, we will show different ways and models for creating and visualizing 3D objects and complex primitives. A short description will be presented to create a complex primitive and ways to visualize it. We will give a brief overview of the main disciplines related to computer graphics, which are taught at both universities. We will make a brief analysis of the advantages and disadvantages.

Keywords: 3D Data Visualization, 3D model, education

1. Introduction

The process of creating realistic images can be represented as the implementation of three consecutive and interrelated stages, called: modeling, rendering (model transformation) and rendering (visualization).

An interactive graphics software system has three components [1], [4]:

- the model that is created, processed and visualized [1], [2], [3];
- the application program, which takes care of its creation, the performance of operations on it, as well as its organization in a form convenient for visualization [2], [4];
- graphics system – provides a set of visualization tools that the application program uses to graphically display data from this application model. The graphics system is the part of the software that is most closely related to the technical devices and that actually performs the visualization after the application program has specified exactly what should be displayed [5].

It is natural for applications to be developed much more often than basic graphics systems [3], [5]. Each application program reflects the specifics of the respective application area, and even the individual programs in the same area can be very different. Despite the huge differences, each application graphics program performs three main activities that have a certain significance [5]:

- modeling;
- description of the model for the graphics system;
- interactive work [8].

The model is an object of different nature, able to replace another object, thanks to a certain correspondence between the properties of objects.

Modeling is the process of building a model and studying the correspondence between the model and the source object in order to obtain new information about it [4], [6], [7].

2. Methodology

In the present study, we consider the creation, processing, and visualization of vector objects (realistic images), also known as primitives. The initial process of creating complex three-dimensional primitives is called modeling. It can be done in two ways: by mathematical description or artificially – by photogrammetry or laser scanning. Modeling is the process of creating or using this mathematical description, also known as a geometric model. The geometric model, in turn, is a geometric description of the object in the form of dimensions, contours, surfaces, etc. similar, given with real numbers – a mathematical description of the 3D model [10].

The next step, which is part of modeling, is to apply a texture or material. We “put” a shell on our three-dimensional object [11]. It has certain physical properties such as transparency, light absorption coefficient, diffusion coefficient, etc. Each of these elements determines the color of the primitive – whether or not to cast a shadow in the World Coordinate System (WCS). The WCS describes all objects relative to a single center and uses the right-hand rule. All created objects unite together and form WCS [5].

She is always right-wing. This is accepted as a standard. In order to be able to “see” in this darkness, it is necessary to add lighting fixtures. They can be diffused or focal light. The different ways of placing or brightness of the light are evaluated [12].

The next stage is the model transformation itself, called rendering. This is the process by which a digital image is generated from a model in computer graphics. In other words, rendering has the task of recreating a three-dimensional mathematical model on a flat two-dimensional surface using various mathematical algorithms [13], [14] (Fig. 1).

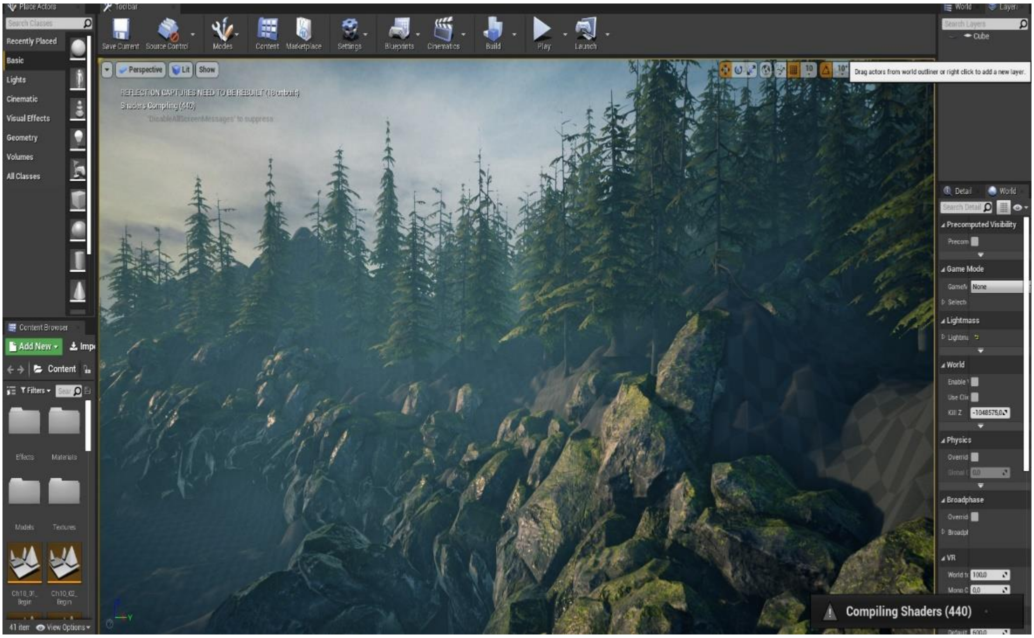

Fig. 1. A woodland model created in Unreal Engine

3. Result and Discussion

With the development of 3D technologies, virtual walks have become an important factor in learning about cultural and historical heritage. They provide a realistic way to more fully present architectural sites, museums and galleries in the digital space. The 3D representation of the models must include the necessary information so that the users get the same knowledge as when actually visiting the site.

Training in the field of CHH is a complex and multifaceted process, requiring interdisciplinary approaches to achieve in-depth knowledge of existing knowledge and at the same time build capacity for discovery, research, storage and promotion of new discoveries. To examine how open young people are to new technologies and whether they want new teaching methods to be included in their lectures, we conducted two surveys [12], [14]:

- Among students studying computer science and
- Among students studying the humanities.

The purpose of the empirical research is to establish, analyze and summarize the extent to which students are familiar with the application of 3D technologies in lecture courses at the university, as well as their attitude to the problems of preserving the cultural and historical heritage of Bulgaria.

Sub-objectives of the study are to examine [12], [15]:

1. The level of knowledge and awareness of the problem of what is mixed reality.
2. The attitude to the problem of the application of mixed reality in the training and promotion of CIN.

In the framework of empirical research, the goal is achieved by solving the following research tasks:

1. To establish the degree of cold knowledge of issues related to the nature of 3D technologies and their application in education;
2. To establish and analyze the level of competence of students regarding the application of mixed reality promotion of CHH;
3. To establish the effectiveness of education and the application of 3D technologies in direction 3.5 “Social Communications and Information Sciences” and the need to introduce this type of education in universities that do not offer it;
4. To establish the attitude and desire of the surveyed students to be included in projects using mixed reality in the training and promotion of CHH.

The two studies were conducted within the project “Application of mixed reality in the education and promotion of cultural and historical heritage in the university information environment” led by Prof. Irena Peteva [12].

Today, 3D modeling is used even more widely from medicine to engineering applications. It and the visualization made it possible to improve the technology, especially together with the animations, the use of these models is more common than before. Early computer graphics were vector graphics made up of thin lines, while graphics today are based on pixels.

We can summarize that the search for opportunities to expand access to cultural content through digitalization and the creation of 3D models, helps to overcome the problems associated with social exclusion, digital divide, as well as to facilitate access to cultural heritage throughout the territory of the Republic of Bulgaria [12], [16].

The trend was investigated through a survey. We tracked through pre-set indicators the change in the number of users interested in new 3D technologies and the extent to which students are interested in them. Innovative technologies and equipment open new opportunities for students and provide them with incomparable competitive advantages, additional knowledge and skills for their professional qualification.

The results of the survey were more than interesting [17]:

- Of interest are the answers to the question “Do you think that studying disciplines related to 3D technologies would enrich your education?” About two thirds (66% say that this would enrich their education. to make an assessment (20%) Only 14% of the respondents answered negatively to the question;
- To the question “Do you think that computer graphics training is at the required level?” 91 answered in the affirmative, 94 in the negative and 65 could not. The results show that the majority of respondents believe that computer graphics training is not at the required level and this shows that it would be good to strengthen computer graphics training;
- Of interest are the answers to the question “Should new computer graphics courses be added?” More than half (53%) indicate that new courses need to be added. However, the percentage of students who cannot make an assessment is worrying (18%);
- Also of interest are the answers to the question “Would you start a career in computer graphics?” 119 indicate that you would start a career in computer graphics. Unfortunately, there is a high percentage of students who cannot make judgments (44), which may be due to poor knowledge of computer graphics and insufficient knowledge of its capabilities.

The survey shows that computer graphics training is not at the required level. Three new disciplines have been introduced at the University of Library Science and Information Technology: Graphic design systems; 3D modeling and Development of computer games. The disciplines are elective [17]. The number of enrolled students is very large. The university management started working with some of the leading companies in the field of computer graphics Autodesk and Epic games. The companies have agreed to provide us with their products for free and currently our training is done through their software such as maya, 3Ds Max and Unreal Engine [4], [18].

Our findings show that the future lies in blended learning. The combination of traditional learning and modern digital technologies works wonders. Our negotiations with the company EON reality for the introduction of mixed reality in education are at an advanced stage. The opportunities provided by the new 3D technologies support the development of students' creativity and provide an opportunity to create complex objects and primitives [18].

Acknowledgments

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Educational Strategies

A Synoptic Approach to Science Education

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Abstract

The University of Nottingham's Natural Sciences degree programme is an interdisciplinary undergraduate science course. Its ethos is that big scientific challenges, such as climate change or curing cancer, can only be met by a holistic approach from the entire scientific community. The scientific response to the coronavirus pandemic is an example of this. The course has a synoptic module which aims to help students integrate knowledge from across different subjects. Further, the module seeks to train students in developing their research and employability skills through interdisciplinary teamwork. Despite its good intentions the module received strong negative feedback from students in 2018/19. They raised concerns regarding the amount of work involved, individuals not participating in group work, a lack of time and resources to conduct research, unclear assessment criteria, and project topics which were not relevant to current world issues. This feedback prompted an overhaul of the module's delivery. The project topics were revised and now address global environmental, economic and social sustainability issues using the UN's Sustainable Development Goals as a framework. Students are now given a choice of assessment tasks so that they can choose whether to conduct scientific research and write a journal article, plan scientific research and write a grant proposal, or write a policy paper to put scientific knowledge into practice. The students are encouraged to use online tools to help manage the project and this also enables staff to monitor engagement and give timely advice to individuals and groups. The assessment criteria were revised by mapping each assessment activity to the employment skills identified by the World Economic Forum. The revised module was implemented in 2019/20 and received positive feedback from students. Student attainment was also very good. The university is now planning to expand this strategy by creating similar provision for students on other science courses. The intention is for research-based education to enable closer integration of research and teaching.

Keywords: Interdisciplinary science, sustainable development, employability skills, research-based education, problem solving

1. Introduction

A university education seeks to achieve two things. There is the acquisition of, firstly, specialised advanced knowledge and, secondly, broader skills useful for a variety of potential career paths [1]. Ideally, the complete graduate from a science course would possess the knowledge and skills to, for example, think critically and independently, conduct research, work collaboratively and communicate effectively. The challenge is how to design undergraduate courses that enable students to realise their potential and fulfil this ideal.

Changes to UK universities since the 1990's have, arguably, made this challenge harder. Firstly, an increase in student numbers has encouraged traditional teaching approaches, such as didactic lectures, which can be upscaled to larger cohorts without increasing staff workload. Secondly, courses are divided into modules which encourages the compartmentalisation of learning [2]. In addition, there is the long-standing challenge of how to turn a raw first year student into someone who can break new ground.

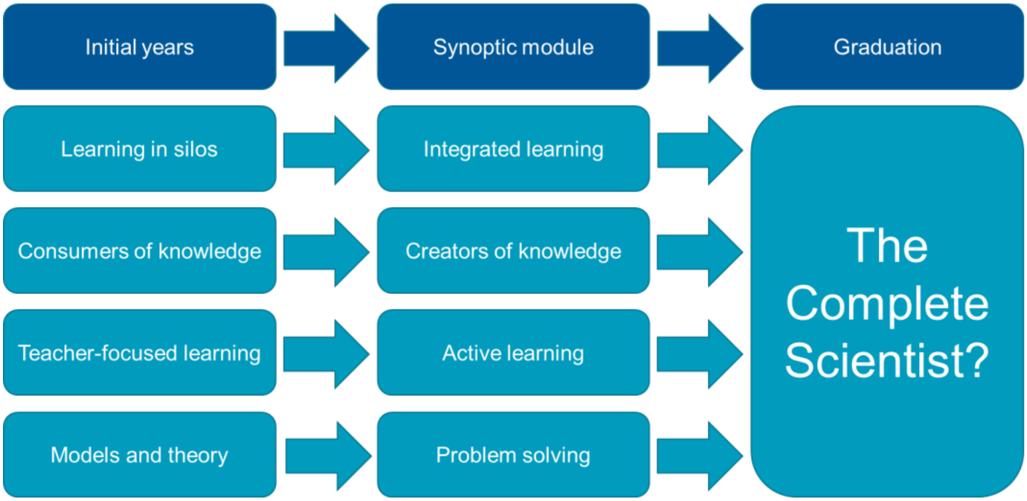

Fig. 1. A schematic diagram showing a comparison of early years of undergraduate education and the Synoptic module

In contrast to most UK programmes, students on the University of Nottingham's Natural Sciences course study multiple subjects (choosing three from Archaeology, Biology, Cancer Science, Chemistry, Earth Science, Environmental Science, Mathematics, Physics and Psychology). Despite the many different routes through the programme, students are brought together for the compulsory final year Synoptic module. This aims to be a capstone student-centred module that enables students to integrate their knowledge from different disciplines and establish new findings to solve real-world problems. However, an evaluation of the module in 2018/19 revealed strong student dissatisfaction. This unfamiliar way of working meant students were unsure what was required of them, thought the workload was unreasonable, thought collaborative group work led to unfair grading, and the science involved was mostly irrelevant. This prompted a redesign of the module for 2019/20.

2. Module design

The module consists of a sequence of graduated tasks to help students develop their competencies, as shown in Figure 2. The first task focuses on establishing skills for communicating science to a broad public audience. For the remaining tasks students work in groups, with each group working on a different topic and supported by a staff member with relevant expertise. The second task focuses on developing critical thinking and synthesising information from different disciplines. The third task has the greatest weighting and time allocation. Finally, each individual completes a task to help them reflect on the experience and evaluate their learning. The implementation of the design raises several questions which need careful consideration.

Fig 2. A schematic diagram of the module design showing timings, tasks and skills development

2.1 What should the project topics be?

In 2018/19 there was negative feedback regarding the lack of variety and relevance of the topics to current world issues. For 2019/20 some topics were changed, and their relevance established through the UN's Sustainable Development Goals framework which encompasses economic, social and environmental issues [3]. Although science can contribute to all SDGs our projects broadly fall in to three areas. Firstly, there are projects connected with SDG 3 (Good health and well-being) advancing understanding of medical conditions such as diabetes and mental health. Secondly, there are projects connected with SDG 7 (Affordable and clean energy) investigating renewable energy sources for homes, industry and transport both in developed and developing countries.

Thirdly, there are projects connected with environmental issues (SDGs 11-15) such as pollution, geodiversity and environmental management. The variety of projects ensures we cater for students with different scientific backgrounds and titles are broad, e.g., "Clean energy", to enable interdisciplinary groups to identify a niche area where all participants can contribute.

2.2 What should be the role of the project expert?

The module aims for knowledge exchange between researchers and students to be a two-way process. While the researcher passes on their expertise to the students, an interdisciplinary team might identify connections between subjects outside a researcher's specialised field, or they can complement the researcher's theoretical work by identifying applications and implications for policy. Staff participation is helped by the course having high entry standards, increasing the potential for high quality outcomes.

Staff are deliberately titled as "expert" rather than "supervisor" because their role is to share specialist knowledge, rather than the week-to-week training and supervision which is centrally provided by the module leader. Despite this, finding staff volunteers is challenging and can limit the variety of project topics.

2.3 How to facilitate student research projects?

In 2018/19 every group was expected to produce a journal-style research paper.

However, the intrinsic constraints of time and money limited the conduct of primary research activities. Some groups were limited to secondary research activities, such as systematic reviews, or mathematical modelling. For 2019/20, it was recognised that research skills (such as sound methodology, problem solving, advanced knowledge, understanding of complex systems) can be equally assessed by other outputs such as a grant proposal or a policy document. By choosing the submission format most appropriate to their circumstances, students gain greater freedom for the direction and scope of their research. Regardless of the submission format, all students are marked against the same marking criteria to ensure fairness.

2.4 How to make the marking fair and transparent?

Writing assessment criteria for an interdisciplinary context which can be implemented consistently by staff from different disciplines is challenging. In 2019/20 the assessment criteria were re-written based on the World Economic Forum’s list of core work-related skills [4]. The aim was to shift the emphasis to competencies that could be demonstrated in different contexts and use an independent source to increase the students’ perception of validity. After removing irrelevant skills (e.g., physical abilities) and skills which could not be objectively measured (e.g., active listening), the remaining WEF skills were mapped against each of the module’s assessment tasks and grade descriptors were written for each. As a further step to enhance fairness each assessment was double marked, including one individual marking across the different projects to ensure consistency.

2.5 How to assign marks to individual students?

In 2018/19 some students perceived that awarding the same grade to all group members, regardless of individual contributions, was unfair. Two changes were made for 2019/20. The first was for each group to log key decisions and achievements using a digital notebook. This provided an objective means through which staff could monitor progress and participation. The second was to include an individual reflective task which highlighted the skills acquired and provided an opportunity to acknowledge their peers’ contributions. Staff could use the log and reflective task to objectively reward or penalise individual students.

3. Module evaluation

The delivery and evaluation of the module in 2019/20 was partly disrupted by the suspension of face-to-face teaching during the coronavirus pandemic. Student feedback was obtained via an online survey with 10 responses from a cohort of 38 students. From the beginning of the module, each group used Microsoft Teams to facilitate group discussions and document sharing. Student feedback regarding Teams was very positive: “absolutely brilliant”, “massively helpful”, “incredibly useful”, “meetings worked well and were functional”; and meant lockdowns had little impact on student progress.

Student feedback on the new marking criteria was also positive with many students indicating it was “very clear”. One student indicated they would have like more feedback and another said they received opposing comments from the two markers. Student feedback on workload was mixed. Several students commented it was “fair”, “reasonable” or “appropriate” while others said “it was a lot of hard work but fair” or “more work” than other modules. When asked about the choice of projects, one student reported they “really enjoyed the topic” and another said was a “good theme and relevant to sustainability”, while others reported they “would have preferred more interesting topics” or it was “so vague it didn’t seem cutting-edge”.

4. Conclusion

Delivering an interdisciplinary research module is expected to be challenging. Its ethos is new to both students and staff more familiar with modules focussed on knowledge rather than skills. However, an active learning approach that integrates knowledge from different fields to solve problems is essential for training the next generation of scientists if we are to meet global healthcare and environmental challenges [5]. In this respect, the current module design does not fully untap the potential for undergraduate students to be integrated into the research community. More ambitious concepts like vertically integrated projects would enable a broader spectrum of students to participate, tackling a wider variety of projects, to cover more of the UN's sustainable development goals [6]. The current module design also does not enable practical and specialised laboratory or field skills to be developed. However, it does provide initial exposure to the broader research process: the identification of a problem, surveying the literature, application of knowledge, and communication of science. It could be argued that all these elements should be given greater weighting in an undergraduate programme. Our plan is to introduce a similar module earlier in the course so that these skills can be developed over a longer time frame. The current module, however, provides a blueprint for how students can get a flavour of interdisciplinary research while in the controlled, safe environment of a single undergraduate module.

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Comparison of Two Different Educational Approaches to the Experimental Teaching of a Luminometric-based Analytical Method

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Abstract

In spite of the increasing presence of luminometric-based analytical methods, their application to the laboratory training of science undergraduate students is almost anecdotic. In the last years, we have implemented at the University of Malaga a new laboratory experiment devoted to illustrate the principles and applications of bioluminescence to undergraduate chemistry and biochemistry students. With the final objective of detecting microbial contaminations in water samples, students quantify ATP by means of the luciferase-catalyzed reaction. We have applied two different educational approaches to carry out this lab experiment: 1) By using a short protocol, carried out in a single laboratory session, in which students follow a "recipe", and 2) In a Problem Based Learning (PBL) context, as a full practical project developed by students during a 7 weeks period.

Our results show that those two experimental approaches may be useful to teach the principles and applications of bioluminescence, helping to develop some foundational scientific competencies that characterize the Process of Science and Quantitative Reasoning core competencies. They include evaluation and use of scientific information, critical thinking, performance of basic calculations, drawing of graphs and data presentation and interpretation. Nevertheless, the PBL learning objectives are much more ambitious, promoting the development of a series of additional skills. They include those learning objectives related to the simulation of a real-world problem, which requires the students to develop skills related to the treatment of information or the design and practical implementation of a protocol, with a high level of autonomy and personal initiative. Working in groups helped the PBL students to cultivate the Communication and Collaboration core competency, by interacting and communicating the research results to biology experts and to the general public. Many of these competencies have an intrinsic relationship with the future development of students as future teaching, technical or scientific professionals.

Keywords: PBL, Luminometry, Undergraduate students, Laboratory experiment, Educational strategies

1. Introduction

There is a lack in the formation of our chemistry and biochemistry undergraduate students, caused by the shortage of practical laboratory experiences to teach the basis and applications of luminometry, a technique that is increasingly used in many experimental and health sciences laboratories. Bioluminescence is a phenomenon observed in some animals, such as fireflies, which emit light for the recognition and attraction of their mates. This light is the result of a chemical reaction catalysed by the enzyme luciferase (EC 1.13.12.7), which requires the presence of the luciferin substrate and ATP, which can be quantified by means of this enzymatic reaction (Fig. 1) [1].

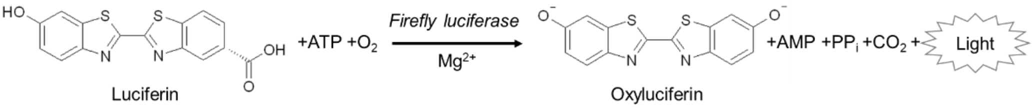

Fig. 1. Luciferase-catalysed enzymatic reaction

The correlation of ATP concentration and bacteria content is the basis for the development of luciferase-based rapid methods to detect microbial contamination in drinking or stored water, skipping the long delays required by the traditional microbiological methods [2]. Throughout the two last academic years, we have implemented at the University of Malaga (Spain) a new laboratory experiment focused to illustrate the use of bioluminescence in analytical chemistry to undergraduate chemistry and biochemistry students. Based on the luminometric measurement of ATP for the detection of bacterial contamination in water, it has been implemented in two different formats, a short protocol and a complete PBL experience.

2. Brief description of the two versions of the laboratory experiment

2.1 Short protocol

Performed by twenty 4th year chemistry students in the 2018-19 course, and by sixty 3rd year biochemistry students in the 2019-20 course, within the “Applied Biochemistry” subject. The characteristics of those groups of students conditioned the design of the protocol, so that it could fit into a short laboratory session (1-2 hours), with an estimated dedication of no more than two homework hours for the students.

After an introductory lecture in which the teacher summarized some key principles and applications of luminometry, students followed the supplied protocol to measure ATP concentrations by using luciferase. They got results to draw a calibration curve and analysed water samples from different sources. They presented their results in a final report, discussing the applicability of this method to the detection of microbial contaminations in tap water, and basing on bibliography to suggest some improvements to the protocol they had followed.

2.2 PBL

This experience was completed in the 2019-20 course by the ten-4th year biochemistry/biotechnology students that were enrolled in the subject “Advanced Instrumental Techniques”. Under the guidance of the responsible teacher in the role of the facilitator, those students carried out independently the activities detailed below, developed over a period of 7-8 weeks.

Students, worked in groups of 5, playing a role of “corporations” that must offer a solution for a given technical issue that has to be resolved throughout the course. A meaningful driving question would guide their work: To implement a rapid method to detect microbial contaminations in tap water, at an affordable cost allowing this type of routine testing. In this question, the main requirements related to the desired analytical method were presented: quickness (results must be available in a few hours), affordability (a high number of water samples should be routinely assayed) and sensibility (sample volumes should be restricted to a few millilitres). Following these guidelines, students performed a complete bibliographic search, leading to the selection of “chemical” methods that do not require several days for their completion, unlike traditional microbiological assays. Once the potential solutions to the problem were identified (mainly methods based on the enzymatic measurement of ATP), students carried out the necessary steps for their subsequent practical implementation. They included the identification of the required reagents and instrumentation, the design and the execution of the experimental protocols leading to the measurement of ATP by means of the luciferase reaction. Post-lab activities included the drafting of both, a final report of scientific journal-quality, and an executive summary that could be understood by non-experts. Finally, each group presented in class the results obtained in a session that replicated a work corporate meeting.

3. Student’s results

3.1 Assessment tests comparison

A first estimation of the students’ progress was made by means of an assessment test composed by the following eight short open-questions:

1. What do fluorescence and luminescence have in common?
2. How are they different?
3. What do a fluorimeter and a luminometer have in common?
4. How are they different?
5. Could you indicate the substrates, effectors, products of the luciferase-catalysed reaction?
6. How are luciferases classified according to their kinetics?
7. What applications of luminometry do you remember?
8. How would you measure the presence of bacterial contamination in a sample?

This test was administered at the beginning of the introductory lecture (pretest) and repeated after students delivered their full reports (posttest). As observed in Figure 2, after performing this laboratory experience, either the PBL or the short protocol, an improvement in the students’ knowledge about bioluminescence and the principles and applications of luminometry was achieved for the three groups. Most students could identify chemiluminescence as a light-emitting phenomenon, and distinguish it from fluorescence, describing the characteristics of the corresponding instrumentation.

Although initially most of the students were not able to recall the components, the kinetic characteristics and the applications of the luciferase-catalysed reaction, their knowledge about these issues increased after they carried out this laboratory experience. However, in spite of the achievement of new knowledge by all the three groups of students, those performing the PBL reached the highest level of performance on all the questions.

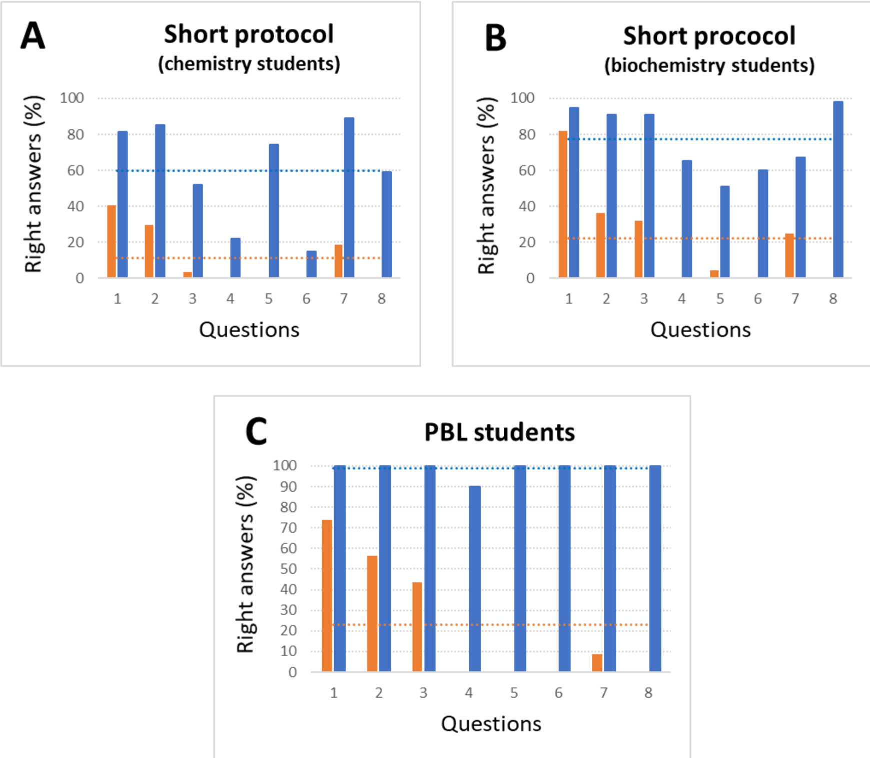

Fig. 2. Student's outcome evaluation. Percentages of students who answered correctly the pretest (orange bars) and the posttest (blue bars) questions are shown. **A**. 4th year chemistry students performing the short protocol (20 students, 2018-19 course, subject "Applied Biochemistry"). **B**. 3rd year biochemistry students performing the short protocol (60 students, 2019-20 course, subject "Applied Biochemistry"). **C**. 4th year biochemistry/biotechnology students performing the PBL (10 students, 2019-20 course, subject "Advanced Instrumental Techniques"). Pretest full average is shown as an orange dotted line and posttest full average as a dotted blue line.

3.2 Students' achievement of the learning objectives

The two versions of the laboratory experiment share a number of learning objectives that are aligned with some of the core competencies included in the *Bioskills Guide*, a set of measurable learning outcomes developed and validated by over 600 college biology educators and based on the *Vision and Change* core curricular recommendations for undergraduate biology education [3]. In this regard, some foundational scientific competencies that characterize the *Process of Science*, such as evaluation and use of scientific information, critical thinking or data interpretation, are related to the following learning goals, successfully achieved by most of the students after performing this experiment:

- To search, apply and reference scientific literature
- To use a luminometer and apply luminometry to a real-world problem
- To know the principles and applications of bioluminescence

The students setting of a calibration curve, the establishment of the application range of a method and the determination of the ATP concentration of a sample, were related with the core competency *Quantitative Reasoning*, including the performance of basic calculations, drawing of graphs and data presentation. In this regard, although most students performed the protocol correctly and could draw valid calibration curves, some of those performing the short protocol made mistakes when calculating the concentration of the problem samples, which did not occur with those who followed the PBL approach.

As expected, the learning goals for the PBL approach included those from the short protocol, and others derived from the more active role played by students in their learning process, making them undertake authentic real-world tasks, similar to those that they would find in their professional future. Thus, many of these students faced for the first-time common issues for a professional, such as the acquisition of reagents and materials, the assessment of the necessary instruments and equipment, the adaptation and scaling of experimental protocols, or the analysis of costs and operational feasibility, among others. In addition, those students performing the PBL presented their results to a diverse audience, wrote a scientific journal-quality report and summarized their conclusions in an "executive report" that could be understood by non-experts. Those learning goals are related to the *Communication and Collaboration* core competency, which incorporates competencies for interacting and communicating the research results to biology experts and the general public.

4. Final conclusion

The detection of microbial contamination by measuring ATP concentration with luciferase is a useful tool to teach the use of bioluminescence to science undergraduate students. Either as a short protocol carried out in a single laboratory session, or as a long PBL experience, the students' achievement of the learning goals was very satisfactory. Students who followed the PBL approach could, in addition, adopt a series of additional transversal skills that could be useful in their future professional careers.

Between these two extreme examples of the protocol, in terms of students' dedication, a whole range of intermediate options could be used by educators to suit their course programming and fulfill the learning objectives to be achieved by their students by means of this laboratory experiment.

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Fostering Student's Engagement in the Digital World: Technology – A Boon or a Barrier?

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Abstract

School education is stepping into a new phase worldwide, with the more use of technology within the classroom. It's a theme of debate between instructors and technology fostering student's engagement in active learning. This paper presents a comparative study of student's engagement versus the instructors' experience of using technology, especially within Science education. Science education promotes more on hands-on experience for better engagement but interesting to work out how technology overcome these barriers and supply similar results. In Science lessons, students are introduced to different tools to maximise participation. These tools not only help them to gain real-life experience but also make them more confident learners. Alongside scientific skills, it also helps them to develop IT skills, necessary in this digital era for lifelong learning. The results of each lesson are evaluated based on how confident instructors and students are with technology, student's involvement, clearing misconceptions at an early stage, and opportunities to develop real-life skills.

Keywords: technology, digital world, student engagement, secondary science education

1. Introduction: Learning environment/Student engagement and technology

Fostering student's engagement through technology is a crucial area of interest, within the secondary educational community in person and remotely [7]. Engagement does not occur in a vacuum, thus impacted and influenced by various factors when using technology. Students' and instructors' access to technology is the biggest issue due to its nature and complexity. Recognising the role technology plays now in education and forever, and the potential it has to involve students, this paper shares experiences of instructors, and the overall impact of technology on their professional development. A survey was conducted among Science teachers to share their real-life experience, confidence level, how they are using technology to clear misconceptions, students' involvement, and any possible ways to develop life-long skills. The aim of every instructor is to make students' successful global learners. This should have an accountability outcome unto itself.

Technology is not simply using computers, it is much more beyond that includes learning tools, audio-visual resources, and diverse forms of communication necessary in all disciplines. Technology provides network connections between subjects, allows learning from and with each other, within the school community and globally. In the past few years, the Science curriculum has focused on the mastery of individual disciplines.

This has now changed to an interdisciplinary approach, which could be achievable with the enhanced use of technology. In the real-world, student engagement is not only limited to core knowledge and understanding, it is more directed towards engaging ways of learning through quality instruction. Intrinsic motivation is at its best when students are fully engaged and actively participating. A need for a change in pedagogy is clear, but the ways to implement the technology are still in the early stages of development.

Various authors have suggested that this change is uncomfortable at first glance, due to the challenges involved in controlling process and content. Further, it is also suggested that this new change allows ambiguity, arises many unfold stories and questions instructor's freedom of speech and expertise. However, on the positive front, this change opens doors for instructors and students to success and prosperity. A deeper transformation is required within secondary schools across the globe to foster student's engagement in this digital world.

2. Research findings

Research shows that various measures have been implemented to see how many students are involved in active learning. But these measures mainly focused on quantitative data such as assessment scores, attendance, behavioural points, pass rate and opting for higher education [14]. The outcome of these measures has been analysed at a later stage. In real sense, instructors are unable to meet the expectation of the students in this fast pace changing world, thus results in reducing higher education and future opportunities [3]. In lieu of that, researchers start focused on another way of measuring engagement quantitatively and qualitatively that can be analysed instantly, which helps to turn disengaged learners to engage learners in no time. Present century needs collaborative critical thinkers, creative and courageous innovators, and true lifelong learners [10]. Today's learners consistently looking for opportunities that allow them to explore and to find solutions and answers for themselves [15]. Embedding interactive technology could bring significant change in teaching and learning [11]. A culture of learning is a need of an hour when teachers and students are learning simultaneously, focussing on teaching, learning and engagement before achievement.

Dunleavy and Milton, 2009 [4] added that, exposure to digital technologies help to bridge student's learning experience in and outside. In contrary to that, (Oblinger and Oblinger, 2005) [15] and (Barnes, Marateo and Ferris, 2007a) [1] stated that the generation may lack information literacy skills and have weak critical thinking skills due to more dependency and frequent use of such electronic tools. OECD (2008) [9] also suggested that many researchers still believe that technology causes more harmed to learners than its positives, however, this view is a minority.

3. Experience

Quite interestingly, after reading interviews and surveys from various science researchers', and educators it is found that everyone is using technology in one form or another while delivering the course content, without actually measuring it quantitatively and qualitatively to know how it is affecting their practice and students' learning.

Surprisingly, it is evident that nearly 90% of students are engaged in active learning when using technology at the school level. It makes learning accessible for all students, but for instructors it's use is limited to the following:

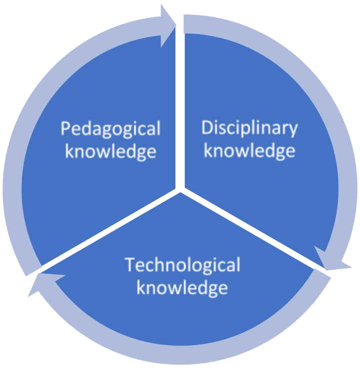

Fig. 1. PTD Model for an Interdisciplinary Approach

- To explain different concepts and make explanations more explicit and visually
- To automatically collect data
- To access student's understanding
- To allow differentiation at a broader level
- To allow deeper questioning that further helps to embed concepts more effectively
- To increase confidence and confidentiality
- To strengthen retrieval practice
- To enhance digital literacy, creativity, and IT skills

Figure 1, shows a continuous revolving model of Pedagogical, Technological, and Disciplinary knowledge, considering these as three strong pillars in an education industry now and forever. If one pillar fails it affects the others, and in turn student's engagement and progress. This further impacts on their future job opportunities. An ever-advancing technological world can be impaired. My survey suggested that students and instructors have an awareness of the technology but a lack understanding of its effective use.

Technology does help to clarify misconceptions if proper training is given to students and instructors to make best use of it. To implement this, most important step is to proper use of allocated budget in the education industry considering its lifelong benefits.

4. Final reflections

It is interesting that everyone favours the technology as a boon over the barrier, even without having a real sense of its impact on progress. The impact of the technology is yet to be measured quantitatively and qualitatively, other than the student engagement.

Thus, there is a need to measure the impact of it at every level starting from a kindergarten to the university, by students and instructors. A need to introduce continuous development programmes primarily focused on IT skills in this era of the digital generation. It is rightly said that the key to the student success is directly proportional to how schools respond to their needs and expectations. Apprenticeships and jobs directly linked to STEM developing these skills across subjects at a secondary level, now-a-days become a necessity. The self-directed learning opportunities also help to develop the skills required to become successful global citizens.

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Gamification with Active Methodologies in Mathematics Learning in Secondary Education

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Abstract

The continuous changes that society has undergone in recent years must be reflected in the classroom, which is a challenge for the educational system nowadays. Students who have been born and who are growing up in a digital age, they are digital native, they cannot adapt to traditional methodologies as usual and they demand a methodological shift more current. Active methodologies help this change, but if used one of these active methodologies in isolation, it may not be possible to take advantage of all the strengths that they offer. This proposal aims to make explicit the advantages of combining some of these active methodologies to form a mixed methodology that can cause a change in the educational paradigm in the subject of mathematics in Secondary Education. For this, we will explain how to embed methodologies such as cooperative learning, mobile learning or flipped learning within gamification strategies. Some results are offered through the observational and experiential method. This will help the student to be the protagonist by building autonomous, meaningful and more lasting learning, in addition to promoting motivation, acquisition of some skills and teamwork.

Keywords: Gamification, cooperative learning, flipped classroom, mobile learning, Secondary education, mathematics education

1. Introduction

Studies carried out by different authors indicate that the implementation in Secondary Education of a curriculum based on competence development requires the use of active methodologies [1]. This type of methodologies converts students to protagonist of their own learning by developing skills of searching, selecting, analyzing and evaluating information, building knowledge and development their participation in different activities in the classroom [2].

Within these active methodologies, can be highlighted gamification that makes use of games, favoring and motivating students learning [3]. At once, this methodology can be combined with other emerging methodologies such as flipped classroom, mobile learning, challenge-based learning that, together with cooperative learning, constitute a great opportunity to redirect teaching practice towards digital native students [4].

Furthermore, regardless of the methodological approach put into practice, we cannot ignore the impact that new technologies have generated in the different educational fields, as technologies such as virtual reality and augmented reality, they cause changes to be generated in the entire teaching-learning process [5].

Therefore, the objective of the present work is to tell the methodology used in an experience with Secondary school students combining all these techniques to create a mixed methodology. For this, a brief introduction will be made in the theoretical framework and the context and how it has been carried out will be exposed, ending with some results of questionnaires answered by the students about it.

2. Theorical framework and research methodology

Educational game platforms adapted to the educational environment improve the teaching-learning process, students enjoy an immersive experience, furthermore they are very versatile and they are based on motivation [6]. These types of platforms form a good binomial with:

- Cooperative learning, where groups are made up in a heterogeneous way and consensus between components and group work is crucial to overcome the proposed challenge (challenge-based learning) [7]).
- Flipped classrooom, where the contents are studied at home through videos and practiced in the classroom by carrying out activities and dynamics [8]. If these videos are in small learning capsules (using microlearning techniques), knowledge is acquired very quickly, there is a greater retention of knowledges by the students and the results are always very good [9].
- On the other hand, in order to the gamification of learning, didactic materials must be transformed, adapting them to the forms of expression of today's digital society and basing them on the logic of games [10]. Specifically, mobile learning presents great possibilities such as personalized, permanent and meaningful learning, available to all students; greater accessibility and usability; possibility of individual and group tasks, detection of learning difficulties and increased participation [11]
- Augmented reality and virtual reality in combination with mobile learning allows us to complete, amplify, enrich by adding layers of additional digital information and allows us to directly or indirectly visualize objects and properties that would otherwise be very difficult to learn without these tools in subjects such as geometry [12]

This proposal is part of and fits into the Design Research Paradigm that involves a series of design and analysis cycles [13]. The experimental method will be taken as a starting point for the autonomous learning of students by discovery [14].

3. Context and experience

The experience has been developed with 30 students between 14 and 16 years old from a public institute in Málaga (Spain) with a duration of approximately one month.

First of all, ICT tools were explained and usability had been overcome, to start with the gamification techniques, students registered on the Classcraft platform creating their own avatar as seen in the Figure 1.

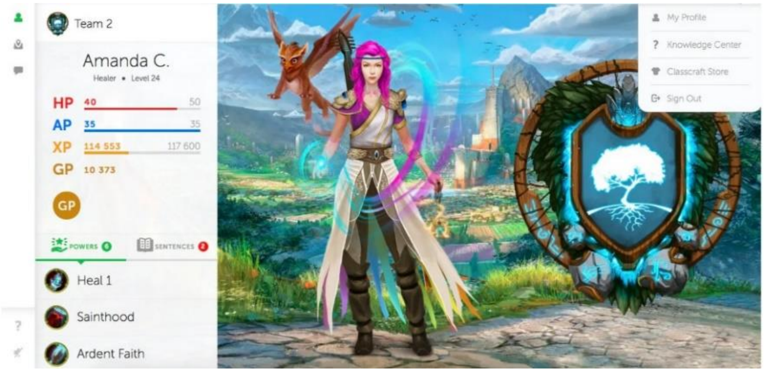

Fig. 1. Example of avatar and points and powers in Classcraft.
Source: Classscraft https://www.getapp.es/software/122443/classcraft

From this platform, the small microlearning video could be accessed every day with contents that would be worked on in class the next day, thus carrying out the flipped classroom methodologies. Consequently, the necessary time was left in the classroom to work in groups and with cooperative learning techniques, performing the different dynamics and assuming each member of the team their cooperative role.

Among these dynamics for learning geometry, some challenges (challenge-based learning) were proposed to work not only math but also gender, research and modeling in a transversal way. Modeling was carried out through mobile learning techniques with the social network Twitter in which some polyhedron was searched in real life by photographing them and retweeting them to the rest of the class. On the other hand, Archimedean solids were studied through augmented reality using the mobile device and later recreating through construction games. Virtual reality techniques were used to draw regular polyhedra and see and study some of their characteristics. All these activities resulted in awarding badges and points to the students at the conclusion of each one of them, with which they could improve their avatar or they contribute to the improvement of the virtual world of the team in the game platform. In this way, as can be seen in Figure 2, all these active methodologies are embedded within the bubble of Gamification, combined with ICT tools such as augmented and virtual reality.

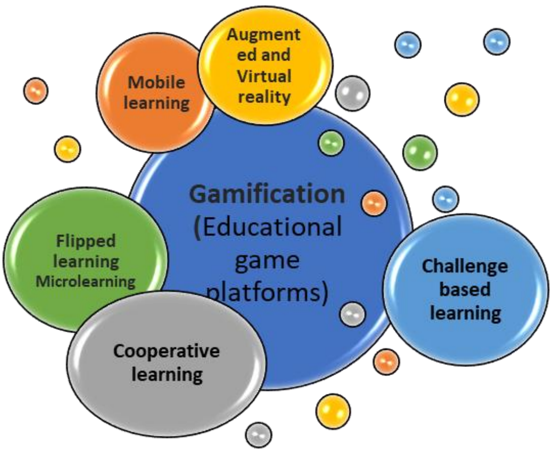

Fig. 2. Scheme of the different active methodologies used in combination with ICT tools. Own source.

4. Results and conclusion

The results of a questionnaire made to the students are shown on a 4-point Likert scale, with 4 being the level with the highest acceptance and 1 the lowest, this scale has been taken so that there is no intermediate value, it is because the students could choose in one sense or another of the answer, some questions are positive and others are negative to attract attention when answering them.

As various authors have already glimpsed in relation to the students' commitment to the proposed tasks, gamification shows a greater degree of participation and monitoring of the educational actions that are proposed [15].

In Figure 3 students express their degree of satisfaction with mobile learning techniques, most of them are totally agree with benefits and utility in math applications.

In Figure 4 most shows that, far from being a distracting element, the mobile device helps to learn math.

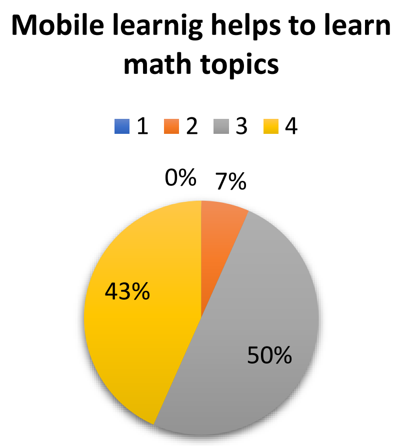

Fig. 3. Students' opinion about mobile learning. Own source.

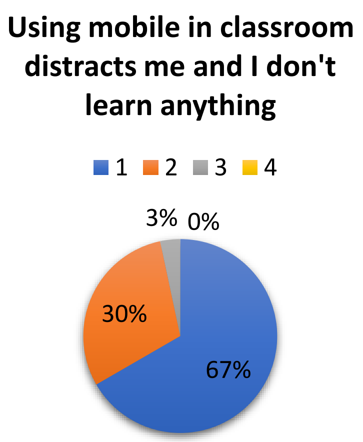

Fig. 4. Students' opinion about the mobile learning utility. Own source.

On the other hand, Figure 5 shows how most of students learn better with the flipped classroom videos and dynamics and in Figure 6 they are totally agree that they want to continue learning with this active mixed methodology in the rest of math topics.

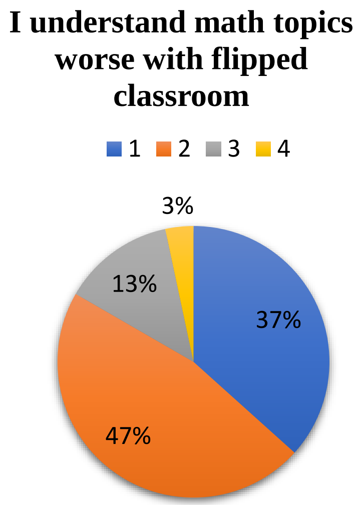

Fig. 5. Students' opinion on the use of Flipped classroom methodology combining with others. Own source.

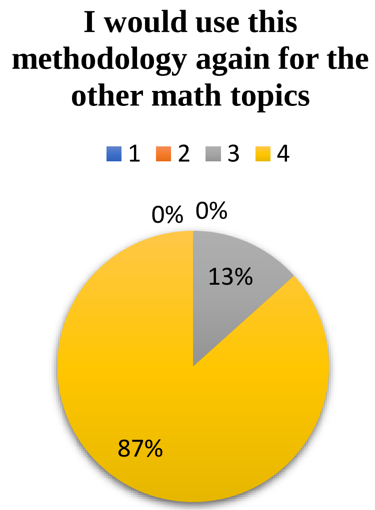

Fig. 6. Student's opinion uses of mixed active methodology in math. Own source.

Among its advantages, the students agreed with highlighting the improvement of motivation, improvement of commitment and active participation, giving rise to experiential learning and learning outcomes [16] Thanks to the use of these technologies and mixed methodology, students are able to develop an autonomous learning [17].

In conclusion, it shows that mixed active methodology is effective and students are comfortable with it while significant learning happen throughout the experience.

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Hidden in Plain Sight: Students with Disabilities in STEM Education

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Abstract

We are not experts in this field. We are learners. We are a group of a teacher education professor and three future teachers focused on STEM equity, and who have become painfully aware of the exclusion of disability from discussions on equitable STEM teaching and learning in the United States. This paper is a review of the literature experiences of learners with disabilities. We examine the underrepresentation of people with disabilities in STEM fields through the lenses of STEM, disability, and education. Our goal is to encourage other educators and researchers to broaden their equity lenses to regularly include disability, rather than viewing it as an issue siloed to special education and disability studies. We write this paper with the hope of inviting you to be co-learners and co-teachers with us in normalizing the conversation around disability.

Keywords: STEM, equity, teacher education, disability, ableism, bias

1. Introduction

The current focus on broadening participation in STEM has led to increased attention to gender and racial disparities and social justice. The STEM pipeline metaphor has been widely critiqued since it's only a "pipeline" for students who represent dominant identities.

The underrepresentation of people with disabilities in the STEM fields is a persistent problem and is under-researched relative to other inequities in STEM [2], [5], [7], [15].

What can we do to build and diversify STEM pathways? Such efforts must be built on a strong foundational body of research, but the amount of currently available research on students with disabilities in STEM is disappointing. Massive gaps in the research are made even more complex and challenging by the widespread underreporting and misreporting of disabilities among adults, making the issue even more invisible.

2. Trends in the Research on Disability, Education, & STEM

A search of the research literature for studies about STEM students and/or teachers with disabilities provided extremely limited and largely outdated results, which is why we describe this issue as either invisible or hidden in plain sight. Our difficulty in identifying helpful research was reflective of the work of Peña [13] who conducted a thorough search of peer-reviewed articles published in four of the top academic journals and found that only 1% of published work in these journals had to do with disabilities; an even more troubling statistic when considered against the trend of increasing college enrollment of students with disabilities. A smattering of articles can be found in the specialized disability/exceptional learners journals. Further, the articles that we found tended to be theoretical, medical and/or pathological in nature, and did not offer the practical information and action steps that could be utilized by practitioners.

Several of the studies we reviewed advocated for qualitative approaches to researching students with disabilities in STEM fields [3], [5], [7], [9]. The importance of quantitative research to promote equitable outcomes for students with disabilities is also recognized: “For decades, literature has documented that practitioners do not find the scholarly literature useful. As such, critical researchers must strive to make study findings accessible and useful to those who create policy and work directly with students with disabilities” [14], p. 37. We found almost no literature that was accessible to US general education practitioners.

We can examine the available statistics for enrolling students with disabilities compared to students without disabilities and the types of disabilities. The 2019 National Science Foundation report includes statistics on the types of disabilities, with census data from 2016. And while the digest has sections on the field *of degree* on women and minorities, it does not have a corresponding section on people with disabilities.

Problematizing the statistics even further, a longitudinal study [12] reported that roughly 37% of students who are identified as having a disability under IDEA in high school *do not consider themselves to have a disability by age 17*. This suggests the possible degree of underreporting by adults due to any combination of factors including social stigma, workplace constraints, or lack of accommodations.

Teachers in the United States have been struggling more than ever with the pressures of teaching, standardized testing, and decreased funding. For teachers who have a disability, those pressures and expectations are often amplified in ways their colleagues and administrators may not understand or know how to support. While de jure compliance with the Americans with Disabilities Act (ADA) is required by law in the workplace, de facto policies to support the needs of educators with disabilities may not be present. This constraint is more severe in STEM classrooms than in courses in the liberal arts due to the nature of the material being taught. Technology offers tools such as voice-to-text that support text-based content, but subjects where equations are fundamental to student learning do not yet have access to the necessary teaching tools.

Representation matters, and students with disabilities need to see themselves in STEM fields and/or in the media to be able to imagine an academic or career pathway in STEM. Even at inclusive schools, teachers may underestimate the intelligence of students with disabilities. Low expectations by educators can directly and negatively impact students’ academic performance [1], [4].

2.1 Disability

We found that when the term “disability” was used without qualifiers, it was often used erroneously as a synonym for learning disabilities. This led to damaging generalizations (some found on the websites of national organizations) that equate to “students with disabilities are struggling readers” and “students with disabilities struggle in science.”

Much of the literature focuses on the pathology of disability [5]. “if included at all, research often utilizes disability as a singular construct, but doing so obscures significant differences among students with disabilities” [14], p. 29. The US Department of Education and the Office of Civil Rights report on the number of students under the overarching category of “disability.” While disaggregating the data could be problematic in terms of student privacy rights, little in these statistics points’ providers toward any constructive actions they can take. The National Center for Special Education Research (NCSER) website [10] lists research that has been funded on math and science, but the link is to a page that only examines research in math. That document begins with the statement “Students with disabilities (SWD) lag behind their peers without disabilities at all grade levels in mathematics.” This represents a deficit-based generalization that is an approach common in the literature [5]. The funded projects listed on the site overwhelmingly represent a focus on learning disabilities.

2.2 STEM

Students with disabilities’ limited access to the science, technology, engineering and math (STEM) pipeline are evidenced by notable under-enrollment in STEM fields [7].

University faculty in STEM fields may have a deficit-based “weed out” mentality rather than a lens of inclusive accommodations. Though it may be unintentional, “teachers, instructors, and professors are frequently unable, unprepared, or otherwise ill-equipped to recognize and address the needs of students with disabilities. As a result, course content may be inaccessible” [8]. This can be countered with an asset-based view of students with disabilities that highlights their potential as researchers, more active citizens, and producers of knowledge [6].

2.3 Education

We find that in the United States, there is a general lack of knowledge about the various disabilities that students face. For many students, struggles with anxiety and depression can compound the issue. There is a systemic failure of the school system itself to properly educate teachers on how to both identify students with disabilities and to give them adequate assistance so that they can learn to their potential. Independent Learning Classrooms that support students with disabilities in becoming more self-reliant are systematically underfunded and understaffed. When teachers feel ineffective as educators, it can contribute to their sense of feeling overwhelmed, frustrated, and lead to increased burnout. Another factor that negatively impacts students with disabilities in the US is that parents of students have to opt-in to special education services. Some parents feel shame associated with the stigma of their child having a disability, and do not register their child for services. While children with special needs are entitled by law to receive accommodations, they must be enrolled in specific programs to do so. These accommodations may include additional support staff, so teachers of children with special needs who are not receiving accommodations may struggle to adequately serve the needs of each student in their classes.

3. Conclusion

Many adults understandably choose not to disclose disabilities. We ask you to help us collect data for our primary research designed to contribute to the normalization of disability with a survey that asks adults with disabilities to share their experiences.

Please distribute the survey linked here widely. If you have any questions, know of any additional resources, or are aware of any relevant studies currently underway, please feel free to email the authors and let them know.

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Interdisciplinarity: Making the Teaching-Learning Process Global and Motivating

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Abstract

The concept and the role of interdisciplinarity in the 21st century teaching-learning process should aim to overcome the rigid compartmentalization of individual syllabus and thus contribute to a more global and integrative education. The formal structure of academic curricula reflects an over-specialization of knowledge that causes an undesirable disconnection of contents between disciplines and, sometimes, within a single discipline. The interdisciplinary approach presupposes a break from more traditional teaching methods. It poses a challenge and requires a behavioural resetting of faculty and students, teacher training, the implementation of new educational policies, and a consequent redesign of syllabuses and curricula. Adequate governance policies, financial incentives, and marketing policies are essential. Though the interdisciplinary approach may seem complex due to the integration of diverse syllabus, disciplines, and individuals from both academia and community, it is a motivating and advantageous pedagogical strategy. The methodology used in this article is to review the literature on this topic, providing a theoretical/scientific framework for the account and analysis of positive experiences conducted and/or observed by the author – a teacher in higher education.

Keywords: Interdisciplinarity; Higher Education; Students; Motivation; Changes

1. The Study

The difficulty in defining the term "interdisciplinarity" is widely recognized, which often has polysemic meanings and makes it difficult to clarify and share ideas, as well as the success of some projects of this nature. For this reason, we believe it is important to base ourselves on a definition and we use one elaborated by Aboelela and coauthors [1] who, based on this same difficulty, carried out a review of the literature on the subject and conducted interviews with researchers to arrive at the construction of the following definition: "Interdisciplinary research is any study or group of studies undertaken by scholars from two or more distinct scientific disciplines. The research is based upon a conceptual model that links or integrates theoretical frameworks from those disciplines, uses study design and methodology that is not limited to any one field, and requires the use of perspectives and skills of the involved disciplines throughout multiple phases of the research process."

Interdisciplinarity is part of the sciences and science teaching area and aims to overcome disciplinarity. It is a buzzword used in the 20th century but the origin of the concept is older. Contextualizing its genesis and designations that referred to this idea as "integration" and "correlation", Klein [2] mentions that the so-called "common curriculum" already existed in the 19th century, although it was only in the 30s and 40s of the 20th centuries that we could observe its visibility. According to the author, in higher education, in the first half of the last century, in America, educational reforms emerged that followed the line of education based on problems and themes, as well as common curricula were adopted as a reaction to disciplinary over-specialization.

Although there are avant-garde examples in favor of the interdisciplinary approach, in higher education, the impact of tradition, whether in the area of compartmentalization of scientific areas, or in teaching with little or no focus on students, marked several decades and determined certain forms of management and pedagogical approaches that are now obsolete and ineffective. Despite a progressive paradigm shift, there is still often an undesirable separation of knowledge and scientific areas that occurs due to several factors inherent to individuals, for example the fear of change and various insecurities, but also due to external factors, such as heavy institutional structures and educational policies that are out of place and that hinder the interdisciplinary approach.

But in addition to the various difficulties that different educational agents face, the advantages of interdisciplinarity are also widely recognized, which in different countries and institutions of higher education are asserting themselves, achieving success and visibility. According to Weingart & Padberg [3], interdisciplinarity is recognized by several universities and academic research policymakers as a condition for the growth of research, even being considered a key factor. In this context, the research centers of universities that develop good practices, according to an integrative and no longer monodisciplinary approach, increasingly enjoy greater financial emancipation and autonomy in terms of structure and human resources, in relation to the past. Also, according to these authors, there are difficulties such as allocation of funds, verifying that: i) interdisciplinary centers can rarely compete, in an institution where the strength and power of departments prevails; ii) the logic of the supremacy of the departments overlaps that of the interdisciplinary centers, recruiting according to disciplinary and non-interdisciplinary quality criteria. Also the criterion of greater "longevity" of the departments is imposed in view of the short lifespan of the interdisciplinary centers iii) the impossibility of the interdisciplinary organizations offering courses and/or diplomas, making the members of these organizations dependent on the departments that organize disciplinary curricula in the logic of its departmental structure; iv) access to employability is organized according to disciplinary logic, with the discouragement of students wishing to choose an interdisciplinary approach, as their career opportunities are scarce and v) reinforcement of disciplinary structures in relation to the modes of accounting and evaluation of higher education systems, for some years.

As an obstacle to a successful multidisciplinary experience Lindvig & Hillersdal [4] point to the danger of an unclear definition of interdisciplinarity at the level of senior management. Referring to the case of the University of Copenhagen, in which none of the most common criteria for improving institutional interdisciplinarity has been applied, such as promoting a collaborative environment or providing incentives to the teachers, they refer to the consequences of such a stance: the consolidation of existing monodisciplinary structures, connoted as stable and safe, instead of introducing new and interdisciplinary approaches.To achieve success in interdisciplinary projects, the idea that teacher training is fundamental and a challenge for the development of core and transversal skills of higher education graduates is shared by several authors (Santos & Silva [5]; Santos, Franco, Leon, Ovigli, & Júnior [6] Santaolalla, Urosa, Martín,Verde, & Díaz [7]). In this sense, Santaolalla and co-authors describe two interdisciplinary projects carried out by teachers and teachers' educators (preservice teachers) and primary school children, in the context of interdisciplinary learning from a museum, being proposed, from that experience, an interesting and useful interdisciplinary model for teacher education. These researchers underline the need for study plans to be aligned with pedagogical methods that allow achieving 21st century skills.

With a view to greater success in terms of employability, interdisciplinarity is advised and contact with the work context is valued, as was the case with future teachers. Also, in a study on Higher education Interdisciplinary in UK, in which an Interdisciplinary Model (HIM) of best practice is proposed, students are pleased with the possibility of solving problems with their colleagues in an industrial context. It is still mentioned that skills such as teamwork, problem solving and communication are valued Power, & Handleyb [8].

The effort to make teaching attractive, whether for students and the educational community, or for the job market, through advantageous partnerships, are aspects increasingly considered by higher education institutions. Just like any institution that has a marketing platform to please stakeholders, universities also manage their budgets annually to attract new students, to maintain current students and to sell their quality brand, scoring points together industry. Regarding interdisciplinarity, L. J. & Bélanger [9] reflect on this situation, denouncing the harmful lack of clarity regarding the marketing message and/or the classification of the product. Taking stock of the path taken and regarding the much talked about concept, [9] speak of a euphoria of interdisciplinarity, of a later stagnation and of a resurgence, today. Thus, the current situation seems more encouraging – there are more programs designated as interdisciplinary, there are job offers with this dimension, more government financial support, requests from community leaders and more censorship in order to fight against the compartmentalization of academic disciplines. Nevertheless, questions remain that await an answer regarding the nature of interdisciplinarity and the place it should occupy in the structure of universities. In short, reconstituting the path of interdisciplinarity and regarding the worrying confusion about the aforementioned concept.

As described in the literature review, the benefits of multidisciplinary experiences are effective. This will be demonstrating by describing various concrete situations experienced in a higher education context, within a long-term project conducted with fellow faculty members and students in a spirit of commitment and partnership to design multidisciplinary methodologies.

A first formal experience took place one year after undergraduate and Masters' programmes were adapted to Bologna – 2007-08 to 2009-2010. In our capacity as coordinator and professor of an Information Science degree, we worked with the course coordination board to design and implement a remarkable work of interdisciplinary articulation of activities between several disciplines of each curricular year. This bennefited from both the encouragement and collaborative work of faculty members, at a time when behavioral changes were required by all educational agents. This initiative aimed to adopt more innovative and motivating active learning strategies, providing the teacher with both meadiating skills and a meadiating role in the teaching-learning process and empowering students to become the protagonists of their own learning.

Several interdisciplinary initiatives took place involving 1st year students attending the undergraduate programme in *Library and Information Sciences and Technologies*. The experiments occured during thre consecutive academic years and involved the classes of Introduction to Information Science and of Information Research Methodology.

Students were invited to conduct research on topics within the syllabus of *Introduction to Information Science* and asked to apply the skills acquired upon, while attending Information Research Methodology course: *i*) the correct structuring of the work, *ii*) the quality of information sources, *iii*) the techniques of academic writing, *iv*) the processes of bibliographic citation and referencing, *v*) the organization of bibliographies, *vi*) the application of studied citation styles and bibliography. All of these items, which had been formally assessed, should be based on the ethical use of information.

During 2008-09, students were also challenged to write a single paper for two 1st year classes – *Organizational Communication Technologies* and *Information and Communication Technologies*. Students were asked to create a website, with the collaboration of the ICT teacher. Our role, as the Communication teacher, was to monitor the contents (texts) created by students for publishing on the website, monitoring and supervising the correct coding of ideas and the adequacy of the texts (written expression) to the target-audience and the organisational context. Within the same higher education institution, the undergraduate programme in Hotel Management developed an interdisciplinary project, adopting an identical strategy involving all classes within the course. Our contribution, from 2009/10 to 2015/16, was directed to 2nd year students attending French as a Foreign language Level 2. In this case, there was amore direct interaction with the ICT teacher who supervised the students as they constructed of a website for a fictitious hotel. The Communication teacher conducted a permanent supervision of the students' translation to French of the website contents – originally produced in Portuguese. More recently, in 2019-20, we implemented another interdisciplinary project involving the undergraduate programme in Library and Information Sciences 2nd year classes of Technology and Information Policies (TIP), Informational Behavior (IB) and Theories and Methods in Communication and Information Sciences (TMCIS) Technologies between three 2nd year subjects – the two latter under our scientific and pedagogical supervision. This project involved two lecturers and a class of twenty students. The investigation was carried out in groups and addressed the identification of information and technology policies being used by the information services of Porto Polytechnic – of which our facuty is part of. The group-work integrated objectives related to syllabus and skills developed in all the three classes. The assignement included both a theoretical as well as an empirical component – an autonomous visit by each work-group to a library of one of the Schools of Porto Polytechnic to ask the service users to answer a questionnaire and to conduct an interview to the librarian. The assignement also required witing a paper – students received clear instructions regarding the structure of a scientific article. In the scope of the evaluation of the works, we highlight the very positive results achieved by the students.

Table 1. Results obtained in the interdisciplinary project (2019-20)

ECTS grading scale	**Portuguese grading system (0-20)**	**Grade**	**N**	**%**
C	Good (14-15)	15	4	20%
B	Very Good (16-17)	16	4	**20%**
		17	8	**40%**
A	Excellent (18-20)	18	4	20%

According to the Application of the European Classification Comparability Scale of Instituto Superior Técnico de Lisboa and the Decree-Law No. 42/2005 [10] which approves the regulatory principles of instruments for the creation of the European higher education space and regulates the European scale of comparability of ratings (from A to E), the results obtained are between good and excellent. Most, 60%, are very good (B), 20% are excellent (A) and 20% are good (C). Therefore, 80% of the results correspond to a score equal to or greater than very good and there are no ratings below good, that is, Sufficient – 10-11 (E) nor Satisfying – 12-13 (D). Regarding the final classification of the two classes under our scientific and pedagogical supervision, we observed that the result of this academic work did not induce the overall final grade average to lower. Our analysis reveals the opposite: in the discipline of TMCIS, the majority of students (65% -13 individuals) increased their average grade by one value while in IB, 35% (seven individuals) of the students increased their average grade by at least one value, with one of the students increasing the average grade by two values on a scale of 0-20. In conclusion, the analysis of the interdisciplinary experiments reveals that the interdisciplinary approach led to a valorisation of the students' autonomous work, encouraged research choices based on credible sources of information, promoted team working and academic writing skills. These pedagogical strategies were deemed positive because they became more motivating and time-effective for the students, preventing them from dispersing on the study of different topics, promoting the adoption of active and proactive postures, developing skills, taking pleasure from their learning and, in some cases, better academic achievement.

There are reasons to think that, despite the difficulties described, interdisciplinarity should not be understood as a buzzword, it should be implemented with courage in the daily lives of higher education institutions. Combating the monochord of disciplinary teaching and bringing open thinking and global training to students, it will be more successful if several synergies and bridges are built inside and outside the walls of universities.

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The Closing Down of Schools due to the COVID-19 Pandemic and the Consequences for Science Education

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Abstract

Because of the outbreak of the COVID-19 pandemic in the year 2020 many countries closed down education on all levels. The students are supposed to conduct their studies at home with digital support from their institutions. In science teaching, with laboratory work, field studies and other types of practical work as important parts of the studies and also the reflective parts, usually often in dialogue form, are suffering. At home the student seems to lack ability for a deeper understanding, especially as teachers showed an increased tendency to base their grading on written texts. This creates a general lower degree of understanding outside the classroom as texts easily may be copied without content knowledge. In the classroom the presence of, not only the teacher, but also other students, stimulate or trigger the wish of deeper understanding. Thus, the teacher has to behave otherwise when working in the digital word compared to in the classroom. Based on interviews with teachers and out our own experiences we here present some basic problems of science teaching in a pandemic world and how they may be solved. Thus, some principles for the design and structure of homework tasks useful for teachers will be presented. The suggestions presented will hopefully promote deeper understanding of learning processes and their environmental dependence.

Keywords: COVID-19, school close down, home studies, science education, science teaching

1. Introduction

More than fifty years today, the lectures attended by the senior author at upper secondary school were interrupted by a teachers' strike. During some weeks the students collectively arranged their studies at school, without any support from teachers, based on the textbooks. The students, between them divided the responsibility of the different subjects. In most cases it worked out fine, in the beginning also in mathematics.

But after one week, a new area was introduced; *calculus*. Although a dozen students worked together with their textbook, they didn't understand neither the ideas or the practice of calculus, although they attended a program with focus on mathematics.

Without their teacher they were lost and nothing new was learned. Today the situation is similar due to the outbreak of the COVID-19 pandemic and students have lost the social culture of their class rooms. The teachers have lost their class rooms and have to find new roles. The students are supposed to conduct their studies at home with different levels of digital support from their institutions. In science teaching, where laboratory work, field studies and other types of practical work are important parts of their education, this often is more problematic than in other subjects. Further, students often also are supposed to do their studies single-handed, in contrast to the, often so important, collective activities performed at school or in the field. But, not only these typical characteristics of science teaching are hard to maintain and often are totally lost. Also, the reflective parts, usually in dialogue form, with fellow students and teachers, suffer.

Here we present some identified explanations to the shortcomings of the changes towards distance teaching and how they may be avoided. This also includes some critical reflections on the present state of the science education at all levels.

2. Common design and general outcome of home studies

There are some general differences between education at institutions and at distance, regarding the designs course content and structure. The tasks and also the evaluation and grading of the students, compared to the ordinary procedures at school differs. These differences seem to have great impact on learning processes and the quality of the knowledge achieved.

2.1 Differences in the design of home studies compared to the design at institutions

The home studies often are based on various tasks, including the collection and presentation of data and texts introduced by relatively short virtual lessons. In some cases, the teachers created tasks similar to those found in textbooks, e.g., concept checks, inquiries, self-quiz, [cf.1]. The presentations of the tasks often are presumed to be presented in written text, quoting course literature or web-sites, more rarely students are forced or promoted to respond in their own words. Thus, the answers usually are correct, although they give none or only very poor information about the real understanding and learning. Teachers experience a difficult situation, generating low quality teaching. But there are exceptions: "I've learned loads. Teaching at distance gives me new opportunities to develop pedagogically" [2]. But most reactions are negative. The close relations of the classrooms are lost, technical problems disturbed the work, the possibility to "see" the students and feel the atmosphere are also lost. This highlights the importance of social interaction and physically close relations in the classroom [3]. A special problem in science studies are the limited possibilities of doing experiments and practical investigations at home [4].

2.2 Differences in learning outcome of home studies compared to those at school

Compared to the classroom, the home of the student, seem to lack the ability to stimulate deeper understanding. This effect is further pronounced as teachers show, at least in Sweden, an increased tendency to base their grading on written texts mainly produced by reproductions. This method leads to the creation of a general lower degree of understanding compared to the situation in the classroom, as texts easily may be copied without content knowledge. Thus, it is possible for the students to present adequate texts without apparent understanding of the scientific content. The possibility to put questions to the teachers and to discuss the content of lectures are restricted in the digital environment and diminish the possibilities of achieving a deeper level of understanding [5].

3. Main factors behind the loss of quality

In the classroom the relations between teachers and students, stimulate or even trigger deeper understanding. The relations to others and the exchange of ideas are most important in the learning processes. Of course, there are contents to be learned, but the learning is a process in relation to others or in dialogue with oneself. Thus, texts and other sources, have to be mentally processed, otherwise they are lacking deeper meaning [6]. Many teachers seem to lack some knowledge about the importance of these factors. In the absence of these stimulating forces the teachers have to behave differently when working in the digital word compared to working in the classroom.

Similarly, the students have to understand the importance of the collective processing of texts and experiences in order to understand the reality behind them, which ought to be the subject content. Otherwise, it will be hard to achieve knowledge useful in real life when their studies are finished.

4. How to gain higher quality in the understanding of the subject content

The teaching of most teachers under normal conditions usually gives good results but teaching and examinations during the pandemic reveals some basic misconceptions.

Many, teachers as well as students, are obviously not sufficiently aware of the importance of social processes for the learning in the classroom. In a manner of speaking, they are taking them for granted, but do not really acknowledge their importance and fail to use them methodologically.

4.1 How to create tasks useful at home

In order to design high quality homework tasks, the teachers have to use processes including these that are lost when leaving the classroom. This is very important regarding the outcome of the performance of the students. If they shall perform at similar level at home, the factors lost when leaving school must be compensated. One way of promoting this are tasks demanding something more than text replicates. In order to achieve this, tasks have to be non-repetitive and the results should be shared between students in order to achieve knowledge of high quality.

4.2 How to solve tasks at home

As mentioned above, it is through the communication between students in the classroom learning often is achieved. Other views, presentations, misunderstandings, etc., often promote understanding. Thus, If the students always are stimulated to present their own (processed) ideas or ideas by others in their own words, it will increase the level of their understanding. This may be achieved by using the students own written texts on subjects proposed by the teacher. It is also important to use verbal communication. Spoken language is processed by other parts of the brain compared to written and gives other possibilities for reflection. As the internet also is possible to use for verbal communication it is easy for the teacher to participate in discussions with the students.

5. Areas of special importance to be focussed on by the teachers

The problem of understanding calculus in mathematics without a professional teacher, described above has similarities with some areas of other subjects. Here we present some areas where the teachers usually, not only have to present facts or methods but has to directly participate, *in dialogue* with the students in order to reach the pedagogic goals of the curriculum. One way of identifying relevant areas is to study the scientific break throughs of each subject. What happened that changed the views?

Further, the age of the students and the level of their studies have to be taken into consideration when planning the teaching.

5.1 Physics

Here the situation often is related to problems in mathematics. The theoretical models of the subject often are mathematical with a high level of abstraction. Thus, it is important to work with different types of presentations facilitating learning by student with different modes of learning. In secondary school simple experiments may be conducted at home.

5.2 Chemistry

In chemistry, the teaching in secondary school partly is based on laboratory work and mathematical methods. The scientifically based understanding, unfortunately, rarely is the main focus. Home studies are a challenge for every teacher. Experiments at school or the university usually are performed collectively in small groups of students which are important parts of the learning. This may be done at home if small groups of students conduct the same experiments simultaneously in digital contact. They may discuss their experiences and together reach a higher level of understanding. This is also relevant for more theoretical tasks which may be solved in cooperation.

5.3 Biology

The Darwinian perspective is essential in all biology but often is distorted by other popular and widespread ideas. Here the challenge is to create tasks revealing the dialectic nature of the science content. Nature is constantly changing without a specific goal due to the activities of the present survivors. Often a small number of individual abiotic factors may create changes. This makes it relatively easy to explain what has happened but almost impossible to predict the future in detail. The teacher may develop tasks where students create their own ideas of how mankind may interact with other organisms to diminish the risk of disturbances. Here it may be possible for small groups of students to make excursions together, keeping distance, and together discuss their observations.

6. Conclusion

In order to achieve learning of high quality, teachers have to preserve the quality factors of classroom teaching and develop tasks maintaining these characteristics when students work at home. From our experience, “Escape room” pedagogy, where groups of students via internet simultaneously under supervision of the teacher solve their tasks, is useful. Other methods may be used but of most importance are teachers prepared to focus on guiding, both individuals and groups of students, in their learning and achieving abilities useful in the future, instead of transferring facts.

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The Model of Teaching Reading as a Type of Speech Activity to Foreign Students of Philology in the Innovative Educational Environment

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Abstract

The article is devoted to the problem of refining the model of teaching reading for foreign students studying a foreign language (Russian) at Philological faculties. The article describes the tasks that were solved in the process of developing a model of teaching reading: the principles of selection of modern texts for reading, the system of lexical and grammatical tasks, tasks aimed at developing the skills of "mature" reading, tasks aimed at developing productive types of speech activity related to reading: "reading-writing", "reading-speaking". The main feature of this system is the presentation of all tasks exclusively for the distance learning format. The given model of teaching reading in a foreign language can be used for blended learning technology.

Keywords: Russian as a foreign language, teaching to read, the portal "Education in Russian", blended learning technology, distance learning

1. Introduction

The reading plays a key role in the process of teaching Russian to foreign students.

They have the integrated task to learn Russian with the help of a variety of texts (scientific texts, literary and non-fiction literature) and at the same time to improve their language while reading these texts: to improve the productive types of speech activity (speaking and writing).

Teachers who work with students at both full-time format and distance learning format face the same task: to teach the productive "mature" reading, which means the ability of using the formed reading skills practically. The "mature" reading is characterized by the automation of reading techniques with a focus on the content of the text, the flexibility of combined techniques which are appropriated to a specific reading task and which can help to solve it not only correctly, but also economically in terms of time and energy costs [1]. In our case, this is reading with the use of various strategies by students, with a full understanding of what they have read, with an understanding the intent, meaning and subtext. This is the aim of teaching reading in a foreign (Russian) language to students of Philology. Thus, for such students the process of reading becomes both the means and the goal of studying.

In the Russian methodological tradition such well-known methodologists as Zhuravleva L.S., Zinovieva M.D., Kulibina N.V. (teaching reading literary texts), Muhammad L.P. (teaching reading scientific literature) and some others paid attention to the problems of teaching reading.

2. Context

In the methodology of teaching foreign languages (including Russian as a foreign one) the researchers of the effectiveness of the teaching process have to constantly seek answers to the two fundamental questions: “What to teach?” and “How to teach?”.

The question “What to teach?” is still actual: the language is gradually but constantly changing and these changes find the reflection in texts of different types. Literary texts are not the exception: on the contrary, they capture all these language changes as well as possible.

Recently the question “How to teach?” was not so rapid: the methodology had rather full description of different methods and technologies of teaching. But the last months’ events have shown us that there are still some problems to be solved. It is clear that the distance and blended learning technologies will develop completely changing the established concepts of teaching foreign languages.

The group of the researchers of Pushkin State Russian Language Institute analyzed the above-mentioned initial data and began to work on improving the model of teaching reading as a type of speech activities to foreign students of Philology within Russian as a foreign language in modern informational conditions (with the use of distance technologies). The following tasks were defined to achieve the goal:

- the sampling of modern literary texts to foreign students of Philology;
- the generating of task system to improve lexical and grammatical skills based on a read text;
- the generating of task system to develop an ability of “mature” reading aimed at understanding not only the general content, but also the meaning of the text, context and subtext;
- the generating of task system aimed at developing productive speech activities related to reading: “reading – writing”, “reading – speaking”;
- the presentation of the task system in the electronic format, the analysis of the means provided to students and teachers by this format of classes for teaching and studying in terms of promoting the advantages and minimizing the disadvantages of e-learning.

The ultimate goal of teaching foreign students to read is to understand the text they have read. How can the teacher assess how deeply and correctly the text is understood by students, if these students are studying at distance learning format? To do this, the teacher needs to know how to check the understanding of the level of the read material.

There are several levels of understanding of the text. In the methodological literature you can find different approaches to determining the levels of understanding of the text.

We will follow the following approach, which we find in the article by A.A. Larionova.

The author mentions the following levels: fragmentary, global, detailed and critical understanding. The fragmented understanding is the ability to divide the text into meaningful parts and understand unfamiliar words in context, the global understanding is the ability to determine the theme of the text, the detailed understanding is the highlighting important and secondary details, the critical understanding is the ability to formulate the main idea of the text [5].

Thus, the set of tasks for understanding some literary text, according to the researchers’ reading model, should reflect not only the fact of understanding/misunderstanding of the read text, but also show the depth of understanding.

Some reading materials and the set of tasks are represented in the course of the discipline for foreign students on the portal “Education in Russian”: https://pushkininstitute.ru/. The materials are not in the open acess, they are only for students studying at the Faculty of Philology of Pushkin State Russian Language Institute. The materials are developed for self-study of students.

3. Description of the contingent who took part in the study

The study involved 1st year foreign students of the Faculty of Philology. The level of the Russian language is B1+. The group includes students from China, France, Serbia, Bosnia and Herzegovina. Students study different disciplines in Russian, so we can say about the metasubject approach to teaching Russian. However, there is the discipline of the practical course of Russian as a foreign language for students, within which they continue to study Russian in general. The study of the Russian language in the current academic year is carried out using distance technologies. A certain amount of study time is the contact work with the teacher, the other part of the study time is filled with work in courses on the “Education in Russian” portal (https://pushkininstitute.ru/).

4. Description of the procedure

4.1 The sampling of modern literary texts to foreign students of Philology

Literary texts for foreign students must meet certain, rather stringent requirements:

- texts must have some literary value,
- the plot of texts should be interesting and relevant for young people,
- texts should be examples of modern literary language,
- texts must be authentic, but correspond to the level of proficiency in the Russian language,
- texts should be related to the topic studied by students.

For our research we selected texts that were not very long, since students studied at the distance learning format using a computer. We considered it inappropriate to read long texts from the screen of computers, tablets and other mobile devices.

We concentrated on the texts of modern authors that do not duplicate the literature program, in the classes of which students study a large number of classical works of fiction.

Thus, several texts were selected that meet all of the above requirements. The texts were not adapted, long texts were divided into semantic parts for the convenience of working with them. The system of tasks was generated for each text.

4.2 The system of lexical and grammatical tasks

The aim of lexical and grammatical tasks is to provide understanding of the information of a literary text, minimizing the difficulties associated with understanding individual units. Some lexical units of the texts which are beyond the level B1 were highlighted. In this case the researchers used the system of checking a text to determine the level to which this text belongs which was developed at Pushkin State Russian Language Institute (https://pushkin-lab.ru/). Further work is based on the development of key words, free and non-free (phraseological) phrases, which must be entered into the active or passive vocabulary of students.

Despite the fact that the types of tasks are limited by the capabilities of the used LMS (Canvas), nevertheless, we tried to diversify the tasks as much as possible. The lexical tasks were the easiest (according to the survey) for the students.

There are some tasks: 1) combining an image of an object (photograph, picture) and the word which stands for, 2) combining a word and its interpretation, 3) crosswords, 4) typing the missing word into gaps in a sentence by meaning, 5) choosing words from the list, united by a common theme, 6) the choice of the correct interpretation of the phraseological unit. All tasks are of a closed type (without the teacher's participation).

Some tasks can be defined as lexical-grammatical, although the goal of studying grammar was not set, since students need not only to understand the meaning of the word, but to learn the lexeme in all the variety of grammatical forms. The "problem" area for foreign students remains, regardless of the level of language proficiency, the use of the imperfect and perfect form of verbs and verb forms, especially when meeting new verbs. Therefore, we included some tasks dealing with this material, predicting that the use of verbs would be difficult when transforming the text. The tasks were of a closed and open type (both without the participation of a teacher and with the possibility of checking by a teacher).

There are some tasks: 1) choosing the correct form of the verb, 2) typing in the gaps of the missing verb in the sentence in the correct form, 3) composing a story with a list of the verbs given in the initial form.

4.3 The task system to develop an ability of "mature" reading aimed at understanding not only the general content, but also the meaning of the text, context and subtext

There are some tasks: 1) combining the description of the hero of his appearance and characteristics with his name, 2) ordering correctly the events of the story, 3) choosing a statement corresponding to the content of the text (closed-type tasks).

4.4 The task system aimed at developing productive speech activities related to reading: "reading – writing", "reading – speaking"

The written speech (writing) and oral speech (speaking) are productive types of speech activity. We are convinced that these tasks allow us to determine the level of critical understanding of the text, as students can't use templates in their answers. In this regard, this block has the tasks of an exclusively open type (they require verification by the teacher). Thus, in addition to the development of productive types of speech activity the implementation of these tasks by students makes it possible for teachers to determine the level of critical understanding of the text.

There are some tasks for the development of written speech: 1) a short-written presentation of individual fragments of the story with elements of analysis of the actions of the heroes of the text, 2) compilation of written stories on the subject of the read text.

There are some tasks for the development of oral speech: 1) audio/video recording of of the student's oral answer with reasoning on the problem of the read text, posted by students in the course. It should be noted that this task turned out to be the most interesting for the students, who in a calm unstressed atmosphere were able to speculate on topics of interest to them. And this task was in demand among students who blog on the Internet.

5. Conclusion

Thus, the generated model of teaching reading has been organically integrating into the whole teacing system for feriegn students of Philology and forming metasubject links with other disciplines, primarily with literature.

We intend to use the generated reading teaching model in the future as part of blended learning, as it has shown its effectiveness.

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The Role of College-Level Mathematics in STEM Major Persistence

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Abstract

The purpose of this study was to examine the association between a first-term college-level mathematics course and STEM major persistence utilizing data from students who declared STEM majors at matriculation at a 4-year university in the United States. Decreasing logistic regression was used to identify significant variables likely to increase student persistence in a STEM major through the sixth college term. Findings indicated that students who passed a first-term college-level mathematics course were at significantly greater odds of persisting.

Keywords: STEM, persistence

1. Introduction

As the focus on STEM major completion increases, there is a need to study the role of entry-level college-level mathematics courses that act as gatekeeper courses in most STEM disciplines. The purpose of this study was to examine the relationship between mathematics course-taking in the first term of college and college student persistence in STEM majors by asking the following research questions: (1) Are there differences between the characteristics of college students who do and do not persist in STEM majors to the sixth college term? (2) What is the contribution of demographic variables, pre-college variables, and college variables to persistence in STEM majors to the sixth college term?

2. Method

The site of the study was a 4-year public university in the western United States with an enrollment of approximately 9,500 undergraduate and graduate students.

Participants consisted of all first-time freshmen who enrolled in the university between the Fall 2008 and Fall 2013 terms and had no missing data, (n=625). At the time of matriculation, all the participants met college-ready mathematics requirements during their first college term. In addition, they declared and were enrolled in an undergraduate STEM major. Data were collected from archival records provided by the university under study. Three demographic variables were included in the model, including students' gender, race/ethnicity, and socioeconomic status (SES). Two pre-college variables, high school grade point average (GPA) and the determinants in high school that regulated student placement in a mathematics course in college, were also included in the model.

The college variable included in the model was whether or not students passed a first-term college-level mathematics course. The outcome examined in this study was student retention in a STEM major at the sixth college term. The choice to study STEM major persistence through the sixth college term was made because most universities require students to declare a major by the end of the spring term prior to their junior year and because of its use in prior research [1], [2], [3].

Data analyses were conducted using SAS University Edition software. To answer the first research question, descriptive statistics were computed, and to answer the second research question, a regression model was used to examine the relationship between the dichotomous dependent variable and the set of predictor variables. Retention in a STEM major to the sixth college term was coded as the reference category. The form of the final model suggested with backwards model selection, the probability of a student being retained at the sixth college term, denoted as *p*, is

$$\ln[p(x)/1-p(x)] = \beta_0 + \beta_1 (Ethnic_i) + \beta_2 (Sex_i) + \beta_3 (Low\_SES_i) + \beta_4 (MCourse_i) + \beta_5 (GPA1_i) + \beta_6 (MthPlmt_i)$$

A second backwards model selection analysis was then run with all calculus courses removed from the data. The backwards model selection determined that logistic regression was an appropriate model. This was performed to determine whether the higher-level mathematics course data deletion yielded any difference in significance between the predictor and dependent variables.

The final logistic regression model was determined by utilizing backwards model selection. The model was fit with all the variables. The binary variable interactions were analyzed and the least significant variable pair was removed. The model was refit with the remaining variables. These steps were repeated until only singular variables without significant interaction remained. The final model used the Wald chi-square statistic and *p*-values to determine model fit statistical significance. $P<.05$ was used to determine whether the predictor variables were significantly related to the dependent variable. The odds ratio variable was used to interpret the effect size of the predictor variables in the logistic regression model. A parameter estimate was run to determine whether the study sample means were indicative of the entire population.

3. Findings

The final sample included 47% female and 53% male students with a declared STEM major at matriculation. A large portion (65%) of the sample was classified as low-SES, and 73% of the participants were underrepresented minority (URM) students.

Additionally, 63% of the sample entered college with a high school GPA of 3.0 or higher. Once enrolled, 63% of the students from the sample passed a college-level mathematics course. A descriptive comparison of students retained in a STEM major through their sixth college term (n=231) versus students who were not retained in a STEM major through their sixth college term (n=394) revealed that male students were retained at a higher rate than female students (75% versus 66%), non-URM students were retained at a higher rate than URM students (73% versus 68%), and students classified as low-SES were retained at a higher rate than students not classified as low-SES (73% versus 69%). Students entering college with a high school GPA of 3.0 or higher outnumbered students entering college with lower GPAs (61% versus 54%).

Students who passed a first-term college-level mathematics course were retained in a STEM major at a much higher rate than students who did not take or pass a first-term college-level mathematics course (75% versus 67%). In addition, students who placed into a first-term college level mathematics course by earning a high score on the SAT or

ACT exam, earned a passing score of 3 or higher on the AP calculus exam, or passing two remedial mathematics courses during a summer bridge program showed higher rates of retention in a STEM major through the sixth college term when compared to the other means in which a student could place.

The variable parameters obtained from the dataset motivated the use of these same variables in answering research question two.

The first logistic regression model considered all variables (e.g., gender, SES, ethnicity, high school GPA, mathematics placement, first-term college-level mathematics course) and two-way interactions between the binary variables (gender, SES, ethnicity, high school GPA, first-term college-level mathematics course). The least significant variable was removed from the model, the model refit, and logistic regression rerun. This method was repeated, removing the least significant variable one by one, until only significant variables remained.

The final model using backwards model selection indicated that of the six predictor variables and 10 two-way interactions, only two had a statistically significant effect on the prediction of retention in a STEM major through the sixth college term (i.e., students who entered college with a high school GPA of 3.0 or higher, students who took and passed a college-level mathematics course during their first term in college; $p<.05$). The overall fit of the model was found to be significant with a Wald chi-square statistic of $p<.05$. The interactions between variables indicated no statistically significant effect on long-term STEM retention.

An interpretation of the significant predictor variables indicated that students who entered college with a high school GPA of 3.0 or higher increased their odds of STEM retention through the sixth college term by a factor of 1.3. Further, the confidence intervals suggest that there is 95% certainty that the odds of STEM retention through the sixth college term increased between a factor of 1.058 and 2.38. Additionally, students that took and passed a first-term college-level mathematics course increased their odds of long-term STEM retention by a factor of 1.3. The confidence intervals suggest that there is 95% certainty that the odds of STEM retention through the sixth college term for these students increased between a factor of 1.12 and 2.23. A two-way interaction was performed between the two statistically significant variables with results indicating a non-significant *p*-value.

Table 1 displays the estimated regression coefficients, standard errors, odds ratios, and 95% confidence intervals for the final logistic regression model.

Table 1. Logistic Regression Model: Analysis of Maximum Likelihood Estimates

Variable	β	Standard Error	Odds Ratio[1]	95% Confidence Intervals	
Pre-College Variables					
High school GPA					
GPA 3.00 or higher	0.235	0.112	1.265*	1.058	2.38
College Variables					
First-term college-level mathematics course					
Passed	0.271	0.1069	1.311*	1.12	2.23

*p<.05; [1]Only odds ratios with significant p-value are displayed

To determine whether students who entered their first term of college and took a calculus course affected the probability of retention, logistic regression analyses were performed on a second dataset in which all calculus courses were removed, leaving only lower-level college-level mathematics courses while all other predictor variables remained the same. Backwards model selection was performed to determine the best model fit using the Chi-square test statistic and its corresponding *p*-value indicating significance at .05. The first logistic regression analysis considering all variables (e.g., gender, SES, ethnicity, high school GPA, mathematics placement, first-term college-level mathematics course) and two-way interactions between the binary variables (gender, SES, ethnicity, high school GPA, first-term college-level mathematics course).

The least significant variable was removed from the model, the model refit, and logistic regression rerun. This method was repeated, removing the least significant variable pair one by one, until only significant variables remained.

As with the primary logistic regression model results, the final model using backwards selection indicated that of the six predictor variables and 10 two-way interactions, only two showed a statistically significant effect on the prediction of STEM retention through the sixth college term (i.e., students who entered college with a high school GPA 3.0 or higher, students who took and passed a college level mathematics course during their first term in college; $p<.05$). The overall fit of the model was found to be significant with a Wald chi-square statistic of $p<.05$. Analysis of the variable interactions indicated no statistically significant effect on long-term STEM retention.

Moreover, a review of the results indicated that students with a high school GPA of 3.0 or higher who entered college eligible to take a college-level mathematics course below calculus increased their odds of retention in a STEM major through the sixth term by a factor of 1.21. Further, the confidence intervals suggest that there is 95% certainty that the odds of STEM retention through the sixth college term for these students increased between a factor of 1.042 and 2.365. Additionally, these students increased their odds of retention in a STEM major through the sixth term by a factor of 1.28 when they took and passed a first-term college-level mathematics course. The confidence intervals suggest that there is 95% certainty that the odds of STEM retention through the sixth college term for these students increased between a factor of 1.055 and 2.156.

Table 2 displays the output including regression coefficients, standard errors, significance values, odds ratios, and model fit statistics.

Table 2. Logistic Regression Model: Analysis of Maximum Likelihood Estimates without Calculus

Variable	β	Standard Error	Odds Ratio[1]	95% Confidence Intervals	
Pre-College Variables					
High school GPA					
GPA 3.0 or higher	0.232	0.108	1.207*	1.042	2.365
GPA 2.99 or lower					
College Variables					
First-term college-level mathematics course					
Passed	0.248	0.101	1.281*	1.055	2.156
Did not pass or take					

*p<.05; [1]Only odds ratios with significant p-value are displayed.

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Using Science and Creativity in Interdisciplinary Liberal Education

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Abstract

The Liberal Education Program at the University of Lethbridge, Alberta, Canada, has a long history of interdisciplinary science teaching. Recently, however, our Program has expanded into a School of Liberal Education serving all students regardless of major. The School is now under the Vice-President's Office whereas previously it was a program in Arts and Science. This paper discusses the role of science teaching in our Creativity and Innovation Across Disciplines course, Liberal Education 3300. In this third-year course, the instructor engages 60 students per semester in an interdisciplinary exploration of thinking outside of the box. The students represent all majors and minors of study. The course is grounded in the Humanities and has a humanitarian base. But all of the main tools that the students use to think creatively are based in the logical and empirical foundations of the scientific method. This course in creativity and innovation represents a teleological synthesis of the Humanities' and Scientific orientations. [1]
Our School of Liberal Education believes in creating innovative learning environments within which all students can inquire into both new and settled interconnections between various silos of knowledge. In this course, students train in logical, step-by-step critical thinking and then present solutions to real world problems. This methodology combines conceptual rigor with genuine innovation. This is attested by the years of accumulated final projects of very high quality as well as the overall popularity of the course. Moreover, it is precisely these skills that employers of our graduates are primarily looking for in today's market. The paper will discuss methods and findings related to interdisciplinary teaching and learning, creativity and innovation, and the grounding benefit of the scientific method in such pedagogy. Though this paper is primarily experienced based, relevant research on science teaching and creativity is addressed. [2]

Keywords: Science teaching, creativity, innovation, pedagogy, social benefit

1. Introduction

I joined the Liberal Education Program at the University of Lethbridge some years ago because the domain specific area of my research and teaching (English, Canadian Literature) had become ingrown and out-of-touch with what I felt my students learning needs actually were. As a graduate student back in the 1990s, I had attended seminars in Semiotics at the International Summer Institute of Semiotics Studies in Toronto. There I developed an interest in interdisciplinary studies while learning from scholars like Michel Foucault, Karl Pribram, Jacques Derrida and others. These studies proved invaluable when I came to develop Liberal Education courses whose content includes texts of a multi-disciplinary and cross-disciplinary nature. My Literature survey courses used to begin with *The Odyssey* and end with *The Waste Land.* Now the same surveys begin with discussions of Newton's *Principia*, Hobbes' *Leviathan*, Descartes' *Discourse on Method,* ending with Einstein, Heisenberg, and Schrodinger's cat. Or, if I had been pulled over for speeding at the beginning of my career, and the police officer said "Do you realize that you were going 130 kilometers per hour", I might have argued that as a professor of literature, a privileged doyen of high culture, I should expect a certain degree of leniency and be let off with a warning. Now, if I am pulled over and the officer tells me I was speeding at 130 kilometers per hour, I might say, "Great. Now I'm lost."

Generally, we see Liberal Education as both an alternative to and a value added to domain-specific programs that students (and parents) regard as being aimed primarily at eventual gainful employment. Our philosophy has been discussed recently in *Liberal Education and the Idea of the University: Arguments and Reflections*. [1] Here Kareem and Magid Youssef argue that the traditional dichotomy between creativity and science needs to be unpinned from the concept if utility. Without creativity, science would be "denuded of imagination and creativity of expression." Rather the goal should be to teach Liberal Education as "both as an art and a science… equivalent and complimentary forms of production of knowledge" (247-8).

2. Methods

The course-outcomes of each Liberal Education course and the Program in general have an immediate, an accreditation, and a life-long learning description: (a) learning-continuity across the various undergraduate and graduate degrees enhanced by cohort ambience among the students, (b) the proper asset of our degrees as avenues to meaningful employment and engaged living, and (c) the sort of long term feedback that psychologist and libertarian educational reformer Roger Schank has being writing about for decades, most recently in *Teaching Minds*. [2] In Schank's long experience as a science educator, it is the cognitive strategies that he modelled and facilitated in his teaching that students most productively responded to months and even many years later. It was not the content-based instruction that inspired them and gave them tools with which to succeed, but what Schank calls cognitive-based learning. Schank is an iconoclast, but he does have a point. The teaching of science in 21st Century schools must respond to student dissatisfaction with the quality and direction of their tertiary educational experiences. This is where creativity comes in. This is where a creative framework (cognitive-based learning) in science courses comes in.

At the University of Lethbridge, we decided not to attempt to replace status quo silos of knowledge, which is not a realistic goal due to the high cost of retooling the professoriate, but to use the structural materials of Liberal Education that already existed in our institutional history to create bridges between the silos. We hope to foster a more coherent degree-long learning experience and ultimately prepare graduates for the rapidly changing world that they will encounter after their studies. In this commitment, we hope to cultivate interaction, cohort ambience and subject-world continuity for students. In this we try to promote what is called a "Bohmian dialog" between instructors and students and between students themselves. [3]

I turn now to Liberal Education 3300, Creativity Across Disciplines, in which the values and method of science are taught in a creative framework. This course is offered every year in the Fall and is extremely popular among students from all majors across campus. Science students especially seem to appreciate learning how to think creatively in the logical, step-by-step terms that they know from their other courses. I brought a set of pedagogies for Creative Writing courses with me when I came into The School of Liberal Education at The University of Lethbridge. In order to create a multi-disciplinary course in creative thinking per se, I availed myself of methods used in Innovation-themed courses often offered in the field of Business and Management. The course Harnessing Creativity for Organizational Growth at the UBC Sauder School of Business, is just one example. I turned then to the literature on creativity in the fields of education and psychology. From these studies, my main take away was an appreciation that there exists a plethora of tools available to the instructor of creativity and innovation. [4]

Enumerating these tools is beyond the scope of this paper. In psychology, I found particularly useful the cognitive anatomy of creative cognition that the influential positive psychologist Mihaly Csikszentmihalyi has famously dubbed *flow*. [5]

The course assembled from these studies is divided into two parts. The first consists of training in a schema of creative problem-solving. The main textbook for the course is Roberta Ness's *Innovation Generation: How to Produce Creative and Useful Scientific Ideas*. [6] Ness is a practicing researcher in women's heath and the Dean of The University of Texas School of Public Health, I adapted her practical tools for teaching science creatively into a course that teaches science-based creative schema to students from all majors, thereby forming a merger between the humanitarian and the empirical.

The first part of the course consists of training in the use of these tools. [7] There is also an accompanying exercise workbook. [8] The second part consists of usually 7-8 groups of students who have self-selected to use the skills learned through practice to mount a final presentation of an innovative idea that has a humanitarian component. [9]

Group-work is a prominent teaching and learning strategy in almost every creatively-motivated course aimed at helping "a zone of proximal development" among instructors and students of all majors. [9] This presentation is weighted at the lion's share of the final grade and is the final measure of how well the students have internalized the skills and tools practiced and tested.

3. Results

Our School of Liberal Education is still a young entity and we have much to learn.

The course I describe herein has been, due to its continuing popularity, a positive element in the School's institutional recognition. Students from all majors continue to be enthusiastic about the final presentations, and the quality of the work the student do is outstanding. This course adapts creativity training to the scientific method. Conversely, it adapts scientific methodology to creative pursuits. Following on Csikszentmihalyi's *flow* experience, teachers and students develop "an enthusiasm for and sense of empowerment around novel ideation". [10] The final group presentation grounds the student in the sense of a problem-solving task well done and prepares them to be creative employees and entrepreneurs in the future.

4. Discussion

Ness emphasizes the urgency of using creativity in health science teaching, "Whether innovation training occurs in premedical curricula, medical/health sciences schools, or postdoctoral training programs, I believe it is worth implementing." [11] I agree with Ness that creativity instruction is already a valuable means of "enhancing scientific innovation."

As teachers, we all have courses that go swimmingly and others that sink to the bottom. I was lucky this time. More work needs to be done in evaluating, testing, and disseminating the results of teaching science creatively. In our small, fledgling School of Liberal Education we already need more sections with new and different instructors, not only to meet the demand, but to help us all move toward a more diverse and interactive future.

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Preschool and Primary Education

Changes in Electrodermal Activity during Science Experiments: Preliminary Results of Case Studies with Six-Year-Old Children

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Abstract

This study aimed to investigate the electrodermal activity (EDA) of first graders during hands-on science activities. It was assumed that the effects of science experiments can cause changes in EDA. A special electrode placement was tested to measure EDA during the conduction of science experiments. Preliminary results of four case studies are presented in the article.

Keywords: Electrodermal activity, children, hands-on activities, science, measurement

1. Introduction

Psychophysical arousal becomes important even in the context of education when pupils have to achieve an objective. Research on which learning situation or context elicits how much arousal is essential to giving teachers an idea of the situations in which children are ready to learn and perform. The optimal arousal levels slightly differ from person to person: someone like a lower and others a higher level; however, people generally feel uncomfortable on a very low (i.e., sedated) or very high (i.e., overexcited) level of arousal. This would mean that at school, learning activities should not be too boring, nor too exhausting [1].

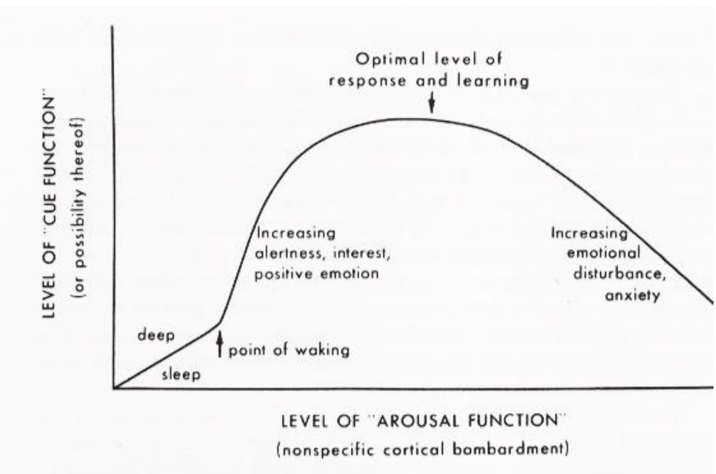

Fig. 1. Interaction between arousal and performance [1, p. 250]

While studies show that primary school trainee teachers do not feel confident to teach physics content due to lack of knowledge [2], it is well known that children generally like to carry out science experiments. Some experiments create amazing effects and elicit fascination in children [3]. Beyond direct observations of children's reactions to science experiments' special effects, technical physiological measurements can offer an accurate insight into psychophysical activities during hands-on science activities [4].

An indicator to detect psychophysical activation is electrodermal activity (EDA), which reflects the autonomous nervous system's activity in response to sweat secretion. A low electrodermal activity indicates parasympathetic activity (inner calm), whereas a high one indicates sympathetic activity (inner tension). Compared to other parameters such as heart rate or temperature, electrodermal activity reacts within a remarkably short time [5]. Changes in EDA can be caused by increasing or decreasing cognitive or emotional load and physical activities. For example, novel and unexpected stimuli can evoke a phasic skin conductance response (short-term changes in EDA) and display an orientation reaction. Such reactions lead to increased attention to ensure optimal stimulus processing in persons [6]. In this context, knowing which psychophysical changes can be observed in children during hands-on science activities could be revealing.

It is important to note that EDA varies from individual to individual and is influenced by age, gender [5] and temperament. Generally, EDA is higher when the child's temperament shows lower anxiety and lower inhibitory control. Therefore, due to individual differences, the same stimulus may not lead to the same changes in EDA [7].

Measurements of EDA, especially in young children and within the context of daily activities, are fraught with challenges: wearing the sensor may not be tolerated by children, children can be distracted by the sensor during the session, and children's physical activity can provoke many artefacts in data, among others. One of a few in situ EDA study with young children shows that sensors were better tolerated on the ankle than on the wrist, probably because the sensor was placed out of sight and children forgot the device [8].

2. Aims of the present study

This study aimed to explore whether changes in children's psychophysical arousal occur during hands-on science activities. For this aim, it was necessary to clarify if a special electrode position on the foot works with primary school children in a real learning situation in science education. Temperament was used as a control variable because this concept describes how individuals deal with their arousal.

3. Methods

3.1 Research design

Four single-case studies with six-year-old first-graders were conducted in a naturalistic laboratory study.

3.2 Procedure

The invited six-year-old participants came to the laboratory accompanied by a parent.

The laboratory (with controlled room temperature) was child-friendly furnished (small chairs and table, nice pictures, soft-toys) and specifically prepared for video registration and EDA measurement. Happy children's music played in the background while children entered the room to create a pleasant atmosphere. One of the two researchers acted as a teacher and familiarized children with the room and the experimental materials.

Before beginning the science experiments, children were asked to put on a white lab coat and special motif slippers (e.g., Spiderman, Frozen). Then, after explaining what would happen next, an electrode was stuck to the sole of their foot (the skin was previously cleaned with rubbing alcohol), and the measuring device was hung around the ankle (see figure 2).

Fig. 2. Adapted sensor and Shimmer device for EDA measurement

The second researcher was responsible for measurements controlling and synchronized video-registration from the background. The parent was placed at a distance from the child but in the child's visual field and was asked to stand down and complete a questionnaire.

The above-described procedure was part of a larger study that cannot be elaborated here. The focus of the present study is on the science experiments that started after a short sensor acclimation period. Under the guidance of the teacher-researcher, the child – sitting at a table near to the teacher-researcher – carried out the following science experiments:

- Experiment 1: They filled vinegar into a bottle and baking soda into a balloon, put the balloon over the half of the bottle and observed that the balloon inflates when vinegar and baking soda come together.
- Experiment 2: They filled saltwater into a spoon, heated it over a tea-light flame and observed that a crust of salt formed on the spoon after some time.
- Experiment 3: They filled with a pipette red-coloured hot water into a small bottle, put the bottle into a high container of cold water and observed that the red water rose to the top.

Fig. 3-4-5. Effects of the conducted science experiments

3.3 Behavioural observation

All sessions were video recorded. Child's behaviour was observed and evaluated by two independent, participating researchers.

3.4 EDA measurement

A Shimmer 3 GSR+ sensor was used to record electrodermal activity during the three science experiments' conduction. Since the Shimmer 3 GSR+ electrodes were designed for adult fingers, they did not suit children's hands nor the research situation's requirements. Therefore, finger-electrodes were substituted by self-adhesive, pre-gelled snap-electrodes (sintered Ag/AgCl) placed on the inner foot's plantar surface. This position allowed for proper signal recording [9, 5] and enabled children to freely move their hands. Special prepared Spiderman (for boys) or Frozen-slippers (for girls) protected the electrodes with a hole on the respective place so that pressure on the electrodes was reduced, as recommended Boucsein *et al*., [5]. EDA data were analysed with the software Ledalab [10].

3.5 Questioning the parent

The "Integrative Child Temperament Inventory" in the German language version (IKT) was used to get information about children's temperament (behavioural inhibition, frustration, activity level, attention/persistence). Therefore, a parent had to rate 30 items [11].

4. Preliminary results

As the analyses have not yet been completed, only the first general results can be presented here.

4.1 Case study 1 (female)

- Behavioural observations: subject 1 allowed the electrode to be applied without hesitation, immediately established a good relationship with the investigator and had fun while experimenting. She was especially amazed by the balloon effect. Sometimes, she moved her legs and feet.
- EDA measurement: EDA data show phasic changes when the balloon was inflated (experiment 1); later, in experiment 3, phasic changes only occurred when the subject was handling the pipette. Artefacts were generally found in a clearly defined moment; hence, data are missing only for a part of the experiment, and other data were relatively artefact free.
- Temperament questionnaire: except for "frustration", where the subject reached below-average scores (PR=20), all IKT scores were within standards.

4.2 Case study 2 (female)

- *Behavioural observations*: attaching the electrodes happened without any negative reactions from the subject. Subject 2 was very calm and did not move her legs or feet significantly. During the experiments she was very shy. She did not speak much with the investigator and generally showed little emotion, except for the balloon-effect.
- *EDA Measurement*: phasic activity could only be recognized during the balloon experiment while the balloon was blown. Only few artefacts were distributed over the entire duration of the experiment.
- *Temperament questionnaire:* subject 2 got scores within the standards apart

from the scale “attention/persistence” (PR=85).

4.3 Case study 3 (male)

- *Behavioural observations*: the placement of electrodes was accepted by subject 3. He was enthusiastic but also easily distracted during the experiments and had difficulties following the instructions. Towards the end of the experimental series, he stood up for a short time.
- *EDA measurement:* during hands-on activities phasic activity was found among the effects of the experiments but also in other situations not particularly relevant for the success of the experiment. Some artefacts were found, especially in the last experiment (vaporizing saltwater).
- *Temperament questionnaire:* subject 3 scored below the standard on the “attention/persistence” (PR=5), “frustration” (PR=10) and “behavioural inhibition” (PR=15) scale. The “activity” score was above the test standards (PR=80).

4.4 Case study 4 (male)

- *Behavioural observations*: initially, subject 4 was afraid of the electrodes and the slippers. After some minutes of playing a game and mother’s encouragement, he accepted, that electrodes were placed on his foot. During experimenting, he was reserved and often reached with his hand towards the foot.
- *EDA measurement*: data showed a high number of artefacts over the whole course of the experiment; hence, phasic activity could not be extracted.
- *Temperament questionnaire*: Subject 4 evidenced the parameters “frustration” and “activity” within the standards. The IKT parameters “attention/persistence” (PR=95) and “behavioural inhibition” (PR=90) were over the standards, and “sensory sensitivity” (PR=5) was below.

5. Conclusions

This exploratory study aimed to investigate whether measuring electrodermal activity in a learning situation close to reality at school is possible. Electrode positions were chosen by considering that subjects needed their hands to conduct hands-on science activities. All four subjects showed that participating in the learning activity – namely, the conduction of science experiments – was possible without limitations.

Since the study took place in a – for the child – foreign environment with foreign researchers, the mother’s presence was unavoidable. In all four cases, electrodes could be placed with the help of the mothers, who significantly encouraged children to accept the electrodes on their feet. Only a male subject initially refused the electrodes but accepted them after becoming more familiar with the new environment.

Nonetheless, during the EDA data sampling, a lot of artefacts were collected due to subjects’ temperament and the fact that children forgot to have a very sensible sensor on their feet. Each child was invited at least once not to move their feet. The subject with low “behavioural inhibition” and “attention/persistence” scores had especially severe problems to stay calm and showed many artefacts in EDA data, whereas the shyly female subject showed a few artefacts and few phasic activities. The male subject who felt uncomfortable, however, was behavioural quite restless and caused many artefacts.

Except for latter subject, all showed phasic electrodermal activity after perceiving the effect of the balloon experiment. This could indicate an orienting reaction in science activities that may be is essential for learning by engaging cognitive and behavioural resources toward a learning issue. Apparently, of the three experiments carried out, the self-inflating balloon caused the greatest amazement and enthusiasm.

Overall, the four cases' analyses indicate that data sampling with an electrode placement on children's feet works under certain conditions, and electrodermal activity in hands-on science experiments can be captured. However, sessions must be limited in time not to overwhelm the child's task orientation, which would cause motoric deprivation and artefacts. Furthermore, subjects must be comfortable in the laboratory.

Planning a habituation phase where the subjects become familiar with the investigator and the laboratory or guaranteeing the mother's or caregiver's presence is strongly recommended.

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Communication Culture Development in Children Aged 5-6 Years Using Educational Gaming Technologies

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Abstract

This article deals with communication culture development in the children aged 5-6 years and the role of the educational gaming technologies facilitating this process.
Presented is a gaming technology model whose structure encompasses two main types of gaming technologies: 1) gaming technologies for social skills development; 2) gaming technologies for developing personal communication skills.
These two groups of skills are developed with the help of the gaming technologies by changing the different structural components of communication.
An important task implemented through the two main types of gaming technologies is development of the child's communicative actions – initiative actions and response actions as well as practicing them for achieving a positive communication outcome, positive interaction, liking and cooperation and hence, improving communication culture.
On the basis of a psycho-pedagogical experiment presented and analyzed are the results from applying the model in the kindergarten teaching practice related to facilitating the process of communication culture development. Formulated are recommendations with regard to the teachers' targeted pedagogical activity focused on developing the children's communication culture by introducing educational gaming technologies within the scope of their interaction through its main form of implementing it in kindergarten, i.e., the pedagogical situation.

Keywords: communication culture, educational gaming technologies, development, pedagogical activity

1. Introduction

Early development of the speaking skills in children is a mandatory pre-condition for a successful integration in their peer group and facilitates the overall development of the child's personality.

According to G. Narkabilova one of the signs of increased attention to the formation of a culture of communication is that cultural communication skills are an essential component of the general culture of a person, is a condition for self-realization, establishing contacts with people around them, and determining life goals. [1]

Pre-school age is a sensitive period in terms of communication culture development since, according to N. Lyapina, in the children aged 5-7 years communication adopts new, non-situational forms of verbal interaction with the adults which radically changes the child's speech behavior – in the process of interaction children start to show themselves as tactful and polite. [2]

According to E. Plaskina, the formation of a communicative culture of a child of preschool age is a process of interaction between a child and adults and other children, aimed at adopting customs, traditions of different cultures and value attitude to them, mastering the norms and rules of interaction in a multicultural environment. [3]

The challenges accompanying communication culture development in the children aged 5-6 years requires more time for developing their interpersonal communication and its encouragement. Due to this reason, of priority is the issue related to the organization of the child's communication process with the child's peers and adults. In this connection the necessity of finding unexplored possibilities for its development arises. Considering the development specifics of the children aged 5-7 years, the gaming environment and in particular the educational gaming technologies appear to be the most suitable for this purpose.

In the last decade, a shift to greater societal reliance on technology has mandated that young children's educators emphasize the use of technology as a play-based tool to tune into children's learning and cognitive engagement [4].

In connection with the issue studied, of interest is the opinion of V. Gorshkova on educational technologies and their interactive nature. According to the author, the interaction becomes possible by intentionally establishing the subject-object relations determining the role of the teacher and the children. The result of this interaction are the states of the participants in the educational process in which they are able to understand the other person and to achieve an accessible language of communication. [5]

D. Dimitrov defines the game technology as "systematically elaborated procedural and structural integrity of interconnected procedures for targeted design of the activities and the educational varieties of the game". [6, p. 23].

S. Ivanov underlines that educational gaming technologies and techniques play a decisive role for implementing the objectives and the tasks of the educational interaction at all levels. They provide for the adequate satisfaction of the child's leading needs and interests and ensure the child's activeness and its targeted educational orientation. [55]

G. Ivanova presents her own opinion for the nature of the educational gaming technologies as being "scientifically justified and practically significant set of interrelated, consistent and joint actions and operations of the teacher and the children, which find expression in specific procedures, and are intended for the formation and development of the children's independent game activity and development of their gaming culture". [7, p. 69]

According to B. Adulbaeva *et al*., the purpose of gaming technology is to create a full-fledged motivational framework for the formation of skills and activity, depending on the functioning conditions of the preschool institution and the level of development of children. The main thing is not to change the child and not to remake him, not to teach him some special behavioral skills, but to give him the opportunity to "live" in the game the situations that excite him with full attention and empathy for the adult. [8, p. 2242]

M. Korotkova summarizing the opinions of different authors points out the following principles which should be observed in the design and introducing of the gaming technologies into the teaching practice: the principle of development; the principle of modelling; the principle of combining the gaming and didactic goals; activity principle and communication principle. [9]

The effect of the educational gaming technologies on the communication culture development in children aged 5-6 years can be found in several aspects: pre-school age is a sensitive period for the development of communication; communication among children in pre-school age unfolds in the context of their practical and theoretical knowledge about the world surrounding them; gaming technologies being innovative educational technologies create conditions for a better development of the child's cognitive, emotional and personal potential; gaming technologies create conditions for spontaneous and targeted contacts, and for promoting cooperation and encouraging communication.

2. Materials and Methods

Based on this theoretical analysis of the nature of gaming technologies, their types and design methods, developed is a model for communication development by gaming technologies focused also on development of speech culture. With the help of the gaming technologies model created are conditions for improvement of the social contacts and conversational skills among children with regard to the following parameters: /acc. N. Vitanova [10, p. 103]/: quantity, content, structure and functions.

To ensure the smooth running of the gaming technologies realization process, pedagogical interaction is used which places the child's personality in the center. Such interaction is focused on the personality. It is characterized by "anthropocentric, humanistic and psychotherapeutic orientation and aims at the the multi-faceted, free and creative development of the child, according to G. Selevko. [11, p. 28].

As a result of this, the efforts are focused on creating and researching the effectiveness of using a gaming technologies model with a focus on communication in the organization of the teaching process in kindergartens targeted at developing the child's skills for effective communication, including also a good communication culture.

In connection with this, an experimental research study has been conducted encompassing the following stages – ascertaining, forming and control stages.

The research study involved 162 children at the age of 5-7 years, of whom 95 girls and 67 boys, divided in two groups – a control group and an experimental group. The number of children in the experimental group was 84 and in the control group 78. All of them were at the age of 5-7 years and attending kindergarten.

During the forming stage of the experiment, the experimental gaming technologies model was approbated. In the structure of the model included were two main types of gaming technologies: 1) gaming technologies for social skills development; 2) gaming technologies for developing personal communication skills.

The first type comprises of the following sub-types of gaming technologies: 1) gaming technologies for development of interaction skills and skills for achieving coherence of opinions, concepts and actions; 2) gaming technologies for development of skills for evaluation of the ideas, opinion, actions and behavior of the others; 3) gaming technologies for development of skills for cooperation/practical, cognitive and personal/; 4) gaming technologies for development of skills for establishing an empathic connection.

The second type comprises of the following sub-types of gaming technologies: 1) gaming technologies for developing skills for expressing evaluation; 2) gaming technologies for developing skills for standing up for one's principles in the group; 3) gaming technologies for developing skills for a more objective self-assessment and self-control for expressing one's own opinion and for self-affirmation; 4) gaming technologies for developing skills for considering the requirements of the group members, their understanding, observance and creation; 5) gaming technologies for developing skills for reading and interpretation of social signs; 6) gaming technologies for developing skills for identification, naming and expression of feelings; 7) gaming technologies for developing reflexive skills; 8) gaming technologies for developing skills for maintaining a positive self-image.

The gaming technologies model includes three types of strategies: strategy for stimulation of the interaction and coherence of actions among children; of the activity in the interaction; strategy for developing an evaluative attitude towards others and towards oneself; strategy for stimulating the evaluative attitude towards others and towards oneself, one's own opinion and the opinion of others, which results is a meaningful relationship, cooperation among children, it suggests adequate organization, encouragement and a communication model and mutual assistance in the game situation.

These three strategies are realized through gaming technologies working at four levels: gaming technologies facilitating perception; gaming technologies facilitating understanding; gaming technologies facilitating expression and gaming technologies facilitating the reflexive interaction.

Each game technology is associated with various types of games related to the developmental stages of communication among children in the game situation.

The particular game unfolds over three successive stages: explanatory-motivational, creative and reproductional and reflexive.

In connection with the scientific literature review on the topic, based on the experience of other authors, the following indicators have been developed for assessing the culture of communication among children:

Zero level /the child does not use the generally accepted polite greetings, forms of address, apology expressions and language etiquette; does not show himself/herself as tactful, helpful and friendly in the process of communication.

Low level /the child uses the generally accepted polite greetings, forms of address, apology expressions and language etiquette in isolated number of cases requiring this and rarely shows himself/herself as tactful, helpful and friendly in the process of communication.

Middle level /the child uses the generally accepted polite greetings, forms of address, apology expressions and language etiquette in most of the cases requiring this and rarely shows himself/herself as untactful, unhelpful and unfriendly in the process of communication.

High level /the child uses the generally accepted polite greetings, forms of address, apology expressions and language etiquette in all the cases requiring this and is doing his/her best to show himself/herself as tactful, helpful and friendly in the process of communication.

Through the experimental situation "Paying a Visit" conditions are created for obtaining information related to the culture of communication among children. The aim of the game is to encourage children to practice the use of generally accepted polite words and language etiquette, according to the requirements of the situation they find themselves in. The needed tools include a white drawing sheet and a coloured pencil set for each child. This experimental situation takes place during the ascertaining and control stages of the experiment.

Guidelines: The teacher informs the children that on this particular day they are paying a visit to the younger children from a group in the same kindergarten (or another kindergarten). For this purpose, each child is asked to draw a picture as a present to a child in the host group. Each child is then evaluated according to the criteria above at the time of giving the present.

3. Results

In order to verify the statistical significance of the results obtained from the control and experimental groups, the Student's' T-Test (Paired Samples T-Test) was carried out.

Table 1.
Test Results – Control Group

		Mean	Std. Deviation	Std. Error Mean	t	Df	Sig.2-talled
Control Group	Ascertaining Control	,17949	1,07804	,12206	1,470	77	,146

Table 2.
Test Results – Experimental Group

		Mean	Std. Deviation	Std. Error Mean	t	Df	Sig.2-talled
Experimental Group	Ascertaining Control	-, 36905	1,10617	,12069	-3,058	83	,003

Referring the control group, there is no statistically significant difference between the results obtained during the ascertaining stage and the control stage of the experiment.

Since p (column Sig. (2-tailed) (Significance, 2-tailed)) is bigger than 0,05 (p=0,146), we cannot conclude that there is a difference between the two-arithmetic means.

Referring the experimental group, we can conclude that there is a difference between the two arithmetic means since p (column Sig. (2-tailed) (Significance, 2-tailed)) is smaller than 0,05 (p=,003). This proves the effectiveness of using the gaming technologies model applied in connection with improving the communication culture of children aged 5-6 years.

We assume that this is due to the direct influence of testing the proposed model of game technologies during the formative stage of the experiment, which includes information about social standards in communication and offers the opportunity to learn them in game situations.

It is characteristic of children who have reached a high level that they clearly express their intentions to help others, take into account the wishes of their partners in the game, use positive forms of addressing them. In a small part of these children the ability to use these forms is combined with selfish motives – to receive a desired toy or object, to be done a certain service.

Children who have reached intermediate level use etiquette and polite expressions in most situations that require it, but sometimes miss them in the process of communication due to strong emotional tension or ignorance of the appropriate ones.

Children, who demonstrate a low level do not use benevolent forms of addressing their peers in the game, usually show disregard for the interests of their partners, their treatment of them is rude and commanding. It is assumed that the behavior of certain adults serves as a model in this regard. In these children, the work of educating the culture of speech in the forms regulated for this purpose needs a serious reassessment.

The children who demonstrated zero level are mostly of non-Bulgarian ethnicity, which raises the question of their appropriate language integration within the kindergarten.

4. Conclusion

The results from the conducted experimental research study prove that the gaming technologies create favorable conditions for the development the culture of communication among children. Improving communication among them under the conditions of purposefully designed gaming technologies, stands out with its specifics.

This communication specifics results from the particular position which children occupy in the course of the game. It is expressed among all by the variety of situational communication and experiences of the child in the gaming situation. The active practical and verbal recreation of one's own social experience in the game in various situations results in improvement of the culture of communication among children as a whole but also of each child individually. in the game interaction to some extent the discrepancy between the current needs for interaction and play with other children and the subjective social experience of the child is overcome. In the conditions of game activity, the experience gained outside of it is supplemented and enriched with experience, assimilated by different subject position/as a real participant in different game situations and role positions. This complementarity facilitates the establishment of social and personal contacts in the process of communication between children and supports the development of their culture of communication.

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Letting Mechanistic Reasoning Emerge: Pre-Service Teachers' Scaffolding Strategies in Primary School Classrooms

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Abstract

This preliminary study explores the opportunities that pre-service teachers (PSTs) give to primary students (PS) to use mechanistic reasoning to give causal explanations of investigated phenomena. Last year undergraduate PSTs performed short inquiries with primary school children within the facilities of the University. Those classroom inquiries were systematically videotaped and used for developing students' self-reflection to foster their professional development. For the pursuit of this study, we analyzed videos from these classroom inquiries where PSTs and PS interactions aimed at constructing explanations of observed phenomena. Specifically, our analysis focused on: (a) what makes mechanistic reasoning appear; (b) which kind of pedagogical moves, responses and resources did or use PSTs in these moments to support and scaffold this kind of reasoning. Results provide insights on characteristics of those interactions helping to determine how they can expand, maintain or shut down opportunities for PS' mechanistic reasoning. Implications for further research are presented.

Keywords: primary school science, pre-service teachers, responsive teaching, mechanistic reasoning

1. Theoretical framework

Many international reports on the state of science education highlight the role of scientific reasoning and explanations in primary school science [e.g., 1]. In this study we focus on one particular type of explanation and reasoning appropriate for scientific understanding: that involving causal mechanism.

Mechanistic explanations are non-teleological explanations, which focus on the cause-effect relationships underlying a phenomenon, and thereby take into account how the activities and properties of the constituent components influence one another [2].

Mechanistic is a powerful thinking strategy, since it allows constructing scientific explanations and make testable predictions about natural phenomena. Supporting student in using such reasoning skills helps, therefore, in the development of scientific work and the knowledge building [2, 3].

All students come to school with resources for understanding and using scientific knowledge, reasoning scientifically, and participating in scientific practices and discourse [4]. Specifically, research with children affirms that mechanistic reasoning is present and episodic even in the discourse of young students [2]. However, their progress depends, largely, on whether and how teachers pay and give attention to these resources. In this sense, there is growing consensus on the importance of teachers having the ability to elicit, recognize, interpret and leverage student thinking by tailoring instruction to these leaner's ideas [2, 5]. This approach is characterized as "responsive teaching" [5, 6].

It is not easy to establish a classroom dynamic through which children's reasoning becomes the building blocks for scientific understanding. A growing number of studies acknowledge the challenges and tensions teachers face when having to attend and respond to their students' thinking in science primary classrooms [6, 7, 8]. Since these difficulties occur, it is essential to intervene at an early stage, providing opportunities for PSTs to learn such skills at their university courses. Research to understand how teacher's responsiveness evolves and how to support it is also required.

2. Objectives

This exploratory study examines PSTs' responsiveness by exploring their abilities and/or difficulties to make explicit, recognize, interpret and support PS's mechanistic reasoning while teaching science. It adds to the literature available by answering the following related questions: (a) what patterns of classroom interactions do emerge when PSTs try to attend student thinking aimed at constructing explanations of observed phenomena? (b) what makes mechanistic reasoning appear? (c) which kind of pedagogical moves, responses and resources use PSTs in these moments to support and scaffold this kind of reasoning?

3. Methodology

3.1 Context of study

This study is part of a larger ongoing investigation on responsive teaching, which has been carried out within the framework of the "Escola-Universitat" project performed by the Universitat de Vic-Universitat Central de Catalunya. Within this project, 143 PST's performed short inquiries with primary school children within the facilities of the University. Those classroom inquiries were systematically videotaped and used for developing students' self-reflection to foster their professional development.

3.2 Data sources and analysis

Data presented here illustrate two representative classroom dynamics. CASE A exemplifies a typical responsive dynamic. On the contrary, CASE B depicts a poor one.

In case A PSTs prepared and conduct a short inquiry cycle to explain natural phenomena regarding air pressure. The scientific concept underlying the investigations in case B was thermal conductivity of different materials. In both cases participants were 8-9 years old PS of two different schools who were observed, videotaped and audiotaped over four 1h sessions.

Transcripts of all class periods were prepared and analysed in a series of iterative cycles. Since our interest relies on pre-service responsiveness, only whole group talk is considered here. We used Russ's framework [2] to identify mechanistic reasoning and its quality. We also coded the transcripts using Michaels and O'Connor framework [9] to identify goals of conversation and talk moves that could allow us to identify: (a) what makes mechanistic reasoning appear and (b) which kind of pedagogical moves, responses and resources use PSTs in these moments to support and scaffold mechanistic reasoning. Authors independently coded transcripts and discussions were held until consensus was reached on definitions of patterns and coding text.

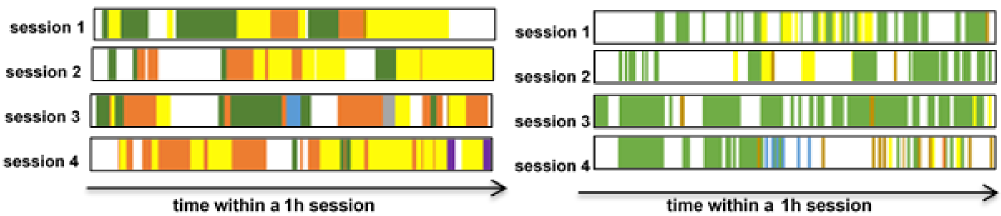
4. Results-discussion

Analysis allowed to identify 8 different patterns of classroom interaction, described in table below.

Colour	Description	Example
(green)	Conversations that led to the establishment of observable relationships between variables (pattern seeking). Such conversations begin after a "what happens" or a "why does it happen" PSTs demand.	*Case A, session 2, trying to explain why can we inflate a balloon within a bottle with a hole but we cannot inflate it when there's no hole.* - ***PST:*** *(…). Ok, then, does someone know why does it happen? [different students rise hands] Someone who hasn't talked before…* - ***Student N:*** *it happens because the bottle…* [6'' pause] … *without a hole, air cannot go out.*
(yellow)	PT support and build on PS' ideas to construct mechanistic explanations by helping them to identify entities, properties and/or activities involved in phenomena and to promote chaining in explanations.	*Case A, session 3, trying to explain why can we inflate a balloon within a bottle with a hole but we cannot inflate it when there's no hole. In this example, student establishes an initial relationship and PSTs intervention aim to identify entities involved in phenomena.* - ***PS M:*** *that the balloon inflated, and squeezed the bottle where there was air inside… and it [referring to the air] went out.* - ***PST:*** *why did it "squeezed" the bottle?* - ***PS M:*** *it pushed down…* - ***PST:*** *but what were we doing? [pointing a kid who rising his hand]* - ***PS F:*** *inflate the balloon* - ***PST:*** *ok… then, what did we put into the balloon?* - ***PS F:*** *air* *(…)*
(orange)	PS expose mechanistic explanations for a phenomenon at request of PSTs. There's not a follow-up conversation guided by PSTs to complete or expand this mechanistic reasoning but just to make it clear and shared.	*Case A, session 3, student tries to explain why a cardstock paper stuck at the bottom of an upside-down glass of water by establishing a balance between air pressures* - ***PST:*** *(…) why do you think the cardstock stuck or doesn't stuck? [pointing at a student] just say! Laud… so that anyone can hear [student does not say anything] Whoever wants…* - ***PS L:*** *Air pressure…. air pressure outside the cardboard makes it stick a little… and air inside presses out, towards water…* - ***PST:*** *which one, outside, this one? [pointing at a schema made previously on board by students]* - ***PS L:*** *Yes, this one!! It also makes pressure towards cardboard and it is more or less equal, and when we press the cardboard a little bit it stuck…* - ***PST:*** *ok, then, this force [drawing arrows indicating pressure towards cardboard] … like this?*

		- ***PS L:*** *The over from top to bottom and this one in this direction…* - ***(…)***
	PSTs expose mechanistic explanations of observed phenomena without taking into account PS' ideas taking a transmissive approach. There's no classroom dialogue, just teacher exposes.	
	PS express explanations for a phenomenon using analogies, making a parallel with other phenomena.	
	Classroom management conversations.	
	Epistemic conversations (aimed to distinguish between conclusions and explanations, explain what are variables, etc.)	
	Conversations between PSTs and PS aimed to identify key ideas.	

In order to visualize the structure and evolution of these classroom interactions through the inquiry teaching sequence, graphic representations were created. Using the above colour codes, episodes of whole group talk with the same pattern were identified and delimitated.



Case A: inquiry classes with a responisve dynamic   Case B: inquiry classes with a non-responsive dynamic

In case A inquiries with a responsive dynamic, classroom interactions that led to mechanistic reasoning increase over time. PSTs seem to have sound epistemic knowledge clearly distinguishing between moments that seek to establish conclusions after experimentation (green patterns) and those aiming to explain phenomenon (yellow-orange). Therefore, PS' mechanistic reasoning (orange-yellow) usually appears after a "why does it happen" PSTs demand, while green patterns appear after a "what does it happen" demand. In such inquires, blue patterns aim, precisely to help PS make this distinction. Furthermore, PSTs seem to see PS' ideas as to be observed-interpreted in order to build on them. Thus, after initial PS' simple explanations, PSTs discursive actions seek that PS recognize entities, properties, activities… that they had not initially contemplated [2, 9]. Discursive actions to share ideas are also common through the whole sequence. Consequently, a slight sophistication of PS' explanations and the participation of many more PS on final sessions is also observed.

PSTs in case B inquiries use "what happens?" questions to either ask for a conclusion or an explanation. Furthermore, when they ask "why does it happen" and PS answer establishing observable relationships between variables they accept the answer, cutting opportunities for mechanistic explanations to emerge (abundance of green pattern).

Yellow patterns appear at a lower frequency and are of shorter duration. PSTs seem to consider students' ideas as indicator of students' learning. Therefore, any children's initial explanation that does not suit canonical explanations is cut off. Difficulties to identify step stones in PS reasoning and to use discursive actions to enhance it are constant. PSTs just emphasize when ideas are correct and rejects/dismiss errors.

Finally, they explain phenomena to students (large presence of brown patterns).

5. Conclusions

This study illustrates basic patterns of classroom interaction that enlarge, sustain or, on the contrary, close down opportunities for PS mechanistic reasoning in relation to PSTs "in the moment" responsiveness. Results from this small-scale study are illustrative of some of the phenomena highlighted in other, similar studies in mainstream education [7, 8]. Further research should be performed in order to deep on causes to explain difficulties to promote this PSTs "in the moment" responsiveness that enhances mechanistic reasoning to occur.

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Planning and Practice of A RIKADOKU (Science Reading) Program "Until Milk Arrives Home" Based on the 5E-Model

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Abstract

Early childhood education in Japan does not have a subject-based framework. Instead, five areas: "health", "human relationships", "environment", "language", and "expression" are set as the contents of the curriculum. A RIKADOU (science reading) program to cross "environment", "health", and "language" using the trade books was developed in addition to the normal Food and Nutrition Education conducted in the "health" area. We adopted Bybee's 5E Instructional Model (5E-model), which BSCS Science Learning that leads life science education in the United States, has shown as an effective teaching model; as a theoretical framework. In this study, the third educational program in our RIKADOKU series, which adds "human relationships" such as food culture and distribution related to career education to the perspective of crossing "environment", "health" and "language" was developed. Two points: 1) using trade books and 2) response to milk allergies; were emphasized in development of the program to make it widely practical. The results of the practices are reported. The practices were conducted in a nursery school in urban area and a kindergarten in rural area. Results show that the children became interested in where their food came from, as well as the increase in awareness to the facilities and people involved in manufacturing and distribution on the way milk arrived at their home. In addition, the results such as the teachers planned an extra activity to visit a nearby supermarket with children suggested that the program influenced on the teachers' view of career education. Many Performance expectations were achieved in both rural and urban children, but some differed. Additionally, after the survey was conducted, the teachers and parents produced extra activities. It suggested that the program affected not only children, but also teachers and parents.

Keywords: 5E-model, Food and Nutrition Education, Career Education, Early Childhood Education in Japan

1. Introduction

Early childhood education in Japan does not have a subject-based framework.

Instead, five areas: "health", "human relationships", "environment", "language", and "expression" are set as the contents of the curriculum.

Food and nutrition education is conducted in the "health" area in early childhood education in Japan [1]. However, issues as follows has been pointed out: undeveloped fundamental points such as setting goals, insufficient training for teachers [2], and inconsistency between preschool and school education [3]. Additionally, career education also has the similar problems: inconsistency between preschool and school education, the difficulty for teachers to introduce many jobs with a sense of reality [4].

As a way to solve the above problems, we have been developing *RIKADOKU* (science reading) program that can be used in early childhood education in Japan. The effectiveness of science education programs that introduced reading in early childhood education has already been reported in English-speaking countries [e.g., 5]. However, it is not possible to use the subject-based educational program in English-speaking countries in early childhood education in Japan as it is. Therefore, it is necessary to develop a program unique to Japan that takes into consideration the contents of the five areas.

2. Examination of the theoretical frameworks

In science education, the process of conceptualizing and accumulating the experience gained from inquiry activities has been examined. The learning cycle of "exploration-invention-discovery" proposed by R. Karplus is one of them [6]. R.W. Bybee expanded Karplus's learning cycle and proposed 5E instructional model (5E-model) from the BSCS Science Learning (BSCS). This model is used for curriculum and lesson design based on the Next Generation Science Standards (NGSS) in US [6], [7]. Picture-Perfect series, the guidebooks including many science/STEM lessons plans using trade books for K-12; also adopt Bybee's 5E-model [5].

RIKADOKU, which has been advocated in Japan since 2010, is a general term for activities that emphasize going back and forth between scientific reading and actual experience of RIKA (Japanese school science) [8].

According to these backgrounds, it is considered the 5E-model is a suitable framework for the development of the *RIKADOKU* program for young children that crosses "health", "environment", and "language". Then, in order to develop a food and nutrition education program, performance expectations of children for "milk, food and nutrition education" was developed based on the 5E-model (Table 1) [9].

Table 1. The performance expectations of children for "milk, food and nutrition education" based on the 5E-model

5E-model	The performance expectations of children
1 Engagement	1-1) Be able to recall experiences of themselves or their sister(s)/brother(s) growing up drinking milk (from mother, other mammal, and/or artificial-made), having eaten milk and dairy products, and try to express them verbally and/or physically. 1-2) Be able to express verbally and/or physically what they noticed and thought while listening to read aloud and engaging in hands-on activities.
2 Exploration	2-1) Be able to aware many jobs on the route of milk and dairy products arriving home, and express that in verbally and/or physically.
3 Explanation	3-1) Be able to know about many jobs exist until milk arrives home, and express that in verbally and/or physically. 3-2) Be able to understand that milk can be transformed into various forms such as cheese and butter, and express it in verbally and/or physically.
4 Elaboration	4-1) Be able to realize that there are many food cultures related to milk all over the world, and milk of various mammals not only cows is also processed and eaten, and express that in verbally and/or

	physically. 4-2) Be able to verbally and/or physically express what they noticed and thought while listening to read aloud.
5 Evaluation	5-1) Be able to realize that there are many jobs related each other until milk and dairy products arrive home. Then, be able to say "ITADAKIMASU (I'll humbly take this food)" / "GOCHISOUSAMA (thank you for the great meal)" at the beginning and the end of meals with gratitude. 5-2) Be able to eat willingly, realizing that foods contain the necessary nutrients to grow and stay healthy.

3. Development of a *RIKADOKU* program based on the 5E-model

Based on the 5E-model, two RIKADOKU programs: "What is milk?" and "Milk is full of nutrition" had been developed in advance for early childhood education in Japan [10].

In this study, "Until milk arrives home" was developed as the third educational program in our *RIKADOKU* series, which adds "human relationships" such as food culture and distribution related to career education to the perspective of crossing "environment", "health" and "language" (Table 2). There were three important points in the development shown as follows:

- Point 1: Ensuring expertise and cross-cutting in science, food and nutrition education, career education and books

The educational program was planned through multiple online meetings by the interdisciplinary members with specialities such as science education, life science education, school library, and teacher training (primary education). Those members collaborated to formulate one program, instead of dividing the work into parts.

- Point 2: Ensuring the versatility of the educational program

1) Using trade books

The trade books have advantages. For example, they are easily available, and "appealing and memorable [5]" for children. Doi *et al*., argued that Japanese trade books also could be adopted to each stage of the 5E-model as well [11].

2) Response to milk allergies

It may not be an appropriate to simply emphasize the nutritional benefits of milk, or to include hands-on activities using milk for the classes with children having milk allergies. Therefore, the following two points were noted: a) to include hands-on activities that follow the process of milk being processed into the products such as cheese or butter, and b) to promote children's awareness that there is a culture that uses milk of various mammals, not only cows.

Table 2. The program of "Until milk arrives home"

5E-model	activities	performance expectations
Engage	Read Aloud: "Bokujou ni Kitene (Come to the ranch)" [12]	1-1)
	Q: What happens to milk after it has been collected by agricultural cooperative staff?	1-2)
Exploration	Q: What route does milk take to reach you?	2-1)
	Let's follow the story of "Journey of Milk"!	
	Activity 1: Trace back the "Journey of Milk" Map	
	6 Home	2-1)

	5 Supermarket	
	4 Distribution center	
	3 Milk factories	
	2 Inspection sites	
	1 Ranch	
Explanation	Let's look back on the milk journey. What kind of workers were there during the journey?	3-1)
	Activity 2: Put "Workers" stickers on the "Journey of Milk" map	
	1 People milking on the ranch	3-1)
	2 People inspecting milk	
	3 People who make packed milk at the factory	
	4 People delivering milk cartons to supermarkets	
	5 People selling milk at supermarkets	
	6 People buying milk at supermarkets	
	Milk may change its form and come our home. Q: Can you tell me the examples?	3-2)
	Let's follow another journey of milk!	
	Activity 3: Expand the "Journey of Milk" map, and put additional "Workers" stickers.	
	1 People milking on the ranch (Common)	3-1), 3-2)
	2 People inspecting milk (Common)	
	3 People delivering milk to dairy factories	
	4 People who make dairy products at the factory	
	5 People delivering dairy products to distribution centers	
	6 People who deliver dairy products from distribution centers to supermarkets	
	7 People selling milk at supermarkets (Common)	
	8 People buying milk in supermarkets (Common)	
	Milk is full of nutrition. It arrives at us in various forms such as butter, powdered milk, and cheese.	3-2)
Elaboration	Read Aloud: "Toya no Hikkoshi (Moving Toya)" [13]	4-1)
	In Mongolia, milk from mammals other than cows was also used in various forms.	4-1), 4-2)
Evaluation	The main character, Toya, was getting camel milk directly, but in case of milk and butter that arrives our home, there were various people involved in various jobs.	5-1)
	Book talk	5-1), 5-2)
	People worked during the milk journey were careful about safety and cleanliness until milk arrive our home.	5-1), 5-2)
	Other foods also travel or change their figures until they arrive our home.	5-1), 5-2)

4. Practices and results

The practices were conducted in A) a nursery school in urban area (face-to-face), and B) a kindergarten in rural area (on-line and face-to-face hybrid). The results were collected through the video records and the interviews (oral and email) to the lecturers of this program and teachers in the nursery school or the kindergarten. Then, they are analysed against the performance expectations of children shown in Table 1.

As infants' "expression" activities, not only verbal expressions but also physical expressions were regarded. Performance expectations 1-1), 1-2), 3-2), 4-2) were achieved by many children in both nursery school A and kindergarten B. Regarding 2-1) and 4-1), many children could achieve it in rural areas, but few in urban areas. The part of 5-1): "Be able to realize that there are many jobs related each other until milk and dairy products arrive home" was confirmed. For other parts, it is necessary to continuously check the effect of the program.

The lecturers mentioned that children seemed to think that they shouldn't make a mistake, or do not want to make a mistake in Activity 2. However, they seemed to start thinking themselves when they proceeded to Activity 3. Furthermore, teachers felt that children became to have each thought about milk or ranch after the program.

In addition to these results, the change in the consciousness of teachers was shown.

For example, extra activities such as "going shopping" at a nearby store to follow the "Journey of Milk", cooperating with nearby ranch to implement an advanced program for children to experience butter making were planned. Moreover, many teachers felt that the program was not only to learn about "milk", but also extends to career education and food and nutrition education.

Besides, at kindergarten B, where hybrid practice was held, the possibility of remote program also mentioned. On the other hand, Wi-Fi environment remained as an issue.

5. Conclusion

Results show that the children became interested in where their food came from, as well as the increase in awareness to the facilities and people involved in manufacturing and distribution that exists before the milk arrived at their home. Practices were carried out in both rural and urban areas, and activity records and interviews with lecturers and teachers revealed that both practices were successful. Many performance expectations were achieved in both rural and urban children, but some differed.

In addition, the results such as the teachers planned an extra activity to visit a nearby supermarket with children suggested that the program influenced on the teachers' view of career education. It suggested that the program affected not only children, but also teachers and parents. In that sense, it was suggested that this program may have been in line with the planning goals.

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Primary School Students' Preconceptions about the Term Nanotechnology and the Water Nano-filters

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Abstract

Nanoscale Science and Technology (NST) concerns the understanding and the manipulation of matter at the nanoscale (1 to 100 nm), where unique properties of materials enable novel applications. Since a lot of NST products are available, e.g., water nano-filters, it is argued that students need to develop their nanoliteracy to come up with everyday issues arising from NST applications. However, research related to students' preconceptions about NST topics in primary school is limited. This paper aims to answer two research questions (RQs): What are the students' preconceptions about (1) the term nanotechnology and (2) the mechanism of the water nano-filters? The participants were 250 (for the RQ1) and 132 (for the RQ2): 5th and 6th-grade primary school students from Greece. A written questionnaire with open-ended questions was used for the data collection. A deductive as well as an inductive qualitative content analysis approach revealed theory-driven and data-driven categories, respectively. In particular, the categories revealed for the RQ1 formulated on the Big Ideas of NST and the data, while categories for the RQ2 formulated on the relational and linear reasoning models in combination with the accuracy of the specific information that students mentioned. The study showed that most of the students conceptualize NST in the context of size in a vague manner, e.g., "a technology for small things". Moreover, a substantial number of participants provided anthropomorphism-related terms ("nano" in Greek means dwarf) while only a few students referred to NST applications as well as to observation tools. Concerning water nano-filters, the majority of students provided linear explanations including vague information about the filtering mechanism, e.g., "the filter consists of small pores". Explanations based on the observable pattern (the use of the filter), were also evident. The findings of this research could enhance our knowledge for designing educational interventions about the NST content through the lens of the constructivist approach.

Keywords: Primary school students, preconceptions, nanotechnology, water nano-filters

1. Introduction

Nanoscale Science and Technology (NST) concerns the understanding and the manipulation of matter at the nanoscale (1-100 nm), where unique properties *of materials* enable novel applications. The literature review revealed specific "Big Ideas" of NST (i.e., core concepts) that are proposed for inclusion in compulsory education, such as the size and scale, the tools and instrumentation, the size-dependent properties as well as the applications of NST [1]. Since a lot of NST products are already available in the market, it is argued that students need to develop their nanoliteracy to come up with everyday issues arising from NST applications [2]. For instance, we can find portable water bottles

that purify the water taken directly from lakes or rivers [3]. More specifically, nanoporous membranes have been developed in order to separate the unwanted particles that can be contained in the water (e.g., viruses) [4]. However, research on primary school students' preconceptions about NST content is in its infancy, indicating that only a few students relate nanotechnology to small size [5]. Secondary school students and adults, in contrast, tend to relate nanotechnology to science and technology in general or applications such as computers [6].
In this paper, we aim to answer two Research Questions (RQs):

- RQ1. What are primary school students' preconceptions about the term nanotechnology?
- RQ2. What are primary school students' preconceptions about the filtration mechanism of a nano-filter?

2. Method

The participants of this research were 250 for the RQ1 and 132 for the RQ2: primary school students (10-12 years old) from Greece. A written questionnaire with two open-ended questions was developed for the data collection:

- "A student has read on the internet about the term nanotechnology and wondered what it means. How would you explain to him/her what nanotechnology is?" (RQ1).
- "Suppose that you have gone fishing to a lake with your friend. You forgot to bring your water bottle but your friend has a bottle with a water nano-filter. Would you drink water from the lake using the water nano-filter? How do you think that the nano-filter works?" (RQ2).

Students' answers were broken down into Units of Meaning (UM). Concerning coding, a deductive as well as an inductive qualitative content analysis approach revealed theory-driven and data-driven categories, respectively. In particular, the categories revealed for the RQ1 formulated on the "Big Ideas" of NST [1] as well as on the data (Table 1).

Table 1. Coding rubric for the term nanotechnology (RQ1)

Category	Subcategory
C0 Vague or no answer	-
C1 Anthropomorphism-related terms	-
C2 Size	Sub. 2.1 General references to small size Sub. 2.2 References to the term microworld or/and microworld objects Sub. 2.3 References to the atomic world objects
C3 Observation tools	Sub. 3.1 References to the limit of the observation tool of the macroworld (naked eye) Sub. 3.2 References to the observation tool of the microworld (optical microscope) or its limit
C4 Applications of nanotechnology	Sub. 4.1 Relating nanotechnology to electronics Sub. 4.2 Relating nanotechnology to

	medicine Sub. 4.3 Relating nanotechnology to the industry of water repellent textiles Sub. 4.4 General references to improvements in life
C5 The new technology	-

The categories for the RQ2 formulated on the relational and linear reasoning models in combination with the accuracy of the specific information that students mentioned [8] [9] (Table 2).

Table 2. Coding rubric for the water nano-filters (RQ2)

Category	Subcategory
C0 Vague or no answer	-
C1 Linear causal reasoning including vague specific information about the water purification process using nano-filter	Sub. 1.1 Linear causal reasoning including vague specific information about the structure of the filter or/and the pattern (use of the filter) Sub. 1.2 Linear causal reasoning including incorrect information about the purification process, e.g., wrong mechanism
C2 Relational causal reasoning with vague specific information.	-
C3 Relational causal reasoning with correct specific information about the filtration (relating the size of the nanostructure to the size of the objects that excludes)	-

3. Results

Concerning the RQ1, the category with the highest percentage of UM was the “size”, followed by the “vague or no answer” and the “anthropomorphism-related terms”. For instance, a student mentioned *“Nanotechnology is the technology of dwarf”*.

Table 3. Categories for the term nanotechnology: Frequencies/Percentages of the UM

Category	Frequency	Percentage (%)
C0	74	27,82
C1	63	23,68
C2	76	28,57
C3	13	4.89
C4	33	12,41
C5	7	2,63
Total	266	100

In Table 4, it is evident that most of the UM about the size were connected to small size in general (Sub. 2.1). Only a small percentage of UM was related to non-visible objects such as *"It is the study of microscopic parts of our body, like cells"* (Sub. 2.2, Sub. 2.3).

Table 4. Subcategories for C2 Size: Frequencies/Percentages of the UM

Subcategory	Frequency	Percentage (%)
Sub. 2.1	69	90,79
Sub. 2.2	3	3,95
Sub. 2.3	4	5,26
Total	76	100

Most of the UM about observation tools were connected to the microscope (Sub. 3.2). An illustrative UM was *"This technology utilizes strong microscopes"* (Table 5).

Table 5. Subcategories for C3 observation tools: Frequencies/Percentages of the UM

Subcategory	Frequency	Percentage (%)
Sub. 3.1	2	15,38
Sub. 3.2	11	84,62
Total	13	100

Concerning the applications of nanotechnology, the highest percentage of the UM was connected to electronics (Sub. 4.1) (Table 6). An indicated UM was "*This technology builds small chips".*

Table 6. Subcategories for C4 Applications of nanotechnology: Frequencies/Percentages of the UM

Subcategory	Frequency	Percentage (%)
Sub. 4.1	29	87,88
Sub. 4.2	2	6,06
Sub. 4.3	1	3,03
Sub. 4.4	1	3,03
Total	33	100

Regarding the results about the RQ2 (Table 7), most of the UM included linear casual reasoning with vague specific information about the water purification process (C1). Most of these UM were connected to the structure of the filter or/and the pattern (Sub. 1.1); an illustrative UM was *"The filter includes holes"*. Fewer UM included a wrong mechanism (Sub. 1.2), such as *"The filter includes cells that purify the water".*

Table 7. Categories for the mechanism of the water nano-filters: Frequencies/Percentages of the UM

Category	Frequency	Percentage (%)
C0	25	18.94
C1	87	65.91
C2	20	15.15
C3	0	0
Total	132	100

4. Discussion

Concerning students' preconceptions about the term nanotechnology, we found that almost half of the students related nanotechnology to the size, the observation tools and the applications of NST even in a vague manner. We assume that the contrast between our findings and literature [5] is due to the following two reasons: firstly, the related study [5] was conducted more than thirteen years ago. More specifically, in 2006 were reported proximately 380 nanotechnology consumer products [9], while in 2020 there are available more than 5000 products (http://nanodb.dk/en/). Secondly, the Greek language maybe made students to relate the term nanotechnology to the small size since the prefix "nano" in Greek means small or dwarf. Consequently, some of the students related nanotechnology to small things, such as cells, while other students related it to dwarfs.

Regarding water nano-filters, students' answers included linear causal explanations about the filtration process. It is evident that students are not aware of the nanostructure of the filter and could not relate the size of the objects that are dispersed in the water to the size of the filter's pores.

The findings of this research could contribute to designing educational interventions about the NST content through the lens of the constructivist approach. More specifically, since students' preconceptions about the term nanotechnology were related to the three concepts of the NST (i.e., the size, the observation tools and the applications of NST), an instructional approach could be designed that will include all of these concepts.

Concerning water nano-filters, an educational approach could consist of tasks that will help students develop an understanding of the size of both the filter's pores and the unwanted particles that could be contained in the water (e.g., viruses), enabling them to develop their relational causal reasoning.

5. Funding

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Study of Parents' Attitudes to Distance Learning of Preschoolers During Pandemic

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Abstract

In the spring of 2020, educational organizations of all types and stages switched to a remote learning format in the Russian Federation. This alternative training solution was one of the measures to prevent the spread of coronavirus (COVID-19). The system of pre-school education also had to change the format of its activities. The role of parents in the education and upbringing of preschoolers has always been high, but in isolation the degree of influence of parents on the effectiveness of the learning process and the quality of its result has significantly increased. Pre-school educational organizations had to organize online work with children and parents in a relatively short time. To understand how parents were able to learn new functions related to their children's online learning, upbringing and leisure activities. It should be noted that not all preschool educational organizations actively used remote educational technologies in their work before the coronavirus pandemic. Therefore, in many preschool educational organizations for the first time began to form a system of distance learning, built on a different model of interaction "parent-parent", "parent-child", "child-teacher", where the parent is an active subject of education of his own child. Our study was conducted to understand the attitude of parents of preschoolers to the distance learning of their children during the pandemic of coronavirus (COVID-19) and how much, they are ready to accept distance learning as a component of pre-school education in normal conditions of its functioning. Two thousand two hundred and fifty parents of preschoolers from eleven preschool educational institutions in Rostov-on-Don took part in an anonymous online survey. Respondents at the time of the survey had two months of experience incorporating themselves and their children into remote pre-school education in the current epidemiological environment. Analysis of the results of the study has made it possible to improve the system of distance learning of preschoolers, which can be actively used in the operation of preschool educational organization under normal conditions.

Keywords: distance learning, preschool education

1. Introduction

In 2020, non-proliferation of coronavirus (COVID-19) has been adopted worldwide, with the most direct impact on education, with decisions to move to alternative form of learning, such as distance learning. Pre-school education has also made the transition to distance learning. Problems associated with the rapid and widespread transition to this format of training have arisen in all countries, including Russia. In these circumstances, studies on the impact of the pandemic on education are becoming quite relevant [1], their results will form the basis for solutions that help to determine in the future the main areas of constructive action in the sphere of changing education, on which the future education system and the society of the future will depend. To address these issues in different countries, scientists have begun to conduct studies on a wide range of issues, such as intergenerational learning [2], family literacy [3], isolation as a cause of the disconnection of families and educational organizations [4], the development of adaptive educational systems [5]. Such studies will help to realize the impact of the pandemic and to understand the deep problems caused by it in education, which will help to build a system of actions aimed at effective changes in the education system. Our research will be the basis for determining the possibilities and directions of rehabilitation and renewal of the preschool education system in southern Russia, as well as its readiness for future crisis situations.

2. Purpose of study

The aim of the study is to clarify the attitude of preschoolers' parents to distance learning during the period of self-isolation due to the pandemic of coronavirus (COVID-19) and to determine the degree of their readiness to accept distance learning as part of their children's pre-school education under normal conditions.

3. Methodology

To achieve this goal, the study used survey methods based on receiving verbal responses from respondents to events and phenomena that happened to them [6]. The choice of survey methods in the study is justified by the fact that they allow you to quickly get the necessary information from a significant number of respondents, to get information in a wide range of specified topics [7]. The survey methods helped to establish the general views of parents on the distance learning of their children during self-isolation and to identify their opinion on the use of their children's distance education as part of pre-school education in the future. The empirical evidence was analyzed. The study interviewed 2,250 parents of preschoolers from 11 pre-school educational institutions in Rostov-on-Don (Russian Federation) using a questionnaire. The questionnaire for parents of children studying in pre-school educational institutions "My view on my child's distance learning" consisted of a total of 24 questions.

4. Results

In connection with the pandemic preschools in Rostov-on-Don switched to a remote format of education in March 2020. In this mode, pre-school educational institutions mostly worked until July 2020. In this regard, the parents of preschoolers were entrusted with the functions not usual for them, which they had to perform during this period. Since both pre-school educational institutions and parents had no experience in a remote format, a survey of parents of 11 pre-school educational institutions in the city was conducted in order to improve the distance learning system and to identify the attitude of parents to the use of this format of education in the future. The survey was conducted after two months of training in a remote format. 2,250 parents of preschoolers took part in an anonymous online survey. The results of the survey showed that 73% of parents had already had experience of participating in online classes at the time of starting their education, but this was not long and not systematic, 16% of respondents said that their children have significant experience of online education and 11% of parents wrote that their children had never had such experience. noted that teachers of pre-school educational institutions did not all continue their classes with their children in the distance during the above period, only 32% of parents answered that teachers did not stop to conduct classes in the format of remote education. When asked what they see as the reasons for such actions of teachers of preschool educational institutions, parents pointed out that their institution has not switched to a new format of functioning (34%); the child himself refused to study in a distant with teachers (37%). lack of either the institution or the family's technical capabilities (29%). Parents of preschoolers believe that their children's remote education had both a positive impact (47%) and a negative impact (45%), some did not pay attention to it (8%). They also noted that the attitude of children to classes in the distance format of e-education changed: the interest of children in the training classes increased 42%, slightly fell 22%, the attitude to classes did not change 20%, interest in classes decreased 16%. At the same time, only 14% of parents are fully satisfied with the quality of education of preschoolers in a remote format; 74% are partially satisfied, 12% are completely dissatisfied. 29% corresponds in part; 3% fully corresponds. Parents believe that the volume of homework during distance learning is generally normal (average) – 76%, quite large – 12%, not large – 12%. Assessing the effectiveness of the process of presentation of information by teachers to parents, 86% noted that the actual information was inaccessible, and sometimes (14%) not available at all. Only 20% of respondents were satisfied with the quality of communication with teachers, 80% of parents noted either a complete lack of communication, or its fragmentation. Most often, teachers used the phone (34%), by email or via messengers, through chats on social networks (22%), in an online format using various services (24%). The survey showed that the most convenient time for consultations for parents (50%) is the period from 12:00 to 16:00, for 22% from 8:00 to 12:00, for 28% from 16:00 to 19:00. 42% of parents surveyed said that significantly increased their involvement in the education of their children, 28% noted a significant decrease in the degree of self-participation, for 30% of parents nothing changed. 78% of parents spent 2 hours a day helping a child, 15% more than 3 hours, 10% did not spend their time. 12% of respondents noted the problem of the lack of didactic materials adapted to the tasks of distance learning, 14% indicated the unformed skills to plan the activities of their child.

87% of the parents think it is necessary to return to the traditional format of education while leaving the possibility of holding several training sessions with preschoolers online.

5. Discussion

The study reveals that parents of preschoolers are aware of the importance of continuous education of their children during the pandemic, they see the potential of remote technologies in improving the quality of these processes. The study identified major problems influencing the effectiveness of distance learning for preschoolers. At the time of the transition of the city preschool system to a remote functioning format, most children had no experience of online learning, which is the first reason. Not all educational organizations and pedagogical staff are ready to use remote technologies.

Inadequate technical equipment of both pre-school education and families was the second reason. The third reason was not willingness of teachers to work in the new regime, inability to quickly adapt the educational materials to the requirements of distance learning. The fourth reason is the lack of motivation of the pre-schoolers to study online. The fifth reason is the low willingness of parents to actively participate in the education of the child, the reluctance to interact with teachers, the inability to build the life of the family in the home space. One of the positive factors of the transition to distance learning is the increased interest of preschoolers to online classes, workshops, online workshops. In general, the parents' satisfaction with the remote education in the first two months of its implementation is quite low.

6. Conclusions

Analysis of the results of the study allows us to formulate the main directions of the development of pre-school educational institutions, in order to improve their activities on the organization and implementation of distance learning both in the conditions of the pandemic, and in the future. Firstly, the continuous improvement of the information competence of the teaching staff through the functioning of the system of intra-organization training and the support of teachers. Secondly, the strengthening of methodical work in terms of adaptation of the content of training sessions, educational and didactic material, as well as the modernization of the methodical recommendations, regulations of the organization and conduct of training sessions with preschoolers in the online format. Thirdly, building a system of effective interaction with parents, through remote counseling and their distance learning in order to improve the level of pedagogical competence. Fourthly, the organization of the youth support and the provision of psychological and educational assistance to parents and children using remote technologies.

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Pre-Service Teachwer's Professional Development

The Project Work Methodology that Promotes Articulation between Educational Levels

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Abstract

Promoting a constructivist paradigm, based on a structured, interrogative and active pedagogy requires a culture that allows the recreation of projects with new resources and new ways of thinking and solving current problems [1]. The Project Method, inspired by Kilpatrick's [2] *approach, favours an intentional, situated, flexible and transversal learning that promotes educational continuity, a relevant dimension in children's development. This study, inserted in the IFITIC (Innovate with ICT in Initial Teacher Training to promote methodological renewal in Pre-school Education and in the 1st and 2nd Cycle of Basic Education) project had the purpose of understanding the impact of the Project Method in the construction of a double profile of teacher training and the opportunity of integration of digital resources. A methodological approach of a qualitative nature was chosen, whose data collection focused on the content analysis of three intervention projects at two educational levels, Pre-School Education and the 1st Cycle of Basic Education. It involved five future teachers and 111 participants aged between 4 and 11 years. The results reveal that educational practices supported by an active pedagogy, within the framework of the Project Method, contribute to the construction of a double profile of formation that favours educational continuity and the transition between educational levels by promoting a common pedagogical project and processes of collaboration and knowledge sharing. In addition, it fosters a teacher and student profile that develops into a new educational paradigm that favours problem solving in a holistic learning environment that includes prior and contextual knowledge, important in meaning. It also includes an intentional and social setting that values diversity and multiplicity, flexibility, complexity of reality and the integration of digital technologies that respond to the interests of children and society in general.*

Keywords: initial teacher training, double profile, project work methodology, educational transition

1. Introduction

For many years, children's education was part of the transmissive paradigm where the child's conception referred to a passive agent who received the teacher's instruction, the latter being considered as the holder of the knowledge. However, with the evolution of psychology and pedagogy, the conception of the child has evolved, giving it an active and participative role in the educational process. In this paradigmatic change, the role of the educator of children and the teacher of the 1st Cycle of Basic Education (CBE) has been imbued with giving a voice to the child, inscribing its educational action in a pedagogy of participation and listening. A reorganisation from the point of view of the formation of future teachers [3] is urgently needed by the double-profile master (Educator of children and Teacher of the 1st CBE) which allows for a formation of continuity between educational levels through the broad vision of the development of the child, the collaborative spirit between those involved in the educational process and the awakening to lifelong learning.

In Portugal, the aforementioned regulations on the initial training of teachers encourage joint qualification for Pre-School Education (PSE) and for the teaching of the 1st CBE, qualifying professionally for the general teaching of these two educational levels that respond to the exercise. Their functions reveal great openness and flexibility in the face of the multiplicity and complexity of the problems of a changing society, but also represent challenges in the face of the instability generated by the constant “becoming” of society and by the relativism that affects philosophical conceptions, cultural beliefs and scientific, technical and pedagogical knowledge that teachers need to rely on in order to base their pedagogical practice on a consistent theoretical vision, as Abreu states in the Education Council Report [4].

A double profile imposes another way of educating. In this sense, a pedagogical method, influenced by John Dewey’s theories, the Project Method (MP) [2], has been revisited as an educational and formative strategy which starts from the interests of children through a question, or a theme to be researched, emphasising action and its actors, considering the experience of the child and the context, in the sense that education is life. In this context, analysing their project perspective, we can see four fundamental actions on the part of children (Figure 1) which reveal a fundamental growth in the construction of new knowledge based on an intentional desire of the actors. Thus, producing, appreciating, selecting the problem and rebuilding are fundamental stages of personal and social growth, particularly when carried out as a team in a real context, so we consider a process adjusted to a changing world like the one we live in today and which responds to the profile of the student considered important in the Portuguese curriculum [5].

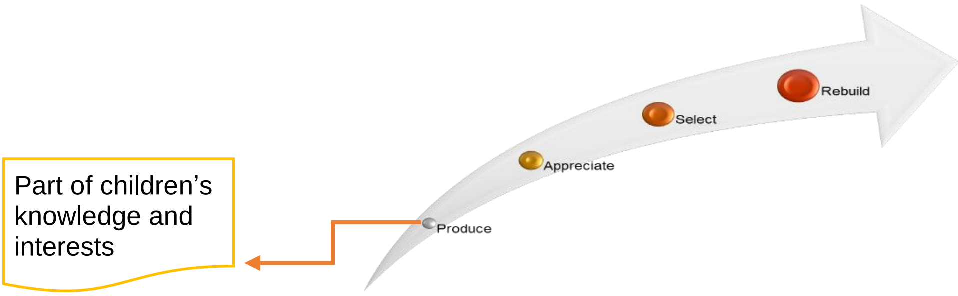

Fig. 1. Project Method from the perspective of Kilpatrick (2006) – Own elaboration

This way of conceiving the intervention emphasises the transversality of curricular knowledge and the development of skills, attitudes and values inherent to the Portuguese curriculum. It is also provocative of a change in the teaching profile that is more guiding and facilitated of learning environments than transmitting, and of the student profile, since it goes from consumer to producer, responding effectively to societal changes with an action contextualized and situated in the time and emerging needs of educational contexts. In fact, the possible pedagogical continuity, enhanced by this methodology, is one of the key aspects in the training of double-profile teachers since “Pedagogy has been identified as a major factor underlying children’s difficulties in the transition to school” [6, p. 66]. From the perspective of Vasconcelos *et al.*, [7], The Project Method is a project-oriented and transformative methodology that develops in four phases: Definition of the problem; Planning and development of the work; Execution, this involves the actions to be developed and their graphic and/or photographic record; Dissemination/evaluation. The phases of the project method stimulate the curricular articulation and the enriching sequence of knowledge, thus promoting meaningful learning from analysis and critical discussion [8]. The pluralization of the resources used emerges as a transversal concern in all phases, justifying mention in the contemporary framework of the relevance of technological and multimedia resources [9].

2. Methodology

The study, ethnographically based, is qualitative in nature and therefore involves an interpretative approach. The choice of this methodology is due to the fact that it constitutes a method of analysis of the thought of communicative subjects giving the researcher the possibility of interpreting their text by taking the organised information [10]. For the collection of data, the analysis of the content of the written testimonies made by five future teachers in their final reports was used. Three categories of Project Method contributions emerged: a) Contributions of the Project Method to the professional development of future double-profile teachers; b) Contributions of the Project Method to the development of active methodologies; c) Contributions of the Project Method to the integration of information and communication technologies. One hundred and eleven children were involved in the projects, fifty of them between four and five years of age, and sixty-one children between eight and eleven years of age.

3. Analysis and discussion of results

3.1 Contributions of the Project Method to the professional development of future double-profile teachers

At PSE and the 1st CBE, teachers respond to the development dimension of teaching and learning, considering the specificity of each educational level, but both conceive and develop the respective curriculum, through planning, organization and evaluation of the educational environment, as well as curriculum activities and projects, with a view to building integrated learning, as stated in the General Profile of Teacher Performance [11]. In this context, a professional with a double profile assumes a global and integrated vision that allows him/her to have an interdisciplinary and between educational levels observation favourable to research on the processes that have an impact on the academic and personal success of children.

What do future teachers say about the contribution of the Project Method to the double profile? We have selected keywords from their discourse (Figure 2) that show that the Project Method fosters a vision of the two educational levels, favouring educational sequentiality and pedagogical continuity, team work and the sharing of knowledge and experiences, stimulates research and an active methodology that changes the educational paradigm.

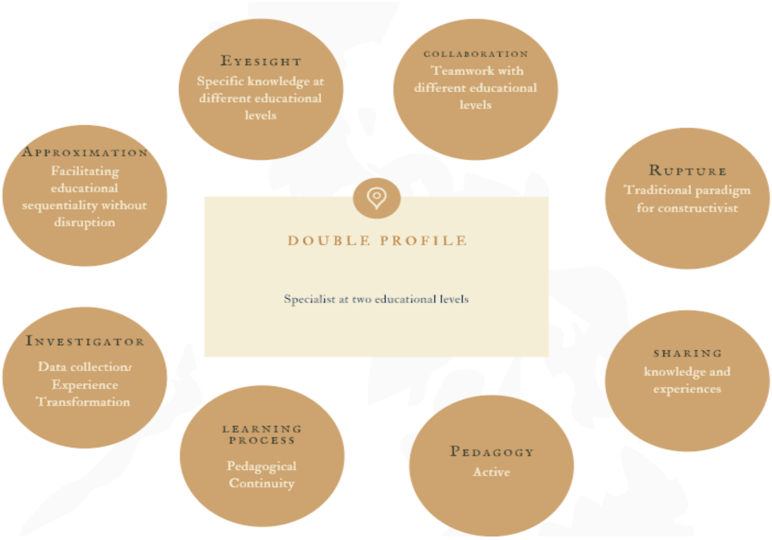

Fig. 2. The Method of Project in the construction of the double training profileprofile

3.2 Contributions of the Project Method to the development of active methodologies

In a child-centred learning process, Project Method gains prominence as a real problem-solving tool promoting transdisciplinarity of knowledge. We wanted to understand the opinion of our students who applied it in real contexts and the analysis of their answers directs us to two dimensions: the learning process and the impact of this methodology. As far as the learning process is concerned it can be seen that effectively the whole process is focused on the child, emerging from it and therefore corresponding to his/her interests. In fact, the students' statements confirm that this methodology involves children in the learning process, cherishing what they do for the meaning and contextualisation they attribute, for the relationships they establish. We add some students' voices:

"this project ended up being cherished" (AC, p. 81); "truly involved and committed" (CA, p. 86); "were of great relevance to the group" (AFC, p. 72); "to respond to the interests and needs of children and thus develop holistic learning" (CF, p. 30); "which occurred in a contextualized and meaningful way" (SM, p. 80); "significant learning by the child" (CA, p. 55); "a rich process, characterised by constant significant learning and which will be valued by the child until its conclusion, only with this process will the child feel truly involved and committed" (CA, p. 86); "together with their interests and motivations, to promote contextualized, holistic and integrative learning" (CF, p. 83).

3.3 Contributions of the Project Method to the integration of information and communication technologies

As regards the integration of digital teaching and didactic resources, the pedagogical strategy takes on importance in educational practices and the academic and personal results of children depend heavily on it. In the selection of the resource, the teacher assigns it meaning according to the context/class and the intentionality of the educational practice, so the added value reflects the harmony between the key dimensions of the educational practice. In fact, it can be seen from the written records of the trainee students that there are factors that stimulate the use of digital technological resources:

a) Children's willingness to use digital technologies, with implications for motivation, encouraging favourable commitment and enthusiasm in the learning process;
b) the recognition by parents that digital resources motivate children;
c) the educational intentionality of educators/teachers: to create a motivating learning environment with implications for well-being at school; to foster communication bridges between educational levels; to develop in pupils' skills, values and attitudes;
d) the recognition of educators/teachers on the effects of the use of digital resources: when associated with a playful environment they improve the learning process; they improve digital skills and competences; they stimulate personal confidence. In this way they advise their use.

4. Conclusions

The Project Method aims at an educational intervention in another operative way in relation to the organisation of the teaching and learning process, where a new vision of educating and teaching how to learn, of managing conflicts and negotiating in order to seek consensus, of creating conditions emerges. In fact, it has been found that the Project Method contributes to a double profile of teachers who look at the two educational levels, PSE and 1st CBE, which favours educational continuity and the approximation of these apparently distant levels. It is also a promoter of collaboration and sharing of knowledge, which means that it can also facilitate the educational transition between educational levels, so we would add not only at the level of activities [12] and methodology [13], but also in collaboration and sharing of knowledge. It is also the promotion of active methodologies, centred on the child, which favour the construction of knowledge and competences based on curiosity, on their previous knowledge and context and on an intentional and social environment, and which value diversity and multiplicity, flexibility and complexity of reality. It is concluded that Project Method responds to the indices of the new educational paradigm and favours other ways of learning, more situated and flexible, holistic, stimulating educational continuity as fruitful for the development of children, seeking to form better citizens, attentive, capable of thinking and acting, intelligently critical to be easily misled, quick to adapt to the most imminent social conditions [2]. In it, information and communication technologies assume an important role in the re(construction) of the professional identity of future teachers through methodological renovation [1], [9] and the promotion of children as builders of their learning in a meaningful and participatory way.

Thus, it is important to orient the initial training of teachers with a double profile in order to contribute to a change in schools, more articulated and continuous, in order to promote a holistic and real learning, in life, natural in the transition and still in knowledge, know-how, opening great avenues of openness, knowledge, innovation, listening, creativity for the common good.

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Where Were We: Science Teacher Professional Development Under the Night Sky

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Abstract

The constellations shine bright over the prairie landscape at our free and public space named "Oodena Celebration Circle" [1] located in Winnipeg, Manitoba, Canada at the fork of the Assiniboine River and Red River. Developed in 1993 as a local collaborative endeavour, Oodena is designed to be, "a gathering place that evokes spirituality without reference to culture-specific symbols, by directing our attention to the beauty of the sun on the horizon, the wonder of starry nights, the serenity of winter bonfires and the drama of spring flooding – experiences, and presumably responses, which we share and thus, experiences which unite us as human beings." [2] It is situated here, while gazing under the awe of the night sky, that our story of inservice science teacher development begins. In this experiential-based session, we will describe how our visit to Oodena became an inspiring context for re-envisioning astronomy education found in the Grade 9 curriculum to emphasize that the sky belongs to everyone. Moreover, with the sky being interpreted differently through cultural lenses, it is an opportune moment to teach broader ideas of social justice, inclusion, and empathy through ethnoastronomy. Using the 5E model [3] as a framework, we will describe our journey of meeting at, and introducing the underlying tenets of Oodena, through the elements of engagement, exploration, explanation, elaboration, and evaluation. In short, we gazed upon asterisms and learned stories of their origins and teachings emanating from local and global cultural knowledge. Together we noted the parallels of constellation constituents and marvelled at the unique starlore passed down from generations of oral history cultures. We identified places for these stories to find their way into our teaching and learning of astronomy. For us, this activity resulted in a collective re-envisioning of curriculum and pedagogical changes to be implemented in Grade 9 classrooms in Manitoba. At its heart, our re-imagining of how to teach and learn introductory astronomical concepts and phenomena can be an opportunity to connect scientific and cultural knowledge. This approach provides a greater richness of studying astronomy that more fully reflects the nature, dynamics, and multiculturalism of our curriculum and classrooms.

Keywords: Ethnoastronomy, Science Teacher Education, Science Teacher Professional Development, Astronomy Education

1. Introduction

Grounded in our desire to create a professional development (PD) opportunity that could bring together culture and science in complementary ways, we began with a common experience for all participants. We gathered at the Oodena Celebration Circle, a free, public space in our local community, to implement the following PD for teachers to develop new teaching and learning experiences that provide students with a more holistic science education. Articulated below through the tenets of the 5E model [3], we share with readers the PD event that we designed and invited inservice teachers to participate in.

2. Engage

"Where are we?" was the opening question posed to the large group of inservice science teachers (n=12) as we arrived at Oodena Celebration Circle. The purpose of this question was to capture the curiosity of this professional development experience being held outdoors under the clear-sky revealing flickering stars on the dark canopy overhead.

Prior to arriving at the learning site for our session, participants were asked to digitally visit curated online media to help generate questions and insights about both the overt and subtle reasons for our location.

The activating pieces were:

- Top Ancient Sites to Stargaze [4]
- Ask an Elder What does the winter solstice mean in the Cree tradition? [5]
- Indigenous Perspectives on the Solar Eclipse [6]

With these resources in mind, we sat in a circle on the grass and began a group discussion intended to raise questions about Oodena, and elicit new and long-held ideas about the sky belonging to everyone. With targeted questions about each of the activating pieces, participant responses meandered through descriptions of our physical location towards insights into the purpose and relevance of Oodena in our city, and country. Interestingly, this opening discussion merged into discussing the absence of multicultural perspectives in our science curriculum that go beyond a cursory comparison. The culmination of this opening activity arrived wondering if there were areas within our provincial wide science curriculum where ethnoastronomy [7] could be introduced. With our cell phones in hand for both its text and photo capabilities, it was time to explore Oodena.

3. Explore

The first aspect of this part of the session was an open invitation for participants to explore the grounds freely in a small group without any direct instruction. The purpose of this aspect was simply to begin to understand the physical layout and organization of Oodena such that it would serve as the context for our learning. A paper copy of the Oodena map [8] was provided to participants, and a digital copy was sent to them via email. While participants were exploring, our role as leaders in this activity was to casually join the groups to listen to participant interactions and ask probing questions as relevant opportunities arose. Further, our role also included assistance for logistical inquiries about the nature and layout of Oodena, and as consultants for more specific ethnoastronomy questions. Students were asked to record their observations, insights, and questions emanating from their exploration for further discussion later on in our session.

The second aspect of the Explore aspect was a teacher-guided inquiry [9] based on a jigsaw structure where groups studied one star formation, and then shared their insights with the larger group. Each group was provided introductory information [10, 11] about one constellation, and they were to use their devices to research a cultural interpretation of that star formation. After identifying one, the following guiding questions were used as prompts:

- *What is the significance of the star formation for those peoples?*
- *Is there a story connected to each variant of the constellation within that culture?*
- *What lesson may accompany the story? What does the story reveal about the culture; what background information did you research to guide your perception?*

Groups shared their findings, mostly in the form of the star stories, in a large group discussion later on in the session.

4. Explain

Before we began this section, we reminded participants that these star stories belonged to the cultures from which they exist, and that care and respect were needed when sharing. Moreover, while the three of us are from different cultural backgrounds, we did not pretend to belong to any background other than our own. We used this moment to initiate a conversation about tokenism, cultural appropriation, and the relationship between western modern science and cultural science.

In a large group setting, participants listened to other groups' presentations and constructed questions about their star formations and stories. Comments and inquiries ranged from learning from the star stories, to determining what time during the year were the constellations visible at the Oodena site. As leaders, we encouraged participants to identify personal resonance in the star stories. This activity allowed the participants to experience the learning as their students will, and gain insight into the possible questions and connections their students may bring up for discussion. Together, we developed a structure for a star formation journal participant would create that included notes, descriptions, diagrams, explanations, and relevant cultural connections emanating from our experience at Oodena.

5. Elaborate

After a break, and with work on participants' star formation journals beginning to take shape, we began the fourth part of the session. Here we extended the conversation to center on the pedagogical reasons for being at Oodena. Our focus was positioned on two independent streams. First, participants explored the provincial science curriculum to locate areas in astronomy education that would serve as places to integrate the knowledge learned at Oodena. Results of this focussed mostly on Grade 9, "Exploring the Universe" cluster [12], and the specific learning outcomes below:

- 9-4-3 Investigate how various cultures used knowledge of the position and motion of visible celestial objects for navigation.
- 9-4-4 Compare and contrast historical perspectives on the relationship between Earth and space. Include: geocentric model, heliocentric model.
- 9-4-7 Compare and contrast scientific and cultural perspectives on the origin and evolution of the universe.

The second stream was a more concentrated discussion about the role of introducing cultural science into the curriculum. We guided participants to generate large-scale questions about how this work has the potential to mitigate racism, build empathy, and create a sense of inclusion and safety for others in our classrooms. The richness of the conversation cannot be overstated. As this topic can extend to many pathways, it was critical for us to guide the conversation back to the tenets of effective and meaningful pedagogy. This section ended on a hopeful sentiment that we can teach science as a more inclusive discipline, and despite the magnitude of the issues discussed, there are actions we can take in the classroom to enact the change we advocate for.

6. Evaluate

In this concluding aspect of our session, participants worked in pairs to collate their new knowledge, insights, and ideas into generating learning plans for their classrooms. We chose pairs to reduce the vulnerability of sharing with PD facilitators for critical feedback as it became a small group conversation rather than a spotlight on their individual understanding of integrating cultural knowledge into science curricula. This also created a professional learning community for participants to connect with post-PD when enacting this in their class. This was designed to extend the learning beyond this session. In doing so, participants would use their new observations, evidence, and explanations in concert with their pedagogical knowledge to develop new teaching and learning experiences. While we did not formally evaluate the activities, we did provide critical feedback in a conversational and supportive manner aimed at strengthening each activity.

7. Conclusion

This professional development experience was grounded in the premise that the sky belongs to everyone [13] but our science curriculum only presents one perspective. This is very miopic. As such, we should be emphasizing the plurality of perspective in our classrooms where our students arrive from diverse cultural backgrounds. Hopefully this professional development activity helped demonstrate that like sky, our classrooms belong to everyone. In answering the question, "where were we", we unpacked concepts ranging from our place in the universe, to how we teach for inclusion and social justice in science. As teachers, we need to create a safe space for everyone to feel included and shine like the stars we saw that night at Oodena.

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Science and Society

Chemistry and Society: Peer-Review as Teaching and Evaluation Devices within a Multitude of Subjects

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Abstract

Chemistry and Society is a compulsory course for the first year of graduation in Chemistry and an optional for the third year of graduation in Biochemistry. In the last six years, it enrolled more than a hundred students in chemistry and the same number of students in biochemistry, with and an average of forty students per year. Students choose their themes with some mediation. Then, they present a pitch with their chosen subject as in a scientific meeting. The instructor acts as a chairperson and there are discussions within the class. After these discussions, the students prepare and submit a revision article with a special format (similar to a scientific journal). The articles are distributed among the colleagues that act as anonymous reviewers. After that, the article is corrected by the author, following (or not) the suggestions of the anonymous reviewer, explaining their reasons, and emphasizing the alterations. The third-year students, act as more mature researchers for the younger ones in the presentations. There are some lessons on finding scientific information, reading articles and books, delivering scientific subjects, writing and revising articles, and other relevant subjects. The final marks are based on the presentation, the revision of the article, and the article itself. In the last six years, parallel to the obvious subjects of sustainability, green chemistry, polymers in society, chemistry and literature, cinema, and various types of arts, chemistry in the war, new materials and drugs, and chemistry in the kitchen, we had some disruptive subjects as the chemistry of hate, religious rituals, homeopathy, and others. All these subjects are treated scientifically, based on evidence, critical analysis of existing peer-reviewed articles, and the revision of the articles. Also, all this fitted easily when the classes were online. The articles and revisions are submitted in specialized platforms by the University of Coimbra, which sends them to plagiarism software automatically. The exchange of articles and revisions is made by the instructor that acts as an editor. The results are very good in terms of marks and evaluation by the students.

Keywords: Soft-skills, Chemical awareness, Writing and analyzing scientific documents

1. Introduction

The importance of chemistry in society is non-questionable (e.g., [1-5]) but most of the time the general public judge it as abstract or difficult. The Royal Society of Chemistry has made a study [6] showing that misconceptions are due to chemists. Others think that chemophobia is real, but not to be contradicted in the usual form but by carefully analyzing the human deeds [7].

Chemistry and Society is a compulsory course for the first year of graduation in Chemistry and an optional for the third year of graduation in Biochemistry. In the last six years, it enrolled more than two hundred students from chemistry and biochemistry, with an average of forty students per year. This year it has 58 students (27 from chemistry and 31 from biochemistry).

2. Methods

After some discussion, students choose their subjects. Parallel to the obvious subjects of sustainability, green chemistry, polymers, chemistry and literature, cinema, and various types of arts, chemistry in the war, new materials and drugs, chemistry in the kitchen, Forensic chemistry, and chemistry in the outer space, they chhose some disruptive subjects as the chemistry of hate (in opposite to chemistry of love and happiness), specific religious rituals and drugs, homeopathy, human spontaneous combustion, and others.

Some subjects reflect personal experiences of the students, others a genuine want to know better, but others are suggested by general books (e.g., [2-5]) shown to the students or by presentations done by the instructor. A few subjects are somehow imposed (for students that do not choose one) or changed to others as students or the instructor judge them too banal or difficult. We must say that first-year students have some general ideas but lacks (of course) lots of knowledge about chemical activity and subjects, thus choosing utility or mediatic subjects. This is one of the roles of the instructor and the mediation is to show the hidden subjects to the final results. On the other side, third-year biochemistry students have a more “biochemical” mind, some of them are making their scientific stages, and tend to choose more specific subjects, some related to their scientific stages. Again, the role of the instructor is to guide the students.

The subjects chosen by the students were collected in the titles found in Table 1. Some are repeated or are similar and are not presented.

Table 1. Subjects that are chosen by students.

Chemistry and food	Molecular gastronomy and colloids, myths, diets, food preservatives, additives, pesticides in food, polyphenols, beer, pepper, piments, chocolate, coffee, milk, sweets, stevia, fast-food, natural toxicants.
Chemistry and medicine	Fighting fungi and bacteria, tobacco, anesthetics and pain, homeopathy and naturopathy, extreme conditions for human life, multiple sclerosis treatments, cortisone and steroids, caffeine, radiochemistry and radio drugs, benzodiazepines, medicinal THC, nutrition, phthalates in the environment, vitamins, chemotherapy, pill, menstrual products, palliative care, green chemistry applied to drugs, Alzheimer’s disease, tooth and dental treatments,depression, metals and metallic complexes, opioids in therapy, nanoparticles in medicine, cannabinoids in epilepsy, photodynamic therapy, diabetes.
Chemistry and energy	Chemistry of combustibles, bio-combustibles, biogas, ethanol, hydrogen, oil products, solar energy, nuclear fusion, nuclear plants.
Chemistry in the boudoir	Beauty, cosmetics, tattoos, makeup, baton, soap, hair treatment, dental hygiene, perfumes, detergents, essential oils, foam in hygienic products.
Forensic chemistry	Chemistry in forensic research, classical poisons: real and

	fictitious, old and modern poisons, natural and artificial poisons, explosives, the chemistry of dead, vitriol crimes.
Other technological and utility subjects	Optical fibers, carbon nanotubes, treatment and quality of waters, pigments and inks for houses, solar protectors, ammonia in agriculture, pigments and dyes, asbestos, paper, the substitution of CFC, sonochemistry, fireworks and green alternatives, swimming pools, plastics, ozonolysis, 3D printing, flame suppressors, photochemical applications, organic solar cells, green and biodegradable plastics, mines and contamination, anti-fire materials, remotion of nitrogen from waters, protection masks, glass industry, money, civil construction, the end of the chemical war, chemical weapons: inactivation and antidotes.
Chemistry explaining the world	Chemistry of emotions (love and hate), transgenics, entropy, vision, stress, allergies and intolerances, the effect of the increase of carbon dioxide, sleeping and dreaming, head transplant, the chemistry of evolution, epigenetics, color of the skin, hardness of materials, global warming, CRISPR Cas9, vanishing of coral reefs, fireflies, dopamine, vírus: chemistry and biochemistry, supramolecular chemistry, oxidative stress and antioxidants, mineralization of waters, Orion Galaxy, beginning of the universe, space exploration.
Local and very specific subjects	Production of saccharin beet in the Azores, Christianized ecstatic rituals, chemical popularization for hospitalized children, adrenoleukodystrophy in the film “Lorenzo oil”, imaginary substances with impossible properties in the literature, laboratory animal sacrifice, dimethyltryptamine.
General and historical subjects	Chemistry and economy and politics, music in teaching chemistry, chemistry in daily life, agriculture, chemistry and cinema, radiochemistry, material from the past and present, chemistry in Jules Verne, witchcraft and popular wisdom, ethical questions in research, the chemistry of the sea, sports, football, tennis, art preservation, restoration and conservation, green chemistry, sports, Egyptian mummification, plastics and circular economy, the chemistry of learning, benzene, alchemy, radioactive dating, recent findings of chemistry, nuclear chemistry, chemist’s biographies, chromium, patents, water mineralization, chemical pollution, computational chemistry and chemoinformatics, chemical weapons in the two great wars.

“Chemistry and war” and “chemistry of space exploration” are a class of subjects that are expected be more chosen, but somehow the students do not choose much this mediatic subjects and their chosing were included in other sets. The approximate timeline can be seen in Table 2.

Table 2. Approximate timeline of activities

Weeks 1-2	Choosing the subject, learn how to find information, about journals, editors, and authors, and how to write and revise an article
Weeks 3-8	Five minutes presentations (pitch) of the subjects plus ten minutes discussion Writing the revision articles based on the presentation and discussion
Weeks 9-12	Writing the revision articles based on the presentation and discussion
Week 13	Engage in the anonymous peer-review process
Week 14	Receive the anonymous revision of the written article
Week 15	Correct the article after the revision (the authors are not obliged to follow the reviewers but it is expected to reflect on their comments and answers accordingly) and responding to the reviewers' comments through the "editor"

The students present their subjects in a pitch of five minutes. Most of them conform to this schedule, but there are some with more material or do not control the time and use more time. The instructor gives some advice on this, as most of the time people are not allowed to have extra time. We have ten minutes for discussion (even for the ones that use extra time) but there is plenty of time to discuss the subject in classes or by e-mail. After this discussion. where the colleagues are encouraged to participate, the student chooses what to write on the article. Then she or he submit it to a platform where the documents are analyzed automatically for plagiarism. If there are some "red bells" the instructor analyzes the document and gives extra advice to the student. After being submitted, the article is sent to an anonymous referee within the class. The students are adverted which is non-ethical to reveal that she or he is the referee. The revision is sent and it is also evaluated. The students have some guidelines on evaluation. Finally, the student receives the revision and acts accordingly, correcting and submitting the final article.

The students are advised that if they find mistakes, they can correct them, and if they are not obliged to act according to the reviewer's advice, but reflect on their words. More, if they do not agree with the review, they can say it but politely. They are also informed that the final decision is of the editor, but there are some journals that the not allow discussion. The final mark is based on the presentation, writing and correcting the article, and the revision. There are some studies similar, where the evaluation is based on peer-review [8, 9].

Of course, we can have some drawbacks. If students do not do each of the three things normally are not allowed to pass. Also, if some reviewers surpass the time scheduled, the instructor makes the revision itself for the student to have the opportunity of passing to the next phase. But this is very rare.

3. Conclusions

The marks are in general very good, there is a genuine enthusiasm of the students, and their evaluation of the course and the instructor is very good. We believe that this course is valuable for developing their soft-skills and through life.

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Educational Mobilization of the Society: Gülen Movement

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Abstract

Maria Montessori, Rudolf Steiner and John Dewey were some of the famous intellectuals who created innovative educational school concepts and fascinated and motivated societies to found private educational institutions in the last century [1]. Today, Fethullah Gülen, Turkish Islamic Scholar and the founder of the so-called Hizmet (Service) Movement, which is also known as the Gülen Movement, also impressed millions of people to found educational institutions inside and outside of Turkey in the last five decades [2]. Through the internationalization process of the movement after the Soviet Dissolution, different Gülen inspired educational institutions were also founded outside of Turkey and expanded this type of schooling to the world [3]. The purpose of this paper is to describe the progressive education model of these Gülen inspired schools and to examine the methodology of Gülen during the mobilization of the society to found such a kind of educational institution. A qualitative research design is used to study this issue. Semi-structured expert interviews are conducted with managers of the Gülen Inspired Schools from three continents: Europe, Africa and the US and scientific experts of the subject. The results show that the education model of Gülen inspired schools depends on reforming the management of a traditional education system, instead of reforming teaching or pedagogy. This new type of management is based on a philosophy of "Global thinking, Local acting" and managers of these schools accomplish this philosophy in three steps such as cooperation and collaboration with the local environment, contributing to local needs or solving local problems and building international connections and partnerships. Through these steps, educational systems in these schools are based on global, secular, moral and ethical values, instead of religious values, but at the same time they empower the local cultural values through international contests. The participation of the community with this type of schooling and the connection between Gülen inspired schools and society is also described in this paper.

Keywords: Gülen Inspired Schools, Financial Mobilization, Human Resources, Globalization

1. Introduction

Especially after the end of the Cold War, financial and economic relations between countries worldwide increased and the economist Theodore Levitt described this change in global economics affecting production, consumption and investment with a new Term "**globalization**" [4]. Gülen, who already canalized his followers to the private education sector and schooling since seventies, saw this trend in the early nineties and motivated his followers to expand a similar type of STEM based private schools all around the world. Depending on the growth and quantitative expansion, it could be said that Gülen inspired schools and tutorial centers have a significant success worldwide in private schooling sector in the last three decades. How Gülen and his followers achieved this success and what's the common features of these schools in depending on financial structure, Human Resources and global schooling strategy are some of the research questions of the researcher in his PhD studies from 2016 to 2020 [5]. This paper is an expansion of the results of this research and adds several new perspectives to this controversial subject.

2. Results

Unlike the religious schools in Turkey, so-called *Imam Hatip Lisesi*, and despite Gülen's religious background, the major difference of this type schooling is its strong structure based on global ethical values, instead of religious values and science education with different STEM courses [6]. The first remarkable feature of these schools in STEM education is their modern facilities with high tech labs. All nine visited schools have laboratories and they use modern technology like smart boards in their classrooms.

"So, the normal schools and the Gülen schools are similar. The Gülen schools are even better. They use modern pedagogy, everything possible and modern technology".

Said Expert 8, who criticizes the movement from different perspectives.

Of course, as it is easy to predict, to realize such a kind of project, the movement needs financial sources first. Later, such kinds of institutions have to be run by teachers and administrators with good experience and quality. In addition to these points, a wise clear global strategy is also needed to keep the movement's schools in a high position in global competitions. It was observed in the field study that the management on these three components supports the success of the Gülen inspired schools.

2.1 Financial Mobilization of the Society for the GIS

From a sociological perspective, Ebaugh researched the Gülen movement and asked how Gülen convinced the society to invest in the educational projects of the movement [7]. As a result, she found that Gülen had a reformist approach to Islam and interpreted basic Islamic financial practices in a new form. As a concrete example "*Zakat*" or almsgiving to poor people, is one of the five pillars of Islam, and Gülen motivated his followers to invest these almsgivings to poor students in GIS as a scholarship. Similarly, other Islamic practices like "Sadaka" (Charity), "*Himmet*" (To help), "*Vakif*" (Foundation), "*Kurban*" (Sacrifice fast) etc … are recreated by Gülen in his speeches which mobilized the Turkish society to invest more on educational projects of the movement in and out of Turkey [8]. On the other hand, it was observed during the field study that, such a kind of contribution has a crucial role only during the first few years of these schools. Later on, it was expected from all schools to finance themselves with tuitions and expand their activities with the profit that they achieved because of their work [9].

In addition to Islamic roots and religious practices, there are two other common features behind the financial mobilization of the society for the educational activities of the movement such as trust and consultation. It was observed in the field study and also in previous research that Gülen himself and his followers have pious lifestyle without any luxury [10] and the financial transparency in these institutions is one of the core focal points of the movement in their projects. Therefore, the society trusts these organizations and supports them financially. Besides, it is clear to see that Gülen presents different projects for different time frames depending on the conditions of the movement and the needs of the environment. Instead of dictating, Gülen discusses his ideas with his followers and makes common decisions which make sense in his follower's minds and they internalize his vision [11]. Consequently, success is seen more in movement activities and loss is very rare because of the realistic and common approach of the projects.

2.2 Human Resources Mobilization for the GIS

The second important issue is to find or recruit the teachers and administrative staff in these schools. Among many other different problems in Turkey, Gülen is concerned about the small number of educators and, due to the lack of educators, for the future of Turkey [12]. Therefore, the first expert participant of the field study, who is a very close follower of Gülen, mentioned that for more than three decades they encouraged their good students to study at the educational faculties of the universities. Besides, the second school manager participant of the study has a computer engineering degree, but because of the need, he later studied educational sciences in his Master and shifted to the education sector. As a result, the movement gained an educational staff who both know Gülen's philosophy and their qualifications before the international expansion part.

According to first expert participant of the study, through the international expansion period of the movement, these teams used the network structure of the movement and moved to the different regions of the world. Therefore, the staff in GISs in Turkey, first moved to Middle Asia and then to the other parts of the world, except Europe. In the field study, it was observed that in general teachers and educators of the movement in Europe are the children of the immigrants of the Turkish minority. Therefore, in comparison to the other parts of the world, the movement first expanded the immigrant Turks, which is the important minority in Europe first, and then they targeted the majority of the society.

In one way or another, initially these teachers and administrators cooperated with the local authorities and founded these schools together. Previous studies demonstrated that the majority of the teachers in GISs outside of Turkey consists of local people who have very little knowledge about Gülen and his philosophy [13]. In the field study in nine schools on three continents, such as Europe, Africa and the U.S., the average of these local teachers makes almost 75% of the whole teaching staff. The question in this point is how the movement practices its educational philosophy with these 25%. As an answer to this question, it was observed in the field study that a common school culture was created where everybody comes together on a common ground in the school environment. The third school manager participant from Europe explains this issue as follows: "The difference between the two (Turkish Teachers and local teachers) was much more, but now the differences are decreasing. So, these two reasons may be, foreignization of Turkish teachers or Turkification of foreign teachers. As time goes by and it is understood from both sides. They approached each other with a little understanding on both sides".

2.3 Global thinking and Local Acting Strategy of the GIS

According to different studies GISs are founded by local foundations or local associations, mostly consist by Gülen followers and despite this common culture and principles, the schools do not have any financial or organizational connection to the other GISs around the world or to Gülen himself [14]. Therefore, it is impossible to find any information about Gülen and his movement in the website of these schools or in their advertisement campaigns. Such a practice is criticized by several scholars like Hendrick who describes Gülen by using the word "ambiguous" [15]. However, especially after the failed coup attempt in Turkey in 2016, political pressure on the Gülen movement [16], human rights violations against Gülen followers in Turkey [17] and several kidnapping activities of Turkish Secret Service against the teachers of GISs out of Turkey [18], demonstrated that there is an important reason behind this practice. Actually, Gülen witnessed the pressure of the State on the minorities in Turkey [19] or the coups history of the early Republic in his adolescence and early career. Later, being aware of the undemocratic structure of Turkish State, he tried to protect his followers and their institutions through a secretive strategy since it was founded. On the other hand, Gülen was aware that there could be people who could be upset about his secular, ethics-based education philosophy, which is focused on science and STEM education in GISs, just because of his background as an Islamic scholar. To remove these obstacles, Gülen and his movement could prefer to use this practice.

It is difficult to analyze the exact reason behind this practice, but in one way or another, especially after the failed coup attempt, the GISs worldwide left their Turkish identity and act like local schools in their region. As a concrete example, two schools in the field study changed their names and prefer to use local names like the name of their region or the name of a famous thinker or writer who lived there before in their schools.

Besides, GISs have a very close relationship with local authorities in their regions and; therefore, they are aware of local conditions and needs. As an example, GISs in Africa conduct several charity activities and try to contribute to their poor local environment. Schools in Europe and in the US have different activities to fulfill different gaps in their regions. Despite this more localization strategy, the network structure of the movement allows these schools to build national and international cooperation's with each other in ease. Specific experiences and know-how extend easily to the other GISs and these schools sometimes cooperate with each other in different fields like human resources management or financial investments [20]. Consequently, GISs practice global thinking and local acting philosophy in their schools and have a clear advantage to the other schools in their regions in local and global competition.

3. Discussion

As a final word, Gülen envisioned an education system depending on global ethical values on the one hand and science, technology and modern education methods on the other hand. From different perspectives it is clear to see that Gülen and his movement realized and practiced this vision perfectly inside and outside of Turkey. In this paper, only three components of the methodology like financial mobilization, human resource mobilization and global network connection of these schools are analyzed. In addition to these points, due to its fifty-year history in private schooling, the movement also has a rich experience in the private education sector and are very professional in their job.

Consequently, because of mentioned reasons, despite the loss of some schools in some countries, which have a close political connection with Turkey [21], GISs worldwide could stand against the political pressure of the Erdogan regime since 2016 and in the field study it was observed that the impact of the pressure is gone today. Depending on these conditions, it could be said that the movement and their schools transformed their identity by leaving their Turkish roots and becoming more local and decentralized in the future.

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Hannah Arendt's Philosophical Thoughts on Plurality as Theoretical Foundation for SoTL Projects

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Abstract

Scholarship of Teaching and Learning (SoTL) is both a theory and a movement in higher education. [1] The idea behind the concept is for academics who work as teachers and tutors to analyze their own teaching habits by means of scientific inquiry, turning their personal experiences in higher education into the subject of their own research. Addressing specific challenges, they face as teachers from the perspective of their own academic discipline, they can develop research-based solutions to real-life problems – and, of course, critically discuss them with their colleagues. This way, SoTL creates a strong connection between teaching and research which is meant to improve the overall quality of higher education by application of a more scientific approach to teaching. [2] As SoTL research can be conducted across all academic subjects, many different approaches and methods are used to research teaching and learning in the different fields of higher education. Although it provides researchers with a wide variety of ideas and data, this very diversity within the field of SoTL also makes it hard for some researchers to understand and appreciate SoTL projects with a very different approach. [3] Our research centers around this diversity debate, focusing on the question whether the basic tenets of SoTL may not already entail a certain plurality of theories. By reconstructing Hannah Arendt's thoughts on plurality [4] and applying them to SoTL, our essay will therefore show to what extent Hannah Arendt's thoughts on plurality can provide a theoretical foundation for the diversity of SoTL projects.

Keywords: Scholarship of Teaching and Learning (SoTL), Hannah Arendt, plurality, diversity

1. Introduction

First introduced in the 1990s, SoTL has long since evolved into an established and widely implemented approach to higher education. Today, it is used to improve the quality of higher education at universities all over the globe. However, there have always been critical voices, too, some even going as far as to call SoTL *a thorn in the flesh of educational research* as it tends to be used not only for initiatives which match the concept's original intention: "much of what is represented as being in the scope of SoTL is unpublished, not available to critical evaluation, not disseminated beyond its original context and unconnected with any previous literature and scholarship". [5] In the light of this opposition, Schmohl recently called credible SoTL research an alternative to so-called "vulgar didactics" within post-secondary education. [3, 6] He characterized SoTL as a way to counter a currently widespread, trivializing attitude towards didactics. In their 2020 article, Canning and Masika present a similar view. After analyzing the recent use of SoTL as the theoretical groundwork for more and more trivial projects, they even draw the conclusion that SoTL should be "thrown on the ash heap of educational history" in order to pave the way for more scientific forms of research on higher education. [5]

The fundamental idea of SoTL is that university teachers can and even should analyze their own approach to didactics by means of scientific inquiry. Through examination of the specific challenges, they face in higher education, professors gain a deeper understanding of how their students learn – and of their own contribution to this process, providing a new perspective on the impact of familiar models and strategies in higher education. At the same time, teachers benefit from a very strong feedback loop within the community of researchers sharing this approach. One of the cornerstones of SoTL is that both publication of the results and discussion with other scientists and educators is considered *conditio sine qua non*: Every project is meant to be shared and discussed, providing new impulses for everyone involved. This way, SoTL combines teaching and research with the main goal of improving the quality of teaching in higher education by sharing new information and ideas. [2, 6]

According to educational scientist Huber, an important condition for getting involved with SoTL is the genuine desire for exchange with other academics teaching in higher education. [7] At the same time, this desire represents a challenge whenever SoTL researchers try to transfer approaches and methods developed to teach very specific subject matter to another academic discipline: SoTL researchers may find that methods which have proven successful in one field may turn out incompatible with other subjects, not due to a lack of flexibility inherent to the model transferred, but due to vast differences between subjects and students' way of approaching them. As SoTL projects are often interdisciplinary efforts – or, at least, reviewed by academics from very different fields – this can lead to uncertainty and disagreements about the quality of SoTL projects.

Therefore, many experienced SoTL researchers today emphasize that a model or a set of guidelines should be part of any SoTL project in order to standardize findings and provide direction to those looking to apply and review them. [2, 6, 7] Nevertheless, SoTL is characterized by the fact that scholars from different disciplines can explore their subject-specific teaching and must therefore always allow for a variety of different approaches.

Although guidelines are necessary, it is equally important for researchers participating in SoTL projects to be able to appreciate the plurality within the field.

In this essay, we aim to provide a fresh perspective on the diversity of SoTL projects.

First, we outline the main SoTL characteristics: openness, diversity and plurality.

Second, we analyze to what extent Hannah Arendt's writings on plurality can be applied to SoTL. Our goal is to show how political philosophy can be used to improve educational research. Concerning its methodology, this essay uses both a hermeneutic perspective and an interpretative approach in which Arendt's thoughts on plurality are reconstructed and placed within an SoTL context.

2. Openness, diversity and plurality: basic concepts of the SoTL movement

The story of what today we call SoTL begins back in 1990 with educational scientist Ernest Boyer deploring the then-low status of learning and teaching in higher education, especially in comparison with other academic activities. [8] Boyer's ideal of "being a scholar" does not only entail great skill in discovering new insights by scientific means, nor is he content to merely remind academics that integration and application of their research must be the next step. Boyer also considers *education* to be of great importance for any true scholar – the education of others, that is. He argues that everyone working in academia should not only be skilled as a teacher but also possess a professional attitude towards teaching.

"Going public" with one's own considerations and one's research into the theory and practice of teaching and learning is considered an inherent part of this professionalism:

"The scholarship of teaching is about improving student learning within the discipline generally, by collecting and communicating results of one's own work on teaching and learning within the discipline". [9]

Thus, the "openness" to create exchange and dialogue within the community has always been considered crucial for the SoTL movement. As Shulman points out, this also means that teaching – as seen through the lens of SoTL – must be regarded as some sort of scholarly "community property that can be shared, discussed, critiqued, exchanged, built on". [10] Trigwell *et al*., use a model which sorts SoTL activities into four categories of how communication on teaching can be organized (e.g., by informal conversations, reports, white papers or by publication in academic journals). [9]

Bernstein and Bass, on the other hand, describe less formally structured ways to document and publish inquiry into student learning, stating that SoTL researchers need "to imagine new genres for sharing insights that are much broader than our current models of publishing". [11]

Felten, in turn, emphasizes the particular framework necessary to appropriately present SoTL research:

"Because SoTL inquiry typically is iterative and highly contextual, the most appropriate ways to go public should capture and reflect the evolving nature of this form of research. In many cases, that is not possible in a traditional scholarly journal". [12]

Due to their open and diverse character, SoTL projects can vary greatly and provide a diverse set of answers to the same questions. *Openness* within the framework of SoTL must therefore refer to two different ways of putting the SoTL mindset into action. On the one hand, it means that teachers share their approach or methods with the public, e.g., in the form of *open educational resources.* On the other hand, openness must also entail a community to support scholarly discourse on teaching, e.g., by means of publications or conferences. Therefore, scholarly teachers should aspire to an attitude that both enables and values feedback offered by peers and students alike (through evaluations, colleagues observing classes or peer supervision). [2]

Since the ideas that underlie each academic discipline's perspective on education are based on heterogeneous epistemologies, methods and concepts, the way these SoTL values translate into research – and, in the long run, back into higher education – may greatly vary from one SoTL project to another. This is why engaging in conversation on teaching and learning across the disciplines as part of SoTL confronts participants with great *diversity*.

In order to deal with this challenge, it is important for SoTL researchers to deal constructively with the complexity and ambiguity of educational research. From data collection and organization to interpretation and discussion, they need to keep an open mind – in their own inquiries as much as with regard to the work of other scholars in the SoTL community. [6] In this light, SoTL can be regarded as a pluralistic concept which emphasizes scientific diversity. Moving on this consideration, the next chapter will explore how theoretical assumptions on plurality by the German political thinker Hannah Arendt provide a theoretical basis to address diversity and openness of SoTL.

3. Hannah Arendt's philosophical reflections on plurality as a theoretical foundation for SoTL projects

Plurality is a central element in Hannah Arendt's political theory. In her book "The human condition", Arendt identifies *equality* and *diversity* as the main conditions of human action. Since all humans belong to the same species and are able to understand each other due to a common way of using language, we are “equal”. Yet, at the same time, we are “diverse” because each individual is irreplaceable and each one has a unique perspective on shared issues or concerns. Taken as a whole, these perspectives can be described as human plurality: “Plurality is the condition of human action because we are all the same, that is, human, in such a way that nobody is ever the same as anyone else who ever lived, lives, or will live.” [4]

Applying Arendt’s theoretical considerations to SoTL projects, we can easily identify both equality and diversity as what drives the community: All SoTL researchers are equal in their goal of laying the scientific groundwork for their own teaching. [1, 6] At the same time, their diversity is reflected in their different disciplines, their personal teaching experiences and research methods. [6] In addition, SoTL projects are always framed in a specific context, which makes each project unique. [7] Thus, SoTL projects can be described as a collection of diverse perspectives on the study of teaching experiences – a collection which we can, in turn, describe with Arendt’s concept of plurality.

According to Arendt’s political theory, *the public sphere* is the place where people can present and discuss their different perspectives. [4, 13] In this regard, Arendt is inspired by ancient Greece and its ideal of a state in which citizens can interact as free and equal individuals. “Being free”, in this context, means that there are no (allegedly) necessary activities keeping people too busy to exchange ideas with others. For example, in ancient Greece, labor was a necessity that led to lack of freedom. [13] At the same time, Arendt also understands the concept of being free and equal in the sense that no one rules or is ruled by another. [4, 13]

SoTL researchers can enter the public sphere by publishing their projects or by engaging in scientific discourse through conferences. However, it remains unclear to what extent SoTL projects can remain detached from the necessities of life, considering that they are created by teachers as part of their work in higher education. Nevertheless, it could be argued that SoTL projects are not, strictly speaking, part of the necessary occupations of these academics. This would make them optional projects based on genuine interest – an assessment which certainly holds true with regard to publishing and discussion among SoTL participants. [2, 7] The desire for exchange with other teachers [7] and discussions about SoTL projects [2] are also very compatible with Arendt’s theoretical considerations and suggest communication structured by the principle of equality.

There is, however, one more critical issue related to plurality: It is not always easy for individuals to accept a variety of views and, in the case of SoTL, to respect diverse research methods and procedures. Arendt advocates acknowledging different perspectives presented in the public sphere and at the same time emphasizes the importance of maintaining one’s own position – as long as it is logically sound. [14] In order to live plurality, the ability to think in terms of other approaches and to use one’s imagination to comprehend them is crucial. [15]

These theoretical considerations also appear useful for making SoTL researchers aware of the inherent plurality of SoTL, reminding them to keep an open mind when facing different approaches to research. At the same time, however, it is still important that SoTL research meets certain scientific standards. The development of guidelines and models for SoTL projects thus seems to be just as important as appreciation for the plurality within the community.

4. Conclusion

This paper has shown that Arendt's thoughts on plurality can, in principle, be successfully combined with SoTL, applying the different aspects of Arendt's theories to SoTL in order to gain a new understanding of the inner workings of both projects and community. However, it also becomes clear that certain aspects, such as freedom from the necessities, seem worthy of further discussion, and that Arendt's theoretical considerations about plurality cannot always be easily adapted to SoTL. In order to make an overall statement about how Arendt's theoretical reflections on plurality might provide a theoretical foundation for the SoTL concept, more in-depth research is required.

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New and Challenging Perspectives in Science Education: Relationship between Involved Parties, Intellectual Property and Intellectual Capital, and Steps Identified in Intellectual Capital Study

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Abstract

Nowadays, due to individuals' continuous seek for discovering and implementing winning sustainability strategies for organizations worldwide, specialists have identified a distinct need for addressing new and challenging perspectives in science education. Under these given circumstances, organizations prime concern should become the relationship between involved parties, intellectual property and intellectual capital, thus being able to focus on interesting practices capable of promoting responsible science education – as required by the European Commission's expert group on science education. In addition, there exists a distinct concern to transform all organizations towards a more sustainable business model, which leads to the importance of identifying the steps in intellectual capital study, thus maintaining organizations' competitive edge and ensuing performance of organizations' sustainability programs. This research is aimed at presenting, on the one hand, new and challenging perspectives in science education and is centered on identifying, on the other hand, new and coherent business strategies during the global pandemic, based on discoveries emerged from the organization's intellectual capital study. Also, this work is intended to present the implications of the COVID-19 pandemic progress in refining the organizations' methods for solving key financial problems, analyzing alternatives in decision making, formulating value-maximizing competitive strategies and taking a value-based approach to marketing management relevant business skills. The research methods used in order to generate the data acknowledged in this paper refer to both quantitative and qualitative analysis, namely: data selection and evaluation, descriptive statistics, survey and questioner design, and interview design and techniques.

Keywords: Intellectual capital, human capital, performance, higher education institutions, intangible variables, quality of education, science education, economics education, quantitative and qualitative analysis

1. Introduction

Recent developments in the field of economic sciences and business administration have led to a renewed interest in analyzing and explaining the complex changes that take place nowadays in our society especially as a result of individuals' continuous seek for discovering and implementing winning sustainability strategies for organizations worldwide [13, 14].

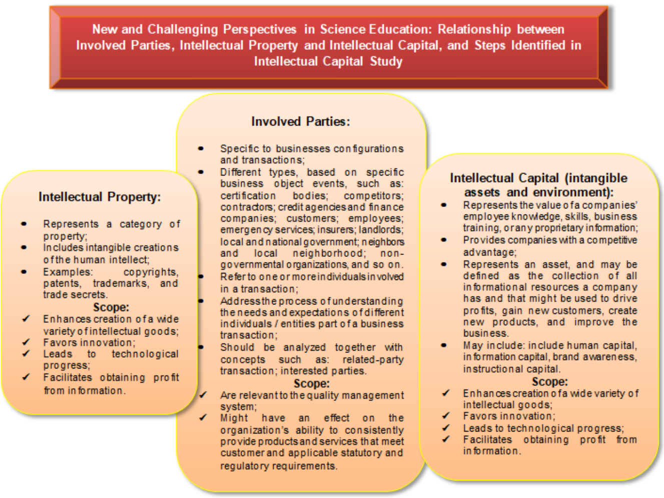
In this matter, reputed specialists have identified a distinct need for addressing new and challenging perspectives in science education, especially in the context in which organizations prime concern should become the relationship between involved parties, intellectual property and intellectual capital, in this way being able to focus on interesting practices capable of promoting responsible science education – as required by the European Commission's expert group on science education [3, 4].

As a consequence, there exists a distinct concern to transform all organizations towards a more sustainable business model, which leads to the importance of identifying the steps in intellectual capital study, thus maintaining organizations' competitive edge and ensuing performance of organizations' sustainability programs, and striving to understand the implications derived from the influence of intellectual capital, human capital, and intangible variables, on performance, in general, and on higher education institutions, quality of education, science education, economics education, in particular (by using also the instruments of quantitative and qualitative analysis) [1, 2].

2. Literature review

A large and growing body of literature has investigated contemporary economy through a multiple perspective: firstly, focusing on new and challenging perspectives in science education; secondly, addressing the relationship between involved parties, intellectual property and intellectual capital; and thirdly, emphasizing the steps identified in intellectual capital study (see Figure 1) [5-9].

Fig. 1. Relationship between Involved Parties, Intellectual Property and Intellectual Capital



Legend: This figure underlines the main components that constitute the relationship between involved parties, intellectual property and intellectual capital

3. Methodology

To date, various methods have been introduced and described to measure the new and challenging perspectives in science education, with a particular accent on the relationship between involved parties, intellectual property and intellectual capital, and with a keen interest in stressing the steps identified in intellectual capital study [6-14].

This study is aimed at presenting, on the one hand, new and challenging perspectives in science education and is centered on identifying, on the other hand, new and coherent business strategies during the global pandemic, based on discoveries emerged from the organization's intellectual capital study. What is more, this work is intended to present the implications of the COVID-19 pandemic progress in refining the organizations' methods for solving key financial problems, analyzing alternatives in decision making, formulating value-maximizing competitive strategies and taking a value-based approach to marketing management relevant business skills. Thus, the research methods used in order to generate the data acknowledged in this paper refer to both quantitative and qualitative analysis, namely: data selection and evaluation, descriptive statistics, survey and questioner design, and interview design and techniques.

4. Data analysis and discussions

In terms of data analysis and discussions this scientific paper suggestively entitled "New and Challenging Perspectives in Science Education: Relationship between Involved Parties, Intellectual Property and Intellectual Capital, and Steps Identified in Intellectual Capital Study" points out the valuable results obtained using data selection and evaluation, descriptive statistics, survey and questioner design, and interview design and techniques in both public and private higher education institutions in Romania (see Figure 2 and see Figure 3) [19-24].

Fig. 2. New and challenging perspectives in science education: steps identified in intellectual capital study

Legend: This figure underlines new and challenging perspectives in science education and steps identified in intellectual capital study in both public and private higher education institutions in Romania

Fig. 3. A scientific model capable to value intellectual capital in higher education institutions

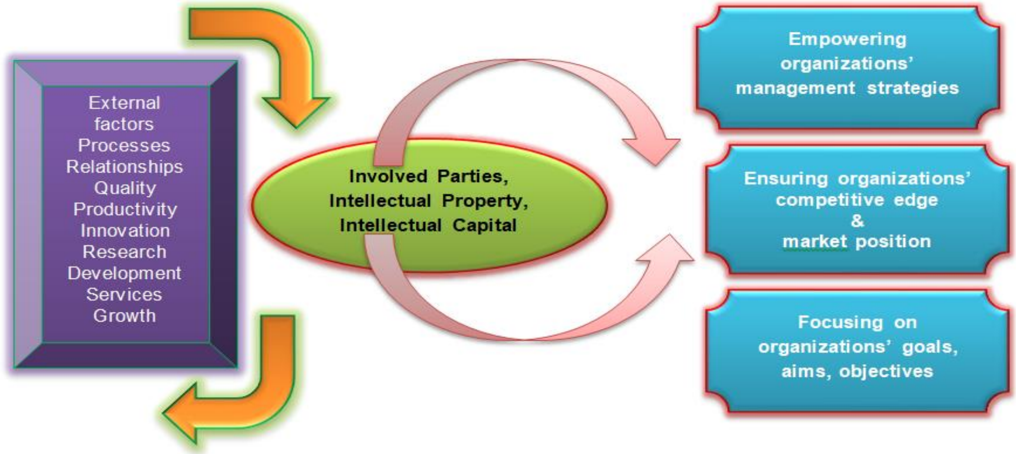
Legend: This figure describes a scientific model capable to value intellectual capital

5. Conclusions, limitations and future work

The general conclusions of this study are shown in the figure below (see Figure 4).

These results come to complete previous works and research on involved parties, intellectual property and intellectual capital [1-3], as well as the interpretation of steps identified in intellectual capital study in our knowledge-based society [14-24].

Fig. 4. Conclusions: Importance and role of involved parties, intellectual property and intellectual capital, and key steps identified in intellectual capital study in our knowledge-based society



Legend: This table underlines the results derived from analyzing the importance and role of involved parties, intellectual property and intellectual capital, and key steps identified in intellectual capital study in our knowledge-based society

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RAWsiko – Materials around us: A Digital Serious Game to Teach about Raw Materials' Importance for the Transition towards a Low-Carbon Economy

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Abstract

Today some raw materials (RMs) have become essential in the manufacturing of common goods and technologies we use every day. Readily accessible RMs, such as rare-earth-elements, indium, neodymium, etc., are important to EU industries and allow the transition towards a low-carbon economy. With the future global resource use projected to double by 2030, addressing raw materials through the entire value chain becomes a priority as well as transferring these ideas to youngsters. "RAWsiko-Materials aroud us" is a serious videogame developed in the framework of Raw Matters Ambassadors at Schools, a European project funded by EIT RawMaterials, with the aim to offer teachers an educational tool able to increase student awareness of the current societal challenges for a sustainable innovation by using an innovative approach. RAWsiko is focused on RMs important for the EU economy but at risk of supply, their distribution in the world, their use in the modern technologies and why access to them is pivotal for European economy. The players can experience the complexity of the raw material supply that occurs behind some everyday life devices such as flat screens and lamps, but also behind the equipment for the transition to the renewable energies such as photovoltaic panels and wind turbines.

RAWsiko can be a support to teach science, technology, and citizenship in a funny way by involving students from 11 to 19 years old and contributing to disseminate the issues of the European Green Deal and the Sustainable Development Goals of the United Nation Agenda 2030.

Such knowledge and awareness among the younger generation is indispensable to secure sustainable success in the European raw materials sector and will help to create a new generation of people skilled in entrepreneurship and raw materials, and respecting our Earth.

Keywords: raw materials, gamification, sustainability, secondary school, cross-curricular learning, serious game

1. Introduction

In human history, every technological progress has always resulted in the use of an increasing number and larger quantities of materials. In the Nineteenth Century, the Industrial Revolution started to produce goods in large scale with a huge use of fossil fuels and raw materials (RMs), but also allowed a large availability of food thanks to new synthetic fertilizers.

In fact, the Haber-Bosh process, invented at that age, enabled to produce ammonia from atmospheric nitrogen, whereas other processes enabled to convert bones first, then phosphate rocks in soluble phosphate useful to enhance the food yield per surface unit of the fields. These two aspects induced an exponential growth of the human population in the world.

The last leap occurred at the end of the past millennium with the miniaturization of electronics and the new devices for communication technologies and renewable energies. The accelerating technological innovation, the increasing world population, and the rapid growth of emerging economies are leading to an increasing demand for a great number of RMs. If the current consumption trend does not change, many metals will not be available anymore in the near future.

Today a large number of RMs are becoming a concern for the production of a broad range of goods and devices of the everyday life (i.e., mobile phones, flat screens, fluorescent lamps, etc.), for the transition to renewable energy (i.e., wind turbines and photovoltaic panels) and for strategic industrial sectors (i.e., telecommunications, defence, nuclear). In particular, the accelerating technological innovation and the fast growth of emerging economies have led to an increasing demand for a great number of metals and minerals that are crucial also for fostering the European economy.

Unfortunately, up to now few people know it.

The European Union (EU) does not have sources of these RMs belonging to the non-renewable resources of our planet, and in a near future their foreign supply will be at risk [1] so, the European Commission has launched an initiative to reduce the dependence of its economy from the import of raw materials since 2008 [2]. Three years later the EU published the first list containing 11 critical RMs, that became 20, 27 and 30, respectively in 2014, 2017 and 2020 (

Table 1. List of the critical raw materials 2020) [3]. The main part of these critical RMs are single chemical elements or their minerals, some of them are groups of metals; in summary the critical RMs represent 46 chemical elements, which is half of the natural ones.

Table 1. List of the critical raw materials 2020

Antimony (Sb)	Germanium (Ge)	Platinum Group Metals (PGMs)*
Baryte ($BaSO_4$)	Hafnium (Hf)	Phosphate rocks (P anions salts)
Bauxite (ore 40% Al)	Heavy Rare Earth Elements (HREEs)#	Phosphorus (P)
Beryllium (Be)	Lithium (Li)	Scandium (Sc)
Bismuth (Bi)	Light Rare Earth Elements (LREEs)°	Silicon metal (Si)
Borate (B anion salts)	Indium (In)	Strontium (Sr)
Cobalt (Co)	Magnesium (Mg)	Tantalum (Ta)
Coking Coal (mainly C)	Natural Graphite (C)	Titanium (Ti)

Fluorspar (CaF_2)	Natural Rubber $(C_5H_8)_x$	Tungsten (W)
Gallium (Ga)	Niobium (Nb)	Vanadium (V)

**PGMs: Ruthenium (Ru), Rhodium (Rh), Palladium (Pd), Osmium (Os), Iridium (Ir), and Platinum (Pt).*
#HREEs: Europium (Eu), Gadolinium (Gd), Terbium (Tb), Dysprosium (Dy), Holmium (Ho), Erbium (Er), Thulium (Tm), Ytterbium (Yt), and Lutetium (Lu).
°LREEs: Scandium (Sc), Yttrium (Y), Lanthanum (La), Cerium (Ce), Praseodymium (Pr), Neodymium (Nd), Promethium (Pm), and Samarium (Sm).

To overcome the concern for RMs, EU is setting the transition to the circular economy [4] that aims to give a use-life as long as possible to goods promoting the reuse and the recycling of the goods and their components in order to reduce the use of primary RMs.

This change from linear to circular economy needs EU citizens to be aware of the criticality of RMs for strategic industrials sector, including the transition to the renewable energy. To trigger the students' interest in raw materials and a sustainable society, the European Institute for Innovation and Technology (EIT), the largest consortium in the raw materials sector worldwide, is funding an educational project titled Raw Matters Ambassadors at Schools (RM@Schools), led by National Research Council of Italy (CNR) in collaboration with 22 partners across Europe, which aims to propose to pupils aged 10 to 18 years an active learning by using different approaches [5, 6]. Among them, the use of serious games.

Educational games can fulfil these two aspects, not only with the simulation of experimental activities, but also with role play games [7] that promote curricular knowledge (chemistry, geography, technology) and soft skills as well, very appreciated in the current labour market. Moreover, gamification in education has successfully proven in many contests to increase the engagement of the pupils by means of rewards and feedback [8] and it is used from primary, to middle, to high schools [9, 10].

Nowadays, with the wide engagement of pupils and teenagers by new media and communication technology, gamification is moving from the shelf to the web.

Thus, to catch the interest of youngsters and open a dialogue/reflection with them a serious videogame focused RMs relevant for technological innovation and the rapid growth of emerging economies was set up and developed. RAWsiko-Materials around us are teaching resource which outlines how teachers can bring these topics, which are relevant to everyone in society, in particular young people, into their lessons (it is available for free at the site: https://arraise.com/rawsiko/).

2. RAWsiko – Materials Around Us

Here we present an educational videogame titled "RAWsiko – Materials around us" [11] that aims to increase, in a digital and funny way, the awareness of teenagers about the geographical distribution of RMs in the world (Fig. 1), their importance for some strategic technologies, and the complexity of their supply to the EU industrial system.

It is possible to play RAWsiko by using personal computers, tablets or mobile phones downloading a resident free software (Microsoft Windows 8 or higher version, Android) or a web version online through an internet browser. Digital RAWsiko can be played simultaneously by 100 players, and each game can involve 3-5 players that can play on the same device or online in remote mode by the browser, in the last case communications is possible thanks a chat embedded into the game.

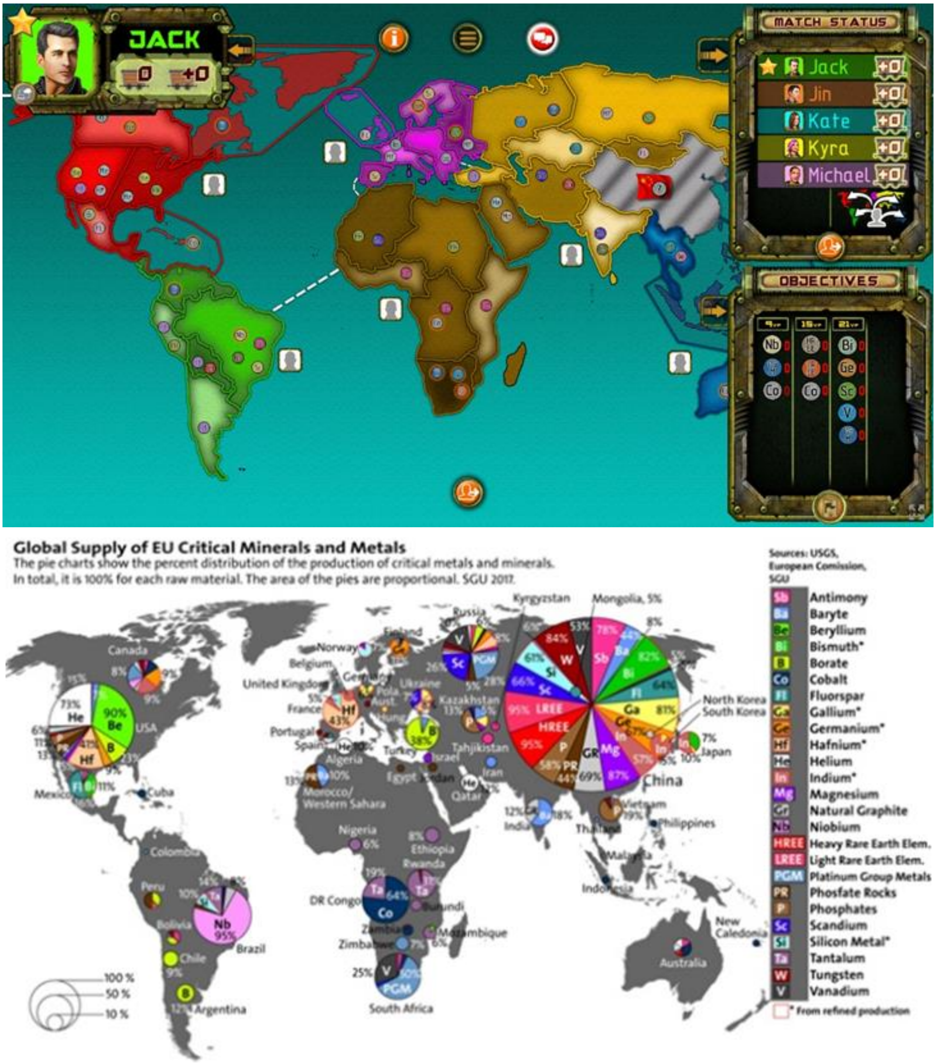

Fig. 1. Up: the game map of RAWsiko – Materials around us. The map was realised on the basis of the real geographical distribution of RMs (Bottom);
Bottom: Countries accounting for largest share of global supply of CRMs (source: Geological Survey of Sweeden) [12]

2.1 Where RMs come from and where they got to

RAWsiko is set in a fantasy future world where the main producer of critical RMs decides to cut the export to the rest of the planet, and therefore a “RM rush” begins. The players have to fulfil some lists of critical RMs that are key components of different devices that they have to build (as example, Fig. 2). To take control of these RM sources, the players have to move their “mining equipments” in different areas of the world and, if a territory is already exploited by another player, wrest the mining concession from them. The position of the main sources of a selection of critical RMs represents the real principal mines of these minerals [12] whereas the elements reported in the objective cards represent the most important RM for the production of that technology (see as example Fig. 2).

The game map reproduces in a simplified way the real geographical distribution of RMs since it was realised on the basis of the map distribution of the main RMs supplied by Geological Survey of Sweeden, partner with CNR in the RM@Schools project. In fact, the irregular distribution of some RMs around the globe is one of the reasons why a material becomes critical. Supply risk is also determined by geopolitical boundaries.

Because of this, resources can be concentrated within individual nations or regions of the globe. This can result in a monopoly and possible supply restrictions due to environmental or regional political factors. Many of the Earth's raw material resources are distributed around the globe, such that criticality may not arise (e.g., Cu, Pb, Zn).

Those that are not equally distributed run the risk of supply shortages and disruptions.

By playing RAWsiko and reaching their objectives, the player will learn which critical RMs are involved in the different technologies and where are the main suppliers. For example, wind turbines depend on metals such as LREEs, HREEs and Co, that come from South Africa, Australia and Congo respectively; fertilizers depend from phosphate rocks (PR) and borates (B), coming mainly from Western and Eastern USA respectively.

Depending on the number and the criticality of the RMs needed to produce a device, the number of victory points (VPs) of the device increases, presenting to the players the idea of different value chains in the EU economy (Fig. 2).

Fig. 2. Some objective cards and the RMs necessary to build them

2.2 Empowering students' skills

Together with the knowledge on geography and uses of critical RMs, RAWsiko can increase the awareness among youngsters about the importance of an affordable RM supply for both society and economy, inducing the players to ask themselves: "What can I do to avoid RM shortages?" The answer to this question is in the European Green Deal, the action that aims to make the EU the first continent climatically neutral [13] and in the Circular Economy Action Plan [14], documents that can be translated in easier and more engaging language [15] by the teachers with the help of other teaching materials supplied by the web portal of the Raw Matters Ambassadors at Schools project [6].

On the other hand, the dynamic of the game induces the players to stimulate the so-called "21st century skills" [16], in particular the game stimulates basic skills in ICT (digital competence S.2); readiness to to address new problems from new areas and capacity for quantitative thinking (STEM competence S.4 and S.5); knowledge of vocabulary and ability to understand and interpret concepts, feelings, facts or opinions in oral and written form (multilingual competence S.5 and S.1); ability to effective interaction with other people and to adapt to the changing situation, being flexible and work under pressure (citizen competence S.1 and S.2); independence, motivation, determination and ability to turn idea into action and to plan-manage tasks (cultural awareness and expression competence S.5, S.1 and S.2); and, finally, the ability to identify available opportunities (Personal, social and learning to learn competence S.2).

Furthermore, RAWsiko contributes to achieve the Sustainable Development Goals no. 4 (access to education), no. 12 (responsible consumption and production), and no. 15 (sustainable use of terrestrial ecosystems) [17].

2.3 Further teaching material

The game is supported by a teacher's card that provides teachers with some context around these important issues such as what critical RMs are, how they are classified and some key terminology, in addition to some information about the background of the activity [18]. A student's card introduces briefly the subject to the potential players, and the instruction to download, install and play the game. In addition, further information to link the game to other curricular subjects, making the activity interdisciplinary are present in these supporting materials.

3. Conclusions

RMs is a great topic for students to investigate politics, policy, consumerism, and the interaction between economics, politics and product use and development. Education and awareness of the uses of raw materials can lead to changes in governance as the values and the voice of citizens are listened to. We hope that students will become more responsible and active citizens when they have gained a better understanding of these complex issues.

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Some Educational Innovations for Overcome the Deficit of Information Literacy in a Time of Crisis

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Abstract

From a pragmatic point of view as well as from a theoretical perspective, the development of social networks has shown the role and importance of information and communication technologies in stimulating a huge number of various processes in society. The impact of information environment today is indisputable, and society has the opportunity to both freely express themselves and to make use of the available technologies, necessary for communication in the digital world at any time and in any part of the world. The age limit of digital technologies users drops off significantly on a daily basis and this makes it necessary to provide information literacy among the population, which will lay the foundations for building critical, independent thinking and will form knowledge and individual skills for intelligence surviving in the information area. The main aim of the scientific research is to show that the dynamics of social processes, especially in a time of crisis, focuses the attention of mankind on one of the most important pillars in its development, namely education, in the hope that education, with its purpose and experience of applying different approaches and methods in practice will have a positive effect on improving the quality of life of the community. And yet, in times of crisis – political, economic, energy, environmental or health, the objectives of our research are focused on education, which still remains one of the most vulnerable public sectors. In conclusion, on the basis of the results received from the scientific investigations and taking into account crises as a factor with negative as well as likely positive consequences, the present research examines various educational approaches of an innovative nature that contribute to conducting research and to the application of new educational technologies during and after periods of crises.

Keywords: innovations, overcome, education, information literacy, crisis, conceptual model

1. Introduction

At the start of the 21st century, information and communication technologies triggered global integration of the information space and led to a drastic change in social attitudes.

Information resources became increasingly accessible changing the way people communicate. The Internet has massively entered each social system turning into a value that people of all ages rely on more and more for the realization of their activities and interests. From an auxiliary resource in the 20th century serving primarily public production, information has become a major resource for all spheres of life in the 21st century.

The creation and mass use of state-of-the-art technology have marked the beginning of new social relations and a new way of life. Modern society is in a new stage of its development – the information society. The basic principle of the information society is that access to information is an undeniable human right, and information and communication technologies have created the conditions for the taking advantage of this right [1].

The creation and development of information and communication technologies have opened up new opportunities for free access to information and its exchange between users [2]. The incredible growth of information resources has immersed people in a kind of information stream. They turn out to be increasingly dependent on new technologies and even more vulnerable in the information environment [3]. Human abilities for the effective handling of information have been questioned – where to look for it and how to use it in their daily lives by retrieving useful knowledge from it.

1.1 Information literacy

The term information literacy was introduced into the scientific space in 1974 by Paul Zurkowski in his paper "Relationships and Priorities in the Field of Information Services", which to date is among the most cited titles on the subject [4]. It was in the 21st century, in response to the need to define the number of skills comprising the effective search, finding, interpreting, evaluation and application of information that the term has been commonly used in society.

High information literacy of society is a basic prerequisite for achieving sustainable development on a global scale [5]. It "Provides the key to effective access, use and creation of content in support of economic development, education, health and services for people, as well as all other aspects of modern societies".

It is assumed that the information literate person is "the one who knows how to work most effectively with new technologies and information. He/she must be able to recognize when there is an information need, be able to locate, assess and use the necessary information effectively". [6], [7].

Several key components can be pointed out as key ones for the information literate person. They are as follows:

- to have the ability to use information resources effectively;
- to have the ability to perform a critical assessment of the source-content-reliability of the information;
- to apply this information ethically.

One of the main pillars of human development is education, and human capital takes an increasing place in it. The role of education in any social system is indisputable [8]. It exists and functions in the public environment for development and for this reason is part of the problems of society. [8]

Globally, education has been subject to changes different in form and size. They necessitate the reviewing and restructuring of institutions in the educational and scientific space.

Modern society today faces a dynamically changing social environment. In early 2020, the whole world faced a new challenge – overcoming the crisis COVID-19. In just a few days, the world declared a state of emergency. It was closed, literally. There was chaos, misunderstanding and fear. A time when we had to learn to live in a new and unknown way, to adapt to the situation, while ensuring the protection of our health and safety.

The crisis did not pass the education sector either. Not only were the borders of a number of countries closed, but also the institutions in them, including schools and universities. The crisis drew attention to the University as a key partner for maintaining a base of fundamental knowledge that will allow the efficient use and development of scientific capacity in achieving progress and maintaining sustainable growth in modern society [9].

Against the backdrop of an avalanche of fake news, often outpacing even the speed of the virus itself, limiting this alarming trend requires people to be information literate.

And since fake news can inherently consist of partially or completely false information, be based on true information, deliberately taken out of the context of events, and certainly have a highly explosive character, modern humans today are expected not only to be prepared to orientate in the digital environment, but also to treat critically the received information [10], as well as to be able to use it appropriately and rationally in order to be of maximum benefit to both themselves and society.

2. The results

In order to achieve the main goal of the current research, namely to show that the dynamics of social processes, especially during a crisis, focuses the attention of humankind on one of the most important pillars in its development – education, good practices and experience in applying different approaches and methods in the field of education have been studied and systematized.

When choosing the methodology of the current research, which includes observations, analysis and study of previous experience, the nature of the purpose of the research was taken into account, as well as the principles of high ethics and precision.

Based on the conducted analysis of the educational activities, the research is oriented towards increasing the scientific and practical potential of the process of teaching and learning. In response to the need for innovation in the education sector during the crisis, the present research focuses on the following (results) recommendations:

- developing curricula to expand digital learning;
- encouraging students to acquire the skills needed in a globalizing world;
- the development of tools to deal with misinformation in rapidly evolving information technologies;
- creating tools for learning in an electronic environment [11];
- preparation of mechanisms for mutual assistance between trainees and trainers;
- providing a single space for universities, students and research;
- stimulating the development of centers of excellence in science;
- creating flexibility and stimulating lifelong learning to enable people, at any time of their age and social development, to return to the education system [12].

3. Conclusion

Recognizing education as a strategic tool for ensuring the advancement and progress of society in the social hierarchy, the sectors based on knowledge and intellectual work are becoming increasingly sought after and valued indicators that guarantee the prosperity of any social system. And although the quality of education is the main responsibility of individual countries, the responsibility of universities to society remains indisputable. The main mission of information literacy is to develop and upgrade critical thinking in people, their ability to consistently and rationally use the information obtained, the acquisition of new knowledge and the preservation of proven effective knowledge, which gives us a good reason to conclude that the information literacy integrated in the educational programs becomes an essential factor favoring the development of any system [13]. In order to overcome the consequences of any crisis – political, economic, energy, ecological or health-related, education institutions should be able to respond to the social need for providing specialized professionals with broad competences. These people should be prepared to work in conditions of contemporary challenges guaranteeing the conduct of a high-quality educational process for the acquisition of the knowledge and skills that are at the heart of social development [14].

Acknowledgements

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SOS for Researching Seafarers – Introducing Professional Doctorate in Maritime Education

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Abstract

Students interested in pursuing doctoral degree can usually choose between studying full-time and part-time with latter option generally chosen by working professionals. However, their drop-out rate from such programs is considerable. The problem is even more specific in maritime higher education sector where professionals working at seas are separated from universities for prolonged periods and therefore cannot often cope with demands of studying at doctoral level. This is why universities must find a way to retain these students at doctoral programs. A possible solution is to provide a professional doctorate over classical research doctorate. This paper elaborates the need for professional doctorate in maritime sector putting emphasize on foundations such program needs in order to be successful: career focus, research type and focus, learning outcomes, mode of study, blending of work and study and distant learning.

Keywords: doctorate, professional doctorate, researching professionals, maritime higher education

1. Introduction

Doctoral degree is the highest formal academic qualification awarded to a student in higher education scheme. Doctoral programs are usually offered as full-time or part-time.

Part-time option is mainly chosen by working professionals (WP) – employed career-focused individuals with specialized knowledge who pursue their doctoral degree along with their regular full-time job. One of the characteristics of these WPs is that they often have considerable practical experience in industry and business.

Experience like that can undoubtedly help in identifying problems that need to be solved using scientific approach. But, practical-solving mindset of these doctoral students often conflicts with somewhat rigid academic environment so their full potential is often not recognized and universities don't benefit from a blend of academic and professional cooperation [1].

This challenge is even more present in maritime industry where professionals working at seas are separated from universities for prolonged periods due to the nature of their work. For instance, data available from Croatian maritime higher education institutions (HEI) clearly show that students in majority opt for part-time doctorate, Fig. 1.

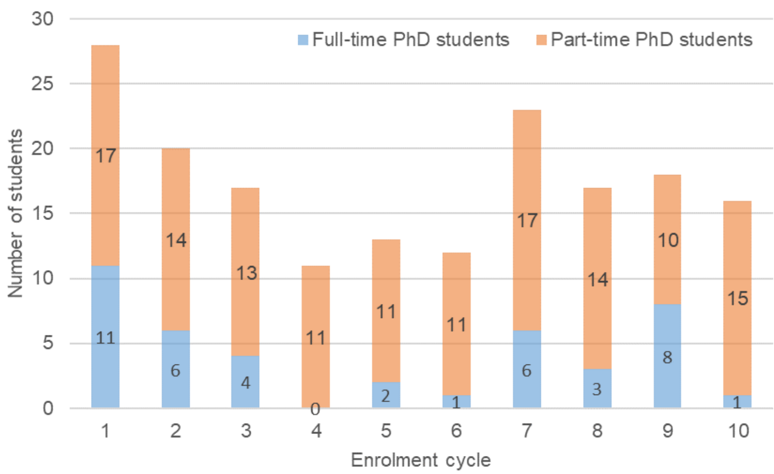

Fig. 1. Structure of PhD students at Croatian maritime HEIs in the last ten enrolment cycles (2009-2020)

In order to attract and keep WPs at their doctoral programs, HEIs need to help them to prevail the challenges on their path to doctoral diploma. A possible solution, that hasn't been used yet in maritime educational sector, is to provide a professional doctorate (Doctor of Engineering, EngD) instead of classical research doctorate (Doctor of Philosophy, PhD). As literature states, PhD is aimed at developing "professional researchers" while EngD is aimed at developing "researching professionals" [2]. Doctor of Engineering program should combine foundational and theoretical knowledge across one or several disciplines with knowledge of research in its context. The idea of introducing EngD in maritime PhD programs is discussed in the following section of the paper. Six pillars that should represent foundations of a successful EngD program are presented. These points are put together by authors after careful investigation of the leading doctoral curricula in engineering sciences, both professional and classical, critical review of the available references and, finally, on independently recognized best practice of the authors who have been actively designing and managing doctoral programs along with mentoring doctoral students.

2. Six EngD pillars

Although professional doctorates vary from the classical research doctorates and, moreover, vary between themselves depending on the subject and the institution that offers them, some common ground can be established. Some shared features can be highlighted as pillars on which every successful EngD program can be built, especially those in maritime sector of education, Fig. 2, [3].

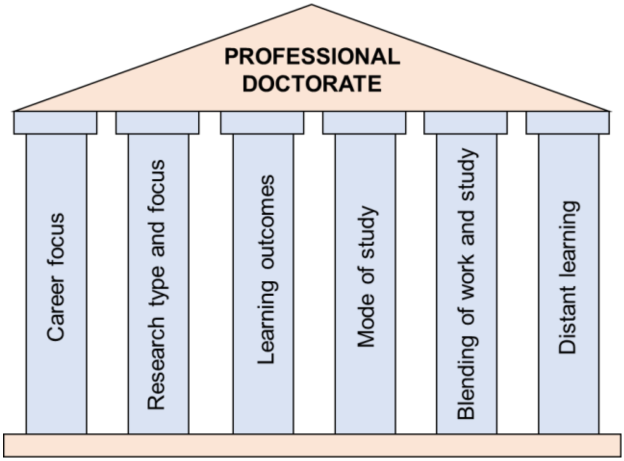

Fig. 2. Six pillars that should represent foundations of a successful EngD program

2.1 Clear career focus

Classical PhD is generally not adequately suited to the needs of professionals pursuing a career outside academia environment or an industrial laboratory [3]. PhD is usually open for candidates who generally have no or little experience of the subject beyond the knowledge obtained at the BSc and MSc level in the proposed field of study.

Moreover, PhD is designed as a pre-service training in research, while EngD is designed as an in-service professional development [4].

This career focus is what sets PhD and EngD apart. EngD is usually aimed at experienced professionals wishing to broaden their expertise and undertake advanced research, while not becoming researchers tied to HEIs or scientific institutes. Prospective candidate for a professional doctorate is usually required to carry 3 years of professional experience and relevant employment.

"Professional researchers" vs. "researching professionals" is a term that maybe most adequately describes the difference in career focus of PhD vs. EngD.

2.2 Defined research type and focus

"Research and experimental development (R&D) comprise creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge" [5]. The term R&D covers activity such as: basic research, applied research and experimental development. "Applied research is original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific, practical aim or objective" [5]. Definition of applied research is what adequately describes professional doctorates.

As for the research focus, PhD candidate is usually expected to perform a preliminary research, identify existing gap and start their work towards making a significant original contribution to knowledge in a subject discipline.

By contrast, EngD candidate starts from what is not known, a perceived problem in professional practice that needs investigation and resolution. Professional research deals with a topic that relates to a candidate's own field of professional practice. In both cases, review papers are a good starting point into clarifying focus of the research [6].

2.3 Proper learning outcomes

Ending their PhD program, students should become independent scientists capable of performing and critically evaluating research using current techniques and methodologies and developing new ones. Developing the capacity to provide a significant original contribution to knowledge in a subject discipline is the intended learning outcome of the PhD.

Learning outcomes of professional doctorates are to develop the capacity to make a significant original contribution to knowledge of professional practice through research.

EngD students should demonstrate the knowledge to create and interpret new knowledge, through original research, of a quality to satisfy peer review, extend the forefront of the discipline, and merit publication. They should, in general, be able to systematically acquire and understand a substantial body of knowledge and applicable techniques for research that are at the forefront of their area of professional practice.

EngD students should, in particular, be able to conceptualise, design and implement a project that is intended to generate new knowledge and its application to professional practice.

2.4 Adequate mode of study

Professional doctorate students are expected to spend their working time in industry and therefore most of the professional doctorate programs are created to be studied in part-time form. However, some programs state that the students are considered to have full-time engagement with the understanding that majority of their time will be dedicated to their duties in a professional or industrial organisation. If the blend between professional work and academic duties is performed seamlessly, it is hard to distinguish between full-time and part-time mode of study. However, some HEIs offer double amount of time for part-time students to finish their study.

2.5 Blending of work and study

As previously stated, most professional doctorates intend to blend the professional work of doctoral students into their studies as much as possible. Harmonizing the extent to which the scientific research will penetrate everyday professional practice of an EngD student seems crucial in attracting prospective candidate to EngD programs and helping them to cope with two difficult tasks: delivering optimal performance at work place and, in the same time, fulfilling academic requirements. Hence, professional doctorates can, in a way, be viewed as a type of work-based learning and life-long learning [7]. This implies acceptance of alternate means of teaching and mentoring at the PhD level of education; a significant step in breaking the rigid frames of academic environment.

Setting the professional work of candidates into their doctoral studies can be done directly or indirectly. Directly, when students deal with a problem that is an integral part of their professional practice and indirectly when students deal with a problem that is not an integral part of their professional practice. Indirect setting is primarily used for students that wish to gain a broader knowledge about their professional sector.

2.6 Introducing distant learning

Students enrolled in the PhD programs are expected to study on-site, committing themselves to full-time program attendance, while EngD students are expected to continue working while taking courses. Moreover, in some specific industries, it is almost impossible to account for students' regular visits to campus. Professionals in transport industry, military, civil engineering or large multinational companies can rarely expect that they will spend prolonged periods at a single place.

A possible solution for their problems would be composing adequate online curriculum of postgraduate program. This program should adhere to same academic rigour as ones taking place on campus ground. Academic rigour means that students are challenged to think, perform and grow to a level that they were not at previously [8].

Standards of the course must be set in a way that they challenge the students, not frustrate him. Academic rigour commonly consists of three different phases: setting the standard for students; equipping students through instructional and supportive methods; student demonstration of achievement [9]. At distant learning, it is often challenging to maintain academic rigour due to the nature of the study, but failing to do so can lead to deficient results of the research and dissertation itself.

3. Conclusions

Classical doctorate programs dedicated to maritime affairs are rare, professional doctorate programs practically non-existent. Out of 64 maritime HEIs, regular members of International Association of Maritime Universities, only 26 offer some kind of PhD program, Fig. 3, and no one offers EngD.

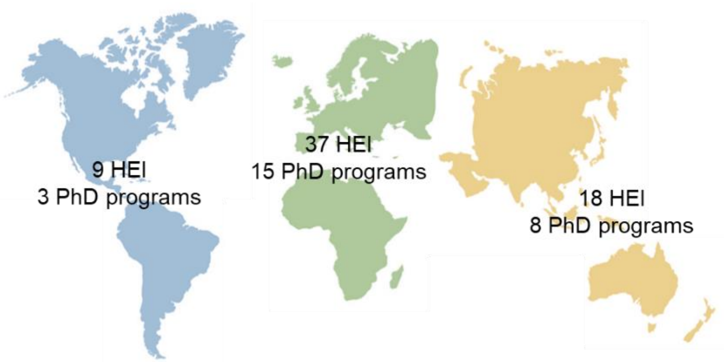

Fig. 3. Number of maritime HEIs, members of IAMU, across continents and PhD programs offered (as of December 2020)

Given the extreme applicability of the research in the maritime domain, it is obvious that there is a place for EngD programs. They do represent a tougher test than the PhD as research takes place in an environment with less support and findings must have an impact on a professional setting as well as contributing to knowledge. However, if enough efforts are put in proper design of professional doctorate programs and dissemination of the idea behind them to WP community, maritime sector has the most serious potential to implement this type of postgraduate advancement.

Acknowledgements

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The Role of the Bulgarian Church in Education – Traditions and Modernity

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Abstract

In the complex historical periods from the development of Bulgaria, the Bulgarian Church has always played a crucial role for the preservation of the Bulgarian language, religious belief and self-consciousness. The paper traces and analyses the role of the Bulgarian church in the development of Education in Bulgaria historically and in contemporary times. In connection with the implementation of the activities under project ДН15/4 "Creation of a Model for the Safeguarding, Promotion and Socialization of Churches in Bulgaria" a number of field studies were conducted in different regions of the country. It was found that in almost all the temples there were schools, which, having emerged as the so-called "cell-schools", gradually became classrooms with a secular character of education. It is noteworthy that the inhabitants of the small settlements far from the center of the country showed a desire for education and enlightenment and with their own means and forces opened schools next to their churches. Nowadays, the role of the church in education is more educational. There are Sunday schools attached to the temples throughout the country, which are on a voluntary basis. The website of the Holy Synod, the websites of the individual holy dioceses and the websites of individual churches in the country provide information about the work of the working Sunday schools, which maintain constant contact with children and their parents and in the form of various entertaining games and activities acquaint them with the foundations of the Christian religion, together with the various religious holidays and rites. On the territory of the Sofia Holy Metropolis alone there are more than 15 Sunday schools, there are no fewer in the large metropolitan cities of Plovdiv, Varna, Veliko Tarnovo, Varna, etc.

Keywords: Education, Bulgarian Church, Sunday schools

1.Introduction

In the complex historical periods from the development of Bulgaria, the Bulgarian Church has always played a crucial role for the preservation of the Bulgarian language, religious belief and self-consciousness. The paper traces and analyses the role of the Bulgarian church in the development of Education in Bulgaria historically and in contemporary times.

Ever since the first Christening of the Bulgarians in 864, the church has played its role in society as an enlightening factor. Gradually, literary centers were established for each newly-built monastery and church, which were the first educational institutions in the Bulgarian state.

With the fall of the state under the Ottoman rule at the end of the 14th century, when the Bulgarian population became part of the Ottoman Empire, the process of establishing the Bulgarian state and its cultural and educational development was interrupted. In the new historical conditions, only the Bulgarian monasteries and temples in villages and towns remained as centers of education from the 15th to the 19th century.

During the five centuries of national dependence – from the end of the 14th to the end of the 19th century, the Bulgarian Church (BC) played a significant and multifaceted role in preserving the Bulgarian self-consciousness, faith and language. This role was extremely important and decisive during the most powerful cultural period in our history – the Revival (from the end of the 18th to the end of the 19th century).

In connection with the implementation of the activities under project ДН15/4 "Creation of a Model for the Safeguarding, Promotion and Socialization of Churches in Bulgaria" a number of field studies were conducted in different regions of the country. It was found that in almost all the temples there were schools, which, having emerged as the so-called "cell-schools", gradually became classrooms with a secular character of education. It is noteworthy that the inhabitants of the small settlements far from the center of the country showed a desire for education and enlightenment and with their own means and forces opened schools next to their churches.

Nowadays, the role of the church in education is more educational. There are Sunday schools attached to the temples throughout the country, which are on a voluntary basis.

The website of the Holy Synod, the websites of the individual holy dioceses and the websites of individual churches in the country provide information about the work of the working Sunday schools, which maintain constant contact with children and their parents and in the form of various entertaining games and activities acquaint them with the foundations of the Christian religion, together with the various religious holidays and rites. Only on the territory of the Sofia Holy Metropolis there are more than 15 Sunday schools, there are no fewer in the large metropolitan cities of Plovdiv, Varna, Veliko Tarnovo, Varna, etc.

The work with the children in the Sunday schools is varied and organized in an interesting way. In addition to getting acquainted with carefully selected religious talks suitable for kids' age, there are various schools at the temples within the Sunday schools: acting, icon painting, children's church choirs, and entertaining games related to various religious holidays.

Observations and analysis of historical and contemporary facts about the role of the BC in the education and upbringing of children show that there is a desire to preserve and modernize traditions in this regard.

2. Historical predispositions

From the start of its existence – the conversion of the Bulgarians into Christianity in 864 – the Church has perceived its role in society as an educator. Gradually, literature centers were established with every newly-built monastery and church. These were the first educational institutions in the Bulgarian state. Monks were educated there, liturgy books were translated, original work was written. Preslav and Ohrid literary schools became known as enlightening and educational centers, some of the most significant for their time.

Throughout the complex historical periods of Bulgaria's development, the Bulgarian Church has played an important role for the preservation of the Bulgarian language, religion and self-consciousness. With the state falling under the Ottoman rule at the end of the 14th Century, when the Bulgarian people became part of the Ottoman Empire, the process of establishing the Bulgarian state and its cultural and educational development was interrupted. After the Ottoman invasion, the educational system in the Bulgarian lands declined. The Ottoman rule became an obstacle for the evolutionary cultural development of the Bulgarians. The greater part of the old educational centers was destroyed, the Bulgarian intellectuals of the time, who took education to extreme heights during the Second Bulgarian Kingdom (12th-14th centuries), were dispersed or killed.

In the conditions of a destroyed state, high bodies of the Church like the Patriarchate and the archbishoprics, and as a result of the secession from the European civilization, the incredibly difficult task of preserving the Bulgarian educational tradition, nationality and self-consciousness fell to the Bulgarian Church. Only the Bulgarian monasteries and temples in villages and towns remained centers of education from the 15th to the 19th century in the new historical conditions. In the so-called 'cell schools' (schools at the monasteries) the Bulgarian lower clergy taught Bulgarian children and thus helped to preserve the Bulgarian language, the Bulgarian cultural heritage and Christian consciousness. Schools were opened near almost every church and monastery, where Bulgarian children became literate.

This education aimed to provide writing, reading and a few arithmetic skills. Church books were mainly used for textbooks. Everything was taught in Church Slavonic or Greek. Cell education had an elementary and religious character, but in the conditions of the Ottoman rule it played a huge role in maintaining the national self-consciousness of the Bulgarians.

In the 18th century the cell schools became even more widespread and by the middle of the century on the territory of today's Bulgaria there were over 100 cell schools, and by the 1830s they were 235, among which the most famous in the cities of Sofia, Kotel, Samokov, in the monasteries of Etropole, Troyan and Rila.

Throughout the five centuries of national dependence – from the end of the 14th to the end of the 19th century, the Bulgarian Church played a significant and multi-functional role in preserving the Bulgarian self-consciousness, faith and language. This role is extremely important and decisive during the most powerful cultural period in our history – the Revival (from the end of the 18th to the end of the 19th century). During the Revival, the Church played the role of a unifier of the Bulgarian population on the territory of the Ottoman Empire and manifested itself as a factor in understanding the building blocks for the preservation of what was Bulgarian.

In its significance, goals and comprehensiveness, the Bulgarian Revival is similar to the European Renaissance, although in its specificity it differs significantly from it. It developed three centuries later, which made it possible to benefit from the experience of advanced countries. The Renaissance motifs on Bulgarian land appeared at the beginning of the 18th century and grew into a national liberation ideology and movement.

Without going into more detail, we will emphasize that due to the specific Bulgarian historical circumstances, the main priorities of the Bulgarian Revival became education, the struggle for an independent Bulgarian church and the struggle for national liberation.

Bulgarian Revival leaders realized and followed something extremely important: the pursuit of education must be a priority of the Bulgarian population, because only an educated person can be aware of the need for freedom and independence. In the country, too, a powerful movement for education emerged and gained momentum among the Bulgarian population.

The movement for modern Bulgarian education is an important element of the general development of the Bulgarian Revival and is organically connected with other Revival processes. The connection with the church-national movement is especially close. The two movements are intertwined because of the common goal – the struggle for spiritual self-determination. The new Bulgarian education was born and developed in the conditions of a society, with the Christian religion in an important place in its view of the world. The movement for modern Bulgarian education was realized as a secular parallel to the movement for church independence in the religious field. Both movements are perceived as a means of survival and establishment of the Bulgarian nation. In this struggle, the church and the school were allies. The churches and monasteries with the cell schools operating on their territory also became the leading educational centers of the historical Bulgarian lands.

Based on the model of the cell schools at the churches and monasteries, patriotic Bulgarians gradually began to open schools with a distinctly secular character of education. Most of such schools were established at the end of the 18th and in the first three decades of the 19th century. In addition to the initial religious education, mostly secular knowledge was taught in them. The striving for secular education is explained mainly by the purely practical needs of the emerging Bulgarian bourgeoisie. Its representatives must be able to read, write, count, have knowledge of geography, commodity trade, history, science, etc., so that they can not only produce but also sell their goods in countries near and far. The expanding economic contacts with the surrounding Christian world, as well as the purposeful cultural and political penetration of France, England, Russia and Austria into the Balkan region, highlighted even more the shortcomings of cell education. The acquisition of secular knowledge was also necessitated by the spiritual needs of society, by the growing interest in new bourgeois ideas, in the historical past, in the Bulgarian language and in folk traditions.

To summarize, we can say that in Bulgaria at the dawn of the movement for modern Bulgarian education, church institutions were the main place where it was born and established. In this sense, it can be confidently argued that historically the Bulgarian Church is the main factor in the emergence of the Bulgarian educational system. In connection with the implementation of the activities under project ДН 15/4 "Creation of a Model for Safeguarding, Promotion and Socialization of Christian Churches in Bulgaria" a number of field studies were conducted in different regions of the country. It was found that in almost all the temples there were schools which began as cell schools and gradually became schools with a secular character of education. Such schools existed in Dobrich (founded in 1859 in a specially constructed building in the yard of the St. Trinity Church), in the Church Holy Epiphany (1868) in the village of Radovtsi, Drianovo Municipality; in Shiroka Luka in the yard of the church St. Virgin's Assumption, in the villages of Pavelsko, Chokmanovo and Nedelino. We can't help but notice that the inhabitants of the small settlements far from the center of the country had shown a desire for education and enlightenment and with their own means and forces opened schools to their churches. For example, we will point out the villages in the Rhodopes, where, despite the difficult mountainous terrain, schools were opened in every village. The first schools in the Rhodopes were in Smolyan /the Pashmakly School-1848/, Dolnoraykovo School, Petkovo School /1837/, Slaveynovo School /1848/, Momchilovo School /1848/.

Schools were opened in Shiroka Luka, Pavelsko, Chepelare. The town of Zlatograd started it all opening its school in 1830 to the Church St. George-the Martyr, which marked the beginning of the educational activities in the Rhodopes. The oldest written monument of the Rhodopes Revival was discovered here – Zlatografski Pismovnik – 1852 /A Letter Book of Zlatograd/. In 1852, the population of Zlatograd raised money and built the Vzaimno School, which was the third in the town after the first two cell schools.

3. The role of the Church today

Today, many of the old cell schools have been turned into museums preserving the memory of the work and merit of the patriotic Bulgarians who gave their strength and resources for the education of young people. In the town of Dobrich, a classroom of a Revival mutual school has been restored, and the school building in the yard of the church in Shiroka Luka is currently being restored and renovated with state funding.

When the building is ready, a church museum will be opened in it with exhibits reflecting the development of education in this area.

The most significant museum on education is the one in the town of Zlatograd. The exhibition entitled "Education in the Mid-Rhodopes" was opened in 1978 and is the second of its kind in Bulgaria after Aprilova High School in Gabrovo (the first secular school in the country). The school in Zlatograd was built with donations and the work of Zlatograd people in 1852. It is located in the building of the Mutual School. Apart from the reconstruction of the classroom with teaching aids and the teachers' room, the museum also keeps a unique collection of old-print editions, notebooks and teaching aids, registers and notebooks as well as everyday possessions of teachers. Among the most valuable exhibits is the Zlatograd Pismovnik /A Letter Book of Zlatograd/, which is a hand-written composition of 1852. The teachers' library is as impressive as rich in books, textbooks and dictionaries in Church-Slavonic, New Bulgarian, Greek, Turkish, Hebrew, English, French and German languages. The museum also keeps books with copies, possessions, photos and documents on the history of the town of Zlatograd. Over 3,500 exhibits have found their home in the museum. As already mentioned, this museum is in the yard of the St. George – the Martyr Church, where the school used to be in the past.

It is interesting to see what the role of the church in education and upbringing of young people is today.

There are Sunday schools in the temples all over the country organized by local priests and working on a voluntary basis. The website of the Holy Synod, the websites of the individual holy dioceses and the websites of individual churches in the country provide information about the work of the working Sunday schools, which maintain constant contact with children and their parents and introduce them in the form of various entertaining games and activities to the foundations of the Christian religion, with the various religious holidays and rites. Today, more than 15 Sunday schools operate on the territory of the Sofia Holy Metropolis alone, and there are no fewer in the large metropolitan cities of Plovdiv, Varna, Veliko Tarnovo, as well as in almost all small and large settlements. In the city of Varna, for example, there are more than 5 Sunday schools – almost in every church.

The organization and work of Sunday schools, as mentioned, is on a voluntary basis, as the main inspirer and initiator is the Bulgarian Church in the face of its representatives – priests, trustees and active laity. Classes with children are held on Sunday, after the liturgy, and they are conducted under the guidance of qualified tutors – teachers, theologians, priests. The parents are present indirectly – they are waiting for the end of the activities on the territory of the temple, and in most cases, they are provided with a small treat in the end.

The work with the children in the Sunday schools is varied and interestingly organized. In addition to being acquainted with carefully selected for their age religious talks at the temples within the Sunday schools there are different schools: acting, icon painting, children's church choirs and entertaining games related to various religious holidays. The fact that the classes are held in the temple gives the children the opportunity to learn about its history with the icons, with the contribution of different personalities to the preservation of the temple in the course of its existence. In each group of Sunday schools there is a purposeful conversation with the children about the temple, its history, its icons and murals. Its importance in the history of the settlement is emphasized.

In Varna in the church "St. Athanasius" work with children, in addition to the Sunday school, has been expanded by publishing a children's church magazine called Kambanka /Bell/. The magazine has been published since 2012 with the blessing of the then Metropolitan of Varna and Veliko Preslav Kiril. Its distribution is completely free for readers.

Kambanka is the only children's religious magazine in our country focusing on the religious and moral education of children. According to the priest in the church, Father Doncho Alexandrov attempts are being made to publish similar magazines elsewhere, but so far Kambanka is the only one. It is written on a voluntary basis by professionals who try to diversify its content, make it interesting and accessible for children of different ages. The entire organization of the publication and responsibility for the content of the magazine fall upon the priest at the church Father Doncho. Apart from being a paper edition, Kambanka is also available in electronic form, which makes it more widespread.

4. Summary and conclusion

Observations and analysis of historical and contemporary facts about the role of the Bulgarian Church in the education and upbringing of adolescents shows that there is a desire to preserve and continue the traditions in this regard. Today there are careful and well-thought-out forms and activities for working with children with the involvement of parents in order to achieve a sustainable positive attitude towards the church, religious values and morals. On the one hand, interesting and entertaining activities with children are achieved for raising the numbers of worshippers who visit the temples not only on major holidays. On the other hand, the population expresses their readiness to participate in the preservation and maintenance of temples at a local level and in many cases at a national one.

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Value-Based Management as an Opportunity to Increase Performance of Higher Education Institutions in Romania: Discovering Successful Methods and Representative Models of Measurement for Intellectual Capital

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Abstract

The new intensively developed economy, focused on multiple knowledge, diversified, refined and strongly supported by the explosion of the information society, is based on a multitude of strategies that prove to be emerging disciplines of management with increasing importance for the century of speed, proving essential not only in the activity of tertiary education providers but also of all other entities, aiming to occupy a special and reforming place in the knowledge economy. Competitive advantage, value-based management and increasing performance in all areas become the priorities that focus the spotlight on the intellectual capital of any company, focused on cognitive knowledge, outstanding skills, advanced ability to understand the new systems available, creative and innovative skills willing to develop and direct them not only in their immediate personal interest but also from the perspective of shareholders. This research is aimed at presenting the advantages and importance of value-based management, as an opportunity to increase performance of higher education institutions in Romania, while discovering successful methods and representative models of measurement for intellectual capital. Thus, the work examines the results obtained by using the following research methods in both public and private higher education institutions in Romania: surveys, interviews, focus groups. Firstly, this paper shows that Value-Based Management and Intellectual Capital play a paramount role in the field of educational in Romania, in general, and in the higher education institutions in Romania, in particular. Secondly, this paper emphasizes the strengths and opportunities brought by Intellectual Capital in Romanian in higher education institutions. Thirdly, this paper has addressed selectively a few successful methods and representative models of measurement for Intellectual Capital in Romanian higher education institutions.

Keywords: Intellectual capital, human capital, performance, higher education institutions, intangible variables, quality of education

1. Introduction

Recent developments in the field of economic sciences and business administration – with a particular emphasis on business administration, economics, management, accounting and finance fields, have led to the key idea that the world's new intensively developed economies decided to become more and more focused on multiple and critical issues, such as, intangible assets, human capital, knowledge, intellectual capital, intellectual property, and other related and interconnected elements [1, 5-9].

Because of these new trends, top specialists worldwide have noticed that today's society is becoming more diversified, highly refined and strongly supported by the explosion of the information (thus, the new name attached to it, "the information society"), which, in the end, turned out to be based on a multitude of strategies that proved to be emerging disciplines of management with increasing importance for the century of speed [10-13].

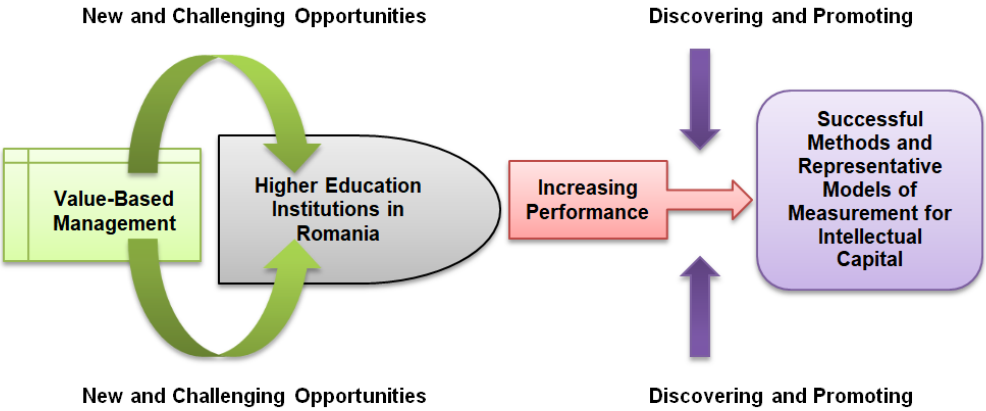
What is more, due to these emerging challenges, reputed scholars worldwide have come to the conclusion that value-based management represents an opportunity to increase performance at a general level and, in particular, should be regarded as a major asset for education institutions – in particular, for higher education institutions, proving essential not only in the activity of tertiary education providers but also of all other entities, aiming to occupy a special and reforming place in the knowledge economy [18, 19].

2. Literature review

A large and growing body of literature has investigated the importance and the vital role of higher education institutions in increasing nations' competitive advantage [20].

However, it seems that these days both value-based management and increasing performance in all areas become the priorities that focus the spotlight on companies' intellectual capital, especially when addressing individuals' cognitive knowledge, outstanding skills, advanced ability to understand the new systems available, creative and innovative skills meant to develop people's creative and work capacity (see Figure 1) [14-16].

Fig. 1. Value-based management as an opportunity to increase performance



Legend: This figure underlines the importance of Value-based management as an opportunity to increase performance of higher education institutions in Romania

Seeing that, protecting people and economies with the aid of integrated policy responses as well as with coordinated governmental actions capable to ensure sustainability, resilience, environmental protection and ecology, the social, economic, and environmental impact of all human actions must be at all times seriously considered and thoroughly monitored [2-4].

3. Methodology

To date, various methods have been introduced and described to measure the processes responsible for managing Intellectual Capital [5-17].

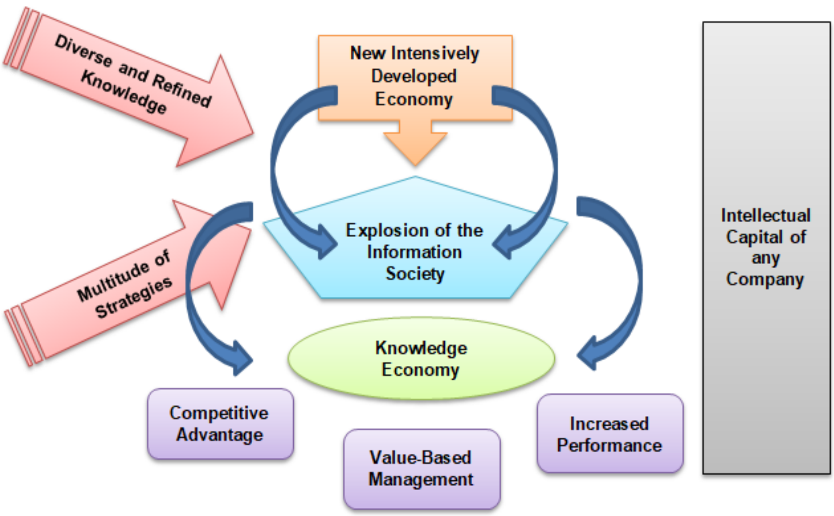
It should be pointed out that this research is aimed at presenting the advantages and importance of value-based management, as an opportunity to increase performance of higher education institutions in Romania, while discovering successful methods and representative models of measurement for intellectual capital.

Consequently, this current work examines the results obtained by using several research methods in both public and private higher education institutions in Romania: surveys, interviews, focus groups.

4. Data analysis and discussions

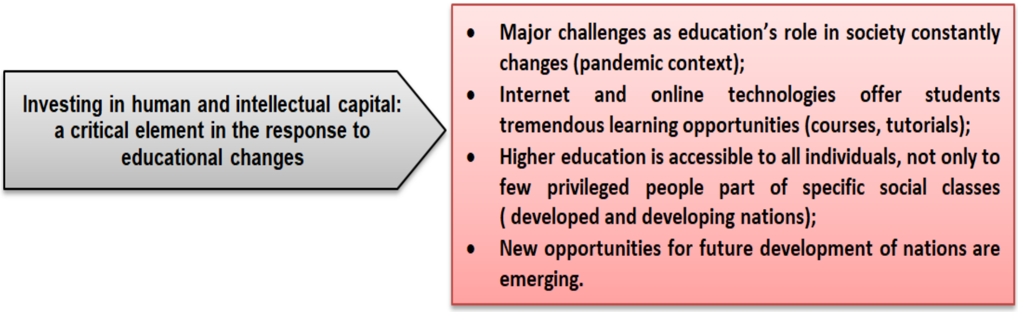
In terms of data analysis and discussions this scientific paper suggestively entitled "Value-Based Management as an Opportunity to Increase Performance of Higher Education Institutions in Romania: Discovering Successful Methods and Representative Models of Measurement for Intellectual Capital" points out fundamental results obtained using surveys, interviews, focus groups in both public and private higher education institutions in Romania (see Figure 2 and see Figure 3).

Fig. 2. Assessing and managing Intellectual Capital in the knowledge economy: focusing on cognitive knowledge, outstanding skills, advanced abilities, creative and innovative skills



Legend: This figure underlines the outstanding importance of assessing and managing intellectual capital in the knowledge economy

Fig. 3. A scientific model capable to value intellectual capital in Romanian higher education institutions



Legend: This figure describes a scientific model capable to value intellectual capital in Romanian

5. Conclusions, limitations and future work

In terms of significant conclusions, the following elements should be emphasized: firstly, this paper shows that value-based management and intellectual capital play paramount roles in the field of educational in Romania, in general, and in the higher education institutions in Romania, in particular; secondly, this paper emphasizes the strengths and opportunities brought by intellectual capital in Romanian in higher education institutions; thirdly, this paper has addressed selectively a few successful methods and representative models of measurement for intellectual capital in Romanian higher education institutions. The general conclusions of this study are shown in the figure below (see Figure 4 and Figure 5).

These results come to complete previous works and research on intellectual capital [21-24], as well as the interpretation of intellectual capital's crucial role in knowledge-based society [25-26].

Fig. 4. Managing Intellectual Capital: conclusions

Results obtained from surveys, interviews, focus groups:		
Human capital and Intellectual capital play a decisive role in:		
- generating long term human development benefits	**- reducing the carbon footprint**	**- supporting individuals' adaptation to constant challenges**
- ensuring sustainability and resilience	**- favoring governmental climate actions**	**- ensuring positive behavior changes**
- reducing greenhouse gas emissions	**- increasing labor productivity**	**- enabling access to low carbon services**
Value-Based Management and Intellectual Capital play a crucial role in Romania' educational field and in higher education institutions in Romania.		

Legend: This table underlines the results of assessing and managing Intellectual Capital

Fig. 5. Managing Intellectual Capital: solutions

Legend: This table underlines the results of assessing and managing Intellectual Capital

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Science and Environment

Glyphoscape: An Escape Room Game based on the Biochemical Principles of Herbicides using the Example of Glyphosate

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Abstract

In the escape room Glyphoscape – The Forgotten Lab, students aged 16-18 explore an old, abandoned laboratory owned by a scientist who conducted private research on the herbicide glyphosate, while deepening their biochemical knowledge about pesticides and the inhibition of enzymes. To protect his research, the lab was sealed with various puzzles. These puzzles are presented in three sections: (1) the theoretical basis of pesticides and herbicides and their general mechanisms of action, (2) enzymes and their structure and (3) enzyme inhibition. After each section, the contents are secured by a gatekeeper puzzle and applied to glyphosate before the next section can be reached. The participants have to solve each puzzle to get out of the lab. After successful completion of the escape room game, students will be able to explain enzyme inhibition in general and the inhibition of 5-enolpyruvylshikimate-3-phosphate synthase by glyphosate in the shikimate pathway in particular. The presented escape room opens up various teaching possibilities and can be flexibly used.

Keywords: escape room game, glyphosate, pesticides, herbicides, biochemistry, enzymes

1. Escape room games in education

In an escape room game, a team of players has to solve logic puzzles and tasks by using clues to finally reach a certain goal. Usually, this main goal consists of escaping from the room. Solving puzzles often leads to further clues or riddles that must be unraveled [1]. Meanwhile, the concept is not only used for entertainment, but has also been adapted for educational purposes by engaged teachers and educators [2].

Due to the challenging nature of the varying tasks, escape room games require logical and critical thinking, teamwork and creativity from the participants [1, 3], similar to common serious games [4]. Educational escape rooms are using this to offer a learning environment that promote these skills in addition to teaching and deepening knowledge [5]. By solving the escape room, learning objectives are achieved.

Research on the effects of escape room games on learning is still in its early stages [6].

Mainly only single case studies can be found, which evaluate self-created escape rooms and show positive effects on learning motivation and enjoyment [5, 6].

2. Framework of "Glyphoscape – The Forgotten Laboratory"

Participants of the escape room game *Glyphoscape – The Forgotten Laboratory* are told that they are young students exploring abandoned places and have accidentally come across an old laboratory. The goal is to explore the place before it is demolished in an hour. The secret lab was run by the fictional person Dr. Alba, who conducted research on the mechanism of action of the herbicide glyphosate. He saved his results on an old computer, but to secure these of unauthorized access he protected the data with various riddles. These riddles require knowledge of basic concepts of biochemistry, so only scientists can get access to the results. Luckily, the players can find old research notes from Dr. Alba containing information about glyphosate and enzymes as well as herbicides in general in the room.

2.1 Scientific principles

Glyphosate (*N*-(phosphonomethyl) glycine) (Fig. 1A) is one of the most used and most important herbicides. The development and use of glyphosate-resistant crops simplified the use of glyphosate in agriculture [7]. Glyphosate was long considered non-toxic to mammals until 2015, when the International Agency for Research on Cancer classified glyphosate as possible carcinogenic, while the European Food Safety Authority came to a different conclusion [8]. This ongoing discussion is not content of the escape room game.

The herbicide inhibits the enzyme 5-enolpyruvyl-shikimate-3-phosphate synthase (EPSPS, Fig. 1B & 1C) of the penultimate step of the shikimate pathway, a metabolic pathway that occurs uniquely in higher plants and microorganisms and is responsible, among other things, for the synthesis of aromatic amino acids. EPSPS catalyzes the reaction between phosphoenolpyruvate (PEP) and shikimate-3-phosphate (S3P) to 5-enolpyruvylshikimate-3-phosphate (EPSP) and phosphate (Fig. 1D) [7]. Glyphosate and PEP share a similar ionic structure and exhibit the same ionic interactions with EPSPS.

The increased length of the molecule can be compensated by slight rearrangements of amino acids [9].

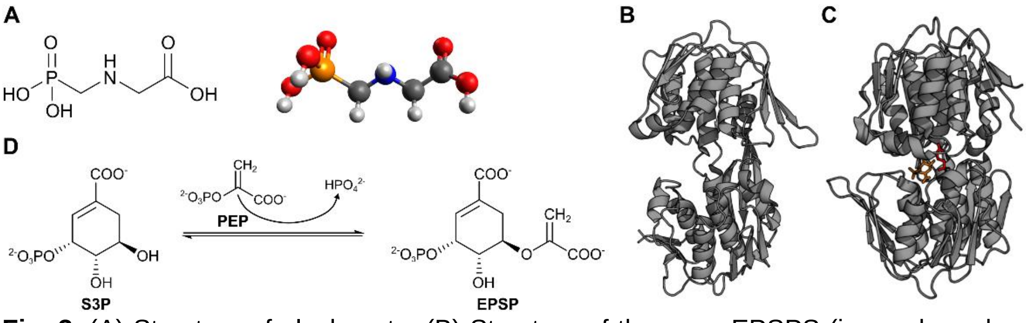

Fig. 3. (A) Structure of glyphosate. (B) Structure of the open EPSPS (image based on [10], PDB: 2GG4). (C) Inhibited EPSPS in grey with S3P (orange) and glyphosate (red) (image based on [10], PDB: 2GGA). (D) Reaction from S3P with PEP to EPSP. This reaction is catalyzed by the EPSPS

2.2 Structure and content of the escape room

The game is divided into three sections with different subtopics. Each section consists of different puzzles in a linear sequence, so that only one puzzle can be solved at a time.

This should prevent the division of the group into subgroups, which could solve tasks independently of each other. After completion of a section the players gain access to the riddles of the next section. Figure 2 shows the three sections of the games and their puzzles.

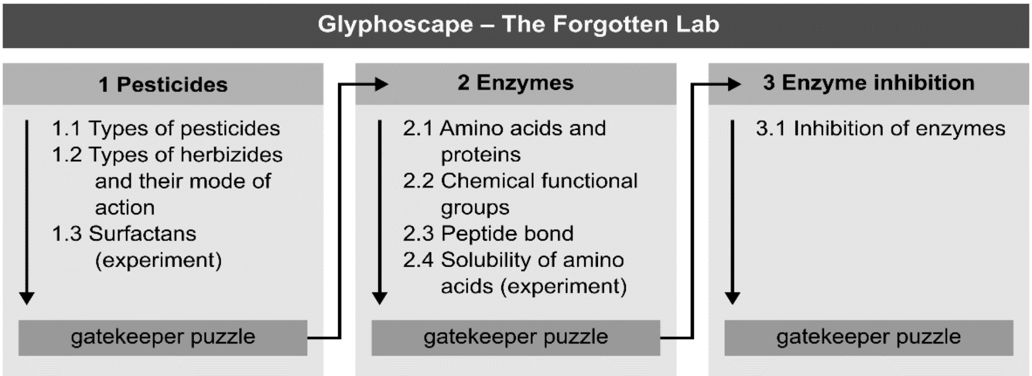

Fig. 4. Overview of the three sections of the escape room game *Glyphoscape – The Forgotten Lab* and their puzzles. Each section is linear in structure and ends with a gatekeeper puzzle on an old computer terminal. The successful completion of this last puzzle is required for the start of the next section

In each section the students have to solve riddles and quizzes regarding the topic of the section. First, the students learn about the different types of pesticides and herbicides and their terminology. Since surfactants are often contained in pesticide or herbicide solutions as a wetting agent, an experiment on surfactants is conducted in the last puzzle of the first chapter. In the second section the players have to use their knowledge about basic (bio-)chemical principles to proceed to the next section. After they learn about the role of amino acids and proteins, they recapitulate some basic knowledge of organic chemistry. This will be important for the next riddles in which the students identify amino acids and peptide bonds in an image of a protein and investigate the solubility of amino acids. The last section provides only one riddle about the inhibition of enzymes. For the last riddle the players define and describe the competitive, uncompetitive and non-competitive inhibition by using a model.

The last puzzle of each section provides a password that can be used to unlock Dr. Albas computer. Before the next section can begin, a gatekeeper puzzles have to be solved on the terminal. The contents of the previous puzzles are applied in this puzzle.

One question per puzzle is asked at the terminal which deepens the learning content or transfers what has been learned to glyphosate. For example, players have to evaluate what type of pesticide glyphosate is (section 1) or which type of inhibition applies to glyphosate (section 3). Correctly answering all the questions in the gatekeeper puzzle leads to the next section or – as in the last puzzle – out of the room. After solving each puzzle and riddle the computer terminal automatically prints a summary of Dr. Albas research, so the players can get a hand-out to take with them.

2.3 Possible use scenarios

The escape room game can be used in order to teach the role of the induced fit or the simplified lock and key model in the understanding of enzymes. It is also possible to use this game for an introduction to the scientific principles of glyphosate followed by a discussion about the carcinogenicity of glyphosate and also the way of classifying it. In a more social and sustainable approach this can be followed by discussions on the general use of pesticides in the environment and its consequences. For a more interdisciplinary teaching the game can be accompanied by discussions [11] or experiments [12] about genetic modifications of glyphosate-resistant crops.

Furthermore, the escape room game can be used for interesting science outreach activities e. g. at open days or for project-based learning where students built this room at their school by themselves.

The escape room was designed to be very flexible and customizable. For half of the puzzles, alternatives were developed that require less effort or estimate lower costs. The difficulties of the puzzles can be adapted to the group of players through editing Dr. Alba's notes. The two proposed experiments are harmless and do not require a lot of laboratory equipment, but can still be replaced by simpler puzzles in which the results of the experimental procedures are discussed instead of conducting the experiment itself.

Since immersion is an important factor for escape rooms [5], various optional interior items and furniture are suggested to decorate the room. Due to the great modifiability of the concept, the escape room game can be used variably under different institutional limitations.

3. Conclusion and outlook

The presented escape room allows an exciting and motivating approach to fundamental ideas of biochemistry, especially concerning the context of enzyme inhibition. As a result of the high flexibility, the game can be used in multiple use scenarios. The linear sequence of the puzzles secures that all players solve the puzzles together and transfer their knowledge to glyphosate in the gatekeeper puzzles. Due to the COVID-19 pandemic, we have not yet been able to examine the game for its learning and motivational effects. It is planned to make the concept freely available on the authors' homepage.

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Rakursi Gallery – Initiatives for People with Visual Impairments

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Abstract

The paper analyses the initiatives for people with visual impairments realized by the Rakursi Gallery in Sofia, Bulgaria as one of the leading institutions in the country that offers educational programmes for this public. The research methodology includes Case Study, interview with a curator from the gallery, analysis of the website, publications and other materials.
Many museums worldwide, such as Victoria and Albert Museum in London, Great Britain, have developed special tours, events or workshops for visitors with disabilities. However, in Bulgaria there are only few examples of such initiatives.
In this context Rakursi Gallery has achieved remarkable results within the exhibitions "Touch the Treasure" (April 2016), "A Look at Modern Art" (June 2016) and "Feel the Art (Access to the visual arts of students with visual impairments)" (March 2019), organized for students from the School of visually impaired children "Louis Braille" in Sofia. As part of the exhibitions the staff of the gallery held workshops during which the children were able not only to learn more about the main theme of the event but to become artists themselves.
Moreover, the founders of Rakursi share their experience with this type of public with other museum workers during specialized training sessions.
The activities of the Rakursi Gallery for children with visual impairments could stand out as a good Bulgarian practice for educational programmes. It will be used as an example in the training process of Bachelor students at the academic courses Access to Information for People with Special Needs and Accessible Tourism at University of Library Studies and Information Technologies. Thus, the students would develop a better understanding of the educational mission of modern galleries and museums as "cultural institutions for all".

Keywords: Rakursi Gallery, people with visual impairments, educational programs, audiences, Bulgaria, academic education

1. Introduction

The importance of ensuring access to cultural venues for people with disabilities has come to the attention of the governments of many countries worldwide ever since the United Nations' Convention on the Rights of People with Disabilities was implemented in 2011 [2]. The European Union, as one of the parties to the Convention, developed a strategy to facilitate the access to culture for people with disabilities via different projects and programmes. A successful step in the right direction was made in October 2018 when the EU ratified the Marrakesh Treaty, administered by the World Intellectual Property Organization, thus facilitating the access to published works for visually impaired people [4]. As important cultural and educational institutions, many European museums adapted their policies and buildings in an effort to become more accessible to people with disabilities. Furthermore, these institutions started to offer special tours and educational programmes for this type of public. Victoria and Albert Museum (V&A) in London, Great Britain, for example, has developed different initiatives for visitors with mobility, hearing or visual impairments, people with learning disabilities and dyslexia.

V&A offers mobility aids, guiding services, talks in British Sign Language for deaf and hard of hearing people, audio guides, tactile books, talks and a range of touch objects for visually impaired people. Museum's specialists have also created an interactive sensory backpack, which helps children with visual impairments and their family to learn more about ceramic objects from China to the Netherlands [13]. All these different types of services show the importance of people with disabilities as a valuable part of the museum public. Moreover, those visitors are no longer passive admirers of art. They participate actively in the cultural dialogue between the museum and its public via various educational programmes.

2. Goals and Methodology

In Bulgaria there are only few examples of museum programmes and initiatives for people with disabilities. Some museums are not even accessible for people with special needs. However, galleries such as National Gallery Kvadrat 500 and Sofia City Art Gallery have created tactile paintings and replicas of their most famous artworks for people with visual impairments [5, 10]. When it comes to working with this type of public many museum curators prefer to cooperate with non-governmental organizations who have experience with projects for people with disabilities.

In this context, Rakursi Gallery in Sofia is a rare example of a private institution which creates its own interactive workshops for children with visual impairments [6]. The main goals of this paper are to analyse those initiatives realized by Rakursi and to highlight the gallery's potential as an educational centre. Rakursi has become one of the leading institutions in the country that offers educational programmes for children with visual impairments. The curators share their valuable experience and know-how with specialists in the field, cooperate with schools and universities during different national and international projects. The research methodology includes Case Study, interview with a curator from the gallery, analysis of the website, publications and other materials.

3. Rakursi Gallery – initiatives for people with visual impairments

Rakursi Gallery was established in 2004 by Rositsa Chusheva and Rumyana Yoneva and mainly focuses on modern and contemporary art. One of the main goals of its curators is "to bring art to public of different backgrounds" [7]. An expression of this mission is the exhibitions "Touch the Treasure" (April 2016), "A Look at Modern Art" (June 2016) and "Feel the Art (Access to the visual arts of students with visual impairments)" (March 2019), organized for students from the School of visually impaired children "Louis Braille" in Sofia. "Touch the Treasure" and "A Look at Modern Art" were part of the international project BaGMIVI: Bridging the Gap between Museums and Individuals with Visual Impairments [8]. The project is a cooperation among the gallery, the Bulgarian Association of Visually Impaired Children, the Sofia University "St. Kliment Ohridski", Faculty "Special Education", and other European universities, museums, institutions. BaGMIVI's aim is to change the understanding that museums only collect, preserve and exhibit artworks. They are also educational institutions and places with important cultural and social roles where people with different backgrounds, interests and needs could come together and exchange thoughts and ideas. In this context, the people with visual impairments are an important part of the public which more and more museums try to attract.

"Touch the Treasure" was a successful event that started a cooperation between the Rakursi Gallery and the School of visually impaired children "Louis Braille". During this initiative the students could examine replicas of famous Thracian treasures and they are encouraged to find the artifacts' locations on a tactile map of Bulgaria. There is a theoretical part which teaches the children about the history and customs of the Thracian tribes. At the end of the programme, the participants create their own replicas of the treasures with the help of museum specialists. The value of "Touch the Treasure" is in the multidisciplinary approach that broadens the students' knowledge in the fields of art, history and geography. The visually impaired children begin to perceive the art gallery as a place to learn but also to have fun with their peers in a cultural environment.

After the success of "Touch the Treasure", the gallery's curators decided to continue the educational programme under a new name – "Feel the Art (Access to the visual arts of students with visual impairments)" [3]. This initiative was similar to the previous one but it included another group of children from the same school. For the realization of "Feel the Art", Rakursi Gallery gained the financial support of the National Cultural Fund of Bulgaria which is another testament for the educational and social role of the initiative.

While developing the educational programmes the museum curators worked closely with teachers and kids from "Louis Braille". They took into account the students' interests and abilities. Moreover, the Rakursi's staff encouraged the foundation of a school museum inside the building of "Louis Braille" where the participants present the artwork created during the workshops [1]. In this way, the initiatives of Rakursi Gallery reached a larger audience. Another programme organized specifically for the students from "Louis Braille" is "A Look at Modern Art". The theme of this project was chosen during a discussion with the children. One of them mentioned that she would love to get familiar with the physique of a horse so the curators asked several Bulgarian artists to donate sculptures of horses. During the workshop the students could touch the sculptures which were representative for different art movements from the 20th century and compare them.

They also listened to a lecture about expressionism, cubism, abstract art, etc. In the end of the programme, the children became artists themselves by creating a self-portrait using different materials, fabrics and aromas. The initiative helps the participants learn more about art history but also encourages them to use their imagination and creativity. "A Look at Modern Art" teaches the children that art offers limitless possibilities.

As experienced professionals who worked closely with visually impaired children, Rakursi's staff were chosen to become partners in the international project EU UNESCO4ALL TOUR. The goals of this initiative are to present UNESCO's cultural heritage sites in an accessible manner, to encourage the cultural tourism for people with visual impairments and to promote multicultural dialogue through art and history [9]. The partners in the project would create replicas of famous UNESCO sites for the visually impaired people to touch and explore. The replicas would include an audio guide that would make the visitor familiar with the history of the site. Bulgaria would be represented by a replica of the Rila Monastery and an icon of St. Ivan Rilski. This initiative offers an innovative and technology-driven way for the people with visual impairments to learn more about valuable local and international cultural heritage sites. Moreover, as part of the project, Rakursi would organize educational seminars for museum curators, university professors, tourist agents, hotel managers and would share its know-how for working with this public [1].

4. Conclusion

The curators of Rakursi Gallery work closely with local and international professionals while developing programmes for the visually impaired. They take into account the specific needs and interests of the public and accomplish remarkable results. They also share their experience with other Bulgarian cultural institutions during special seminars and sessions thus turning the gallery's building into a social place and an educational centre. The activities of the Rakursi Gallery for children with visual impairments could stand out as a good Bulgarian practice for educational programmes. It will be used as an example in the training process of Bachelor students at the academic courses Access to Information for People with Special Needs and Accessible Tourism at University of Library Studies and Information Technologies [11, 12]. Thus, the students would develop a better understanding of the educational mission of modern galleries and museums as "cultural institutions for all".

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The Anthropocene Project – A Solution to the new Environmental and Digital Challenges

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Abstract

The article is based on a study of the Anthropocene project (Erasmus+ programme), developed within a partnership of schools, education and ICT institutions from four European countries: Belgium, France, Italy and Romania. The project focuses on the new environment challenges brought about by two economic and digital accelerated developments and highlights the role that school can play in preparing young people to manage them. The project aims to help teachers prepare young people for the new environment in three steps. To this end it suggests studying how these challenges are addressed in political, societal and educational spheres, raising educators' awareness and offering resources to make teachers' work more effective. The article introduces the project's objectives, outputs and activities. It also gives insights into the research conducted in Romania to explore how the environment and digital issues have been addressed in the education system so far.

Keywords: economic and digital accelerations, environment challenges, education

1. Context

Europe faces new environment challenges brought about by economic and digital accelerated developments. Climate change has become a significant major problem in recent years when extreme events have begun to occur more frequently with often devastating consequences. School must assume and enhance its role of preparing students to face and manage the challenges of the future world. The Anthropocene project aims to help and equip teachers with the necessary tools to prepare young people for the new environment [1].

2. The Anthropocene project

The Anthropocene project (Project Number: 2019-1-FR01-KA201-063149) focuses on two accelerations related to technical mutations. The first is the ecologic acceleration that has ignited debates on how to call our time. Humans have recently left unprecedented geological force-like marks on our planet such as mass extinctions of plant and animal species, pollution of the oceans and the atmosphere. That is why some experts suggest another term: “Anthropocene” – from *anthropo*, for “man,” and *cene*, for “new”. The second acceleration is the digital one that has introduced the concept of “homo data”. The term dataism was coined by David Brooks in an article in the New York Times in 2013 [2], and further developed by historian Yuval Noah Harari in his 2016 book *Homo Deus*. Dataism considers the universe as a system of data streams where the value of objects and people is determined by their capacity to process data [3]. To dataists, data and especially big data are supreme values. According to Harari, big data algorithms are likely to know people better than they know themselves [3].

2.1 The main objectives of the project

The project aims to help prepare young people to handle the new environment by studying how political, societal and educational spheres address these challenges, raising awareness in the educational sector and offering teachers resources to facilitate the teaching/learning process.

2.2 Target groups

The project addresses:

- twelve- to twenty-year-old European people, the future European citizens, who will have to successfully implement the low carbon transition.
- Teachers, who support young people in daily life and who will be an intermediate target and act as a lever [1].

2.3 Intellectual outputs

The first output is a study investigating how several European education systems address environmental and digital issues, particularly in curricula and related subjects.

The study is based on quantitative and qualitative surveys carried out on teachers from the partner countries (Belgium, France, Italy and Romania).

The teachers’ e-learning platform aims to raise teachers’ awareness and provide them with resources and activities meant to stimulate students’ motivation and get them actively involved in the topic.

The teachers’ Toolkit consists of a toolbox with educational scenarios, which engage students in experiments and role-plays inviting them to exciting journeys to discover environmental challenges [1].

3. Research on the current environmental and digital education in Romania

The research identified a lack of specialized education in the field of climate change.

There is no stand-alone school subject tackling the issues of risks and opportunities related to climate and environmental acceleration. Environmental issues are allocated up to 4-8 hours/year [4] and very often they are integrated into other subjects. However, teachers can opt for the Curriculum at the school’s decision and allocate an estimative number of 35 hours/year, as an optional class, within topics such as Create your environment; Ecological and environmental protection education etc.

Table 1. Presence of the Environmental Issues in school text-books

	Subjects	Answers
Lower of secondary level	Literary Subjects	✓ Non-existent or almost non-existent ☐ Relatively little addressed ☐ Significantly
	Humanities	☐ Non-existent or almost non-existent ✓ Relatively little addressed ☐ Significantly
	Sciences	☐ Non-existent or almost non-existent ✓ Relatively little addressed ☐ Significantly
	Technological/Professional Education	☐ Non-existent or almost non-existent ✓ Relatively little addressed ☐ Significantly
General upper secondary level	Literary Subjects (national and foreign languages)	✓ Non-existent or almost non-existent ☐ Relatively little addressed ☐ Significantly
	Humanities (Hist/Geo, Social sciences, eco, philosophy...)	☐ Non-existent or almost non-existent ✓ Relatively little addressed ☐ Significantly
	Sciences (Math, PhysSc, Bio)	☐ Non-existent or almost non-existent ✓ Relatively little addressed ☐ Significantly
	Technological/Professional Education	✓ Non-existent or almost non-existent ☐ Relatively little addressed ☐ Significantly

The survey carried out in Romania, within the Erasmus+Anthropocene project 2019-1-FR01-KA201-063149, involved 70 teachers and 150 students (from over 40 schools from 4 counties – Iasi, Suceava, Vaslui, Bacau; schools from rural and urban areas).

The vast majority of teachers considered that the number of classes is insufficient and in most cases the issues are dealt with theoretically rather than practically. To meet students' needs teachers have to organise extracurricular activities regarding the environment and climatic changes. The most popular are educational projects in partnership with other schools followed by school competitions and the celebration of special days (March 22nd – World Water Day, April 7th – World Health Day, April 22nd – Earth Day, May 22nd – International Day for BiologicalDiversity, June 5th – World Environment Day).

Teachers also complained about the lack of educational materials developed by specialists in the field of environmental protection. Regarding the way the topics are addressed in the official programme/curriculum only two out of 70 considered this to be appropriate. Most of the teachers stated that they had no in-service training: "I consider myself a self-study learner. I always find something to read to learn about what could threaten human well-being, first and foremost. Questions like What Happens? on various environmental issues (Air pollution, Biodiversity, Chemicals, Climate change, Environment and health, Overuse of soils, Natural resources, Noise, Soil, Waste and material resources, Water, etc.) incite students' curiosity".

As for digital education, this has recently become one of the priorities in Romanian education. The integration and use of various types of technology in the educational process is no longer seen as an avant-garde movement, but as a necessity. Virtual education has become a phenomenon in recent years, and its short, medium and long-term effects should be evaluated more carefully.

The national curriculum includes the study of Administration of computers and networks or professional occupational studies but there is no school subject addressing the issues of risks and opportunities associated with digital acceleration and big data.

Teachers can allocate an average of 4-8 hours/year for the study/debate on issues of risks and opportunities associated with digital acceleration and big data within counselling or optional classes [5]. Nevertheless, even for the specific ICT schools, the specific approach of the digital acceleration and big data issues are under the responsibility of each teacher. The digital acceleration and big data issue are relatively little addressed.

Table 2. Presence of the Digital Acceleration Issues in school text-books

School level	**Subjects**	**Answers**
Lower secondary level	Literary Subjects	✓ Non-existent or almost non-existent ☐ Relatively little addressed ☐ Significantly
	Humanities	☐ Non-existent or almost non-existent ✓ Relatively little addressed ☐ Significantly
	Sciences	✓ Non-existent or almost non-existent ☐ Relatively little addressed ☐ Significantly
	Technological/Professional Education	☐ Non-existent or almost non-existent ☐ Relatively little addressed ✓ Significantly

General upper secondary level	Literary Subjects (national and foreign languages)	✓ Non-existent or almost non-existent ☐ Relatively little addressed ☐ Significantly
	Humanities (Hist/Geo, Social sciences, eco, philosophy...)	☐ Non-existent or almost non-existent ✓ Relatively little addressed ☐ Significantly
	Sciences (Math, Physics, Bio)	✓ Non-existent or almost non-existent ☐ Relatively little addressed ☐ Significantly
	Technological/Professional Education	☐ Non-existent or almost non-existent ✓ Relatively little addressed ☐ Significantly

All teachers agreed that although there were programmes for digitizing schools, they are insufficient in relation to the existing needs. Having technology at our disposal means learning not only how to use it but also how to manage its challenges. Our school covers this issue superficially (4-8 hours/year during Counselling classes), in most cases through extracurricular activities. “The technologically saturated space in which children grow up is constantly changing. Children grow up in an environment of converged media devices, where significant opportunities for sociability, expression, learning, creativity and participation are provided by online media and especially mobile media. Beyond opportunities, children may encounter a number of risks on the Internet. The more children use the Internet, the wider the range of opportunities, as well as increasing their exposure to risky experiences. Given that mobile media has improved the access to the internet new research is needed on the opportunities and risks of the mobile internet for children.” Teachers agreed that the topic is important and deserves to be addressed in the official curriculum. It also requires new methodological approaches and training for teachers.

4. Conclusions

The importance of studying the issues of environmental changes and digital acceleration and big data is not yet reflected in our educational system. There have been programs for environmental and digital education, but they are insufficient in relation to the existing needs. At the school level, risks in this regard are insufficiently controlled.

The Romanian authorities do not, yet, focus specifically on the issues of climate change and digital acceleration, but slow steps are being made. Under the current situation, the Romanian authorities launched a new strategy for the pre-university education system (in February 2020). The law is expected to be enacted, and the two most important “transformations” contained in the bill adopted by senators are [5]:

- The change in the proportion between the common core and the curriculum at the school’s decision: instead of 80-20, it is now 65% by 35%. This is the most significant as it means greater openness to students’ decision and greater weight in the school's offer.

- The second important aspect is the configuration of the current Article 262, which, in fact, develops/proposes an entirely new model of teaching and standardization careers, focused on equivalent horizontal options. This means that, from now on, teachers will be able to be remunerated not only for teaching, but also for other non-teaching actions such as, for example, career counselling for children, coaching and mentoring for teachers-beginners, project management for the benefit of the school [4, 5].

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The Effectiveness of Physics Lab Reports and Practical Tests as Assessment Tools of Practical Skills

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Abstract

In Malta, at Secondary Education Certificate (SEC) level – equivalent to the British GCSE – candidates' practical skills in Physics are assessed through written laboratory reports. Despite criticism of this assessment mode by researchers, research studies into other assessment modes for reliable feedback on practical skills are non-existent. This study investigates the appropriateness of the assessment of practical skills through the current mode, and whether practical tests can be better assessment tools for such skills. The qualitative approach adopted was ethnographic and was carried out with two groups of Physics students: one group exposed to practical tests and written laboratory reports, and the other group presenting laboratory reports only. All 36 students underwent a practical exam at the end of the scholastic year, during which they used the think-aloud method; they were video-recorded. Data collection included students' written documents, verbal and non-verbal communication, for triangulation of data. This study showed that assessment based solely on lab reports does not give suitable feedback on students' practical skills. It was concluded that practical tests should accompany, and not replace, the assessment of lab reports for more reliable information about students' practical skills. The feedback regarding practical skills elicited from the students' written work was shown to be limited on its own.

Keywords: practical work/skills, lab reports, practical tests, feedback

1. Introduction

1.1 The Aim

The aim of this study was to devise and evaluate methods to assess practical skills better. Often, emphasis is placed on exploring new pedagogies for the acquisition and enhancement of practical skills. However, it is important to have a compatible mode of assessment. This research study sought to investigate whether practical skills are being properly assessed through the current mode of assessment, and if they could be better assessed through practical tests.

1.2 How are Students' Practical Skills being Assessed?

The introduction of the SEC examination system in 1994 included coursework (15% of the final mark) in the science subjects, to give importance to practical skills. Students are required to present a number of practical reports, assessed by educators against a set of criteria specified by the MATSEC Examination Board. The assessment of practical skills is included through the allocation of five marks for '*Actual conduct of experiment* *including handling of apparatus*', with no further 'specification' on the awarding of these marks. [8]

1.3 Reliability of Current Assessment of Practical Work

Prior to reviewing the reliability of its current mode of assessment, one must consider the primary aim of practical work: is it a reliable tool for what it is primarily intended?

Throughout this study, the primary aim of practical work was held as acquiring feedback on students' practical skills and to enable the educator to scaffold students' learning and enhancement of practical skills. It is often assumed that participation in practical work automatically leads to gaining scientific skills. Students' grades for 'traditional' practical work may be incompatible with actual performance. [7] A student might copy results, follow instructions to complete the write-up and achieve a good grade – the grade would reflect the student's diligence rather than proficiency in practical skills. [9] Even when students achieve excellent results, they may feel uncomfortable without errors to discuss and may even introduce stray readings. [13]

1.4 The Need for Change in Assessment of Practical Work

The current assessment mode of lab reports led students to evolve into good cooks rather than good scientists. [15] As the report contributes towards the final grade, only a narrow range of students give it importance as a means of developing and enhancing practical skills. [7] Standardised, external assessment methods influence both students and educators. Behaviour will not change unless the assessment methods are also amended. [4], [7] We may need a more extensive, continuous assessment model during practical sessions throughout the year. [11] There is no simple solution for a valid and reliable method. The use of multiple formats offers more opportunities to demonstrate students' knowledge and skills; disadvantages in one assessment method may be compensated by advantages in another. [6]

2. Methodology

This qualitative research study focused on meanings and processes. The research method adopted must be compatible with the social actions present. In line with the research questions, observations were preferred over interviews since the former include participants' feelings, perceptions and opinions. [3] This study dealt with the assessment of practical skills rather than perceptions about them, and thus required a variety of modes. The study was carried out in one school, with 36 participants taught by the same teacher: 22 Form IV and 14 Form III students. The two groups were exposed to different assessment strategies during their Physics course. Form III students carried out experiments and completed a lab report as required by the SEC exam, apart from being exposed to a number of practical tests throughout the year. The Form IV students compiled SEC lab reports but were not exposed to practical tests. At the end of the year, both groups had a practical exam, held under the same conditions.

The practical exam was held individually, where students used the think-aloud method. When students write their answer on completion of a task, it usually summarises the whole process. Decisions and discussions underpinning the final answer are often absent. Thus, final answers in the practical exam may not yield all 'information'.

The sessions were video-recorded to identify the students' thinking process and the practical skills used throughout the task. The method provided the verbalization of the students' mental processes. The recordings enabled the researcher to 'revise' the same student, increasing data reliability and validity.

3. Analysis of Results

3.1 Handling Data

Following organisation of the data, it was extracted and analysed. This process consisted of three parts, namely the analysis of: (i) verbal communication; (ii) non-verbal communication; and (iii) students' written results. The process adopted is schematised in Figure 1.

Throughout the extraction and analysis of data, coding as set by Strauss was adopted. [12] The steps marked in blue in Figure 1 represent open coding, where data is condensed into initial categories, themes and codes. The steps marked in yellow represent axial coding, where focus is on connections between themes and pattern formation. The modules marked in green represent selective coding, where the researcher scanned the links and themes and drew comparisons to recombine data and form conclusions.

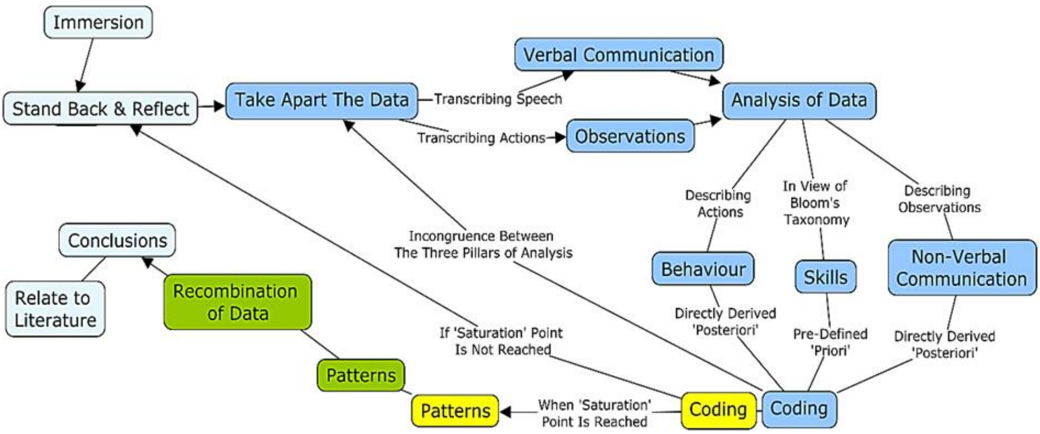

Fig. 1. The process of extraction and data analysis (compiled from [1], [2], [10], [12], [14])

3.2 Current Assessment of Practical Work

This research study indicates that current practice in assessment of practical work does not promote the maximum potential in understanding scientific concepts since the feedback does not address the students' true weaknesses. Notwithstanding, the current practice should not be discarded, but rather be enhanced by supplementary practices.

Even though some students did not possess 'good' scientific habits, they still managed to achieve good results in certain cases. The lack of understanding, thinking and behaving in a scientific manner alongside the learning of the scientific knowledge were almost 'undetectable' in the students' reports. Consequently, relying solely on the lab reports would hinder the valuable feedback for both student and teacher. It would not be possible to review pedagogies according to students' needs.

3.3 Assessment of Practical Work through Practical Tests

Students distinguished between objects that float or sink based on density values.

But the 'succesful' students may still lack the practical, analytical skills and might only be comparing the density values and recalling the fact that denser objects sink, and vice versa. So, by reviewing only students' written work, it would be difficult to assess the competency in analytical skills. Through the practical exam, some students demonstrated their high proficiency in analysis during 'unexpected' occurences during practical work. Through feedback from the practical exam, the teacher would be able to re-evaluate the teaching pedagogy, which would have not been achieved through the assessment of laboratory reports only.

3.4 Promoting Practical Tests as an Assessment Tool

Evidence from this study shows that using practical tests as an assessment tool provides better feedback about practical skills. Integrating practical tests within the current assessment system may seem time consuming. It is recommended that educators have a form for each student throughout the three-year course. The teacher can conduct practical tests in various topics, where students are required to use practical skills. It would be impossible to assess each student on each skill during the same session. The teacher can organize practical tests according to what has been assessed and has yet to be observed. Should students fail to demonstrate a skill in one test, the teacher would plan: (i) sessions where students need to practice practical skills; and (ii) other tests where students can demonstrate these skills. Thus, students will be given the opportunity to work on their weaknesses and improve their learning. Such tests will consider students individually rather than in relation to others, and help to "identify strengths and weaknesses individuals might have so as to aid their educational progress." [5, p. 8] The skill of writing a report and using technical vocabulary constitute a very small proportion of these skills. Thus, the frequency of written lab reports should be reviewed, whilst exploring alternative methods of assessment such as practical tests.

4. Conclusion

This research study indicated that the current assessment mode of practical work is not effective in providing useful feedback about practical skills. It exposed how students who do not own given practical skills can still 'conduct' practical activities and create 'good' laboratory reports – at the expense of very 'limited' feedback regarding students' practical skills and not being able to act on such lack of skills. Practical tests should not replace the assessment of lab reports (students also learn how to present a scientific report), but should rather compliment them for more reliable information about students' practical skills. The frequency of written lab reports should be re-evaluated and adapted according to students' needs by the teachers themselves, rather than 'imposed' by an external examination body. Better assessment of practical skills leads to better opportunities – for both students and teachers – to identify and work on the weaknesses, which is the primary function of assessment.

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STEM Education

"Don't Throw Away your Mobile!": Pupils' Perception of Raw Materials in Electronics Through Citizen Education

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Abstract

In this paper we analyse the comments resulting from citizen education pathways proposed to two classes of a Scientific Lyceum in Italy. The path is inserted in the "Raw Matter Ambassadors at Schools" project (RM@Schools). The project proposes to 10-17-year-old pupils an active learning pathway where students, after attending RM-related classes, are asked to become science communicators and to create dissemination products focused on issues related to RMs. Given the actual COVID-19 restrictions, the pathway took place in hybrid form with on-line seminars and a live laboratory session in which the pupils could watch a researcher execute an experiment. Three seminars, about circular economy, raw materials in electronics, and applications of graphene in sensing, were given by researchers with the aim of illustrating the social relevance of scientific research findings. The experiment showed the reasons for further research to transfer a research result into a commercial product. The students were asked to comment on the contribution of scientific activities connected to RMs to the achievement of the Sustainable Development Goals (SDGs) of the Agenda 2030 and to comment on the effectiveness of the communication activity of the RM@Schools project in raising awareness among youngsters. The analysis evidences that i) the objective of framing a scientific topic as a possible solution to a social issue has been reached; most of the pupils think of social network as the best ways to communicate to youngsters; the live experiment that complemented the pathway is effective in catching pupils' interest.

Keywords: secondary school, critical raw materials, electronics, research, citizen education

1. Introduction and Methodology

The supply of raw materials is crucial for Europe economy. Since the supply of a certain group of raw materials is a major concern for European industry growth [1], it is important to create a strategy to face this problem with a holistic approach: better exploitation of local resources, substitution of critical raw materials, transition to circular economy. Education of highly skilled professional is a mandatory element in such strategy. For this reason, the European Commission has funded a pool of educational projects, finalized to explain the value of raw materials to society. The project Raw Matters Ambassadors at Schools (RM@Schools) [2] has received funding by the

European Institute of Technology (EIT) in the sector of Raw Materials [3] since 2016. It is aimed to raise awareness of the importance of some materials in everyday life in schools and promote the image of science & technology for students aged 10 to 19 years in order to make new professional careers in this sector attractive to youngsters.

The learning pathways proposed in RM@Schools are addressed to a whole class and are featured by a modular structure. The core activities consist in attending a lesson on RM-related issues lead by a researcher and in the creation of a dissemination product inspired by the lesson [4]. Further activities can include either attending a second lesson to learn more or to deepen the previous knowledge, or running an experiment, or visiting a research center, or a company.

In this paper we focus on learning pathways related to raw materials in electronic devices proposed to three classes of a Scientific Lyceum in Italy in the frame of citizen education, an interdisciplinary topic introduced in 2019/2020 in high school curricula. The first lesson was a public webinar in the frame of the science festival “Futuro Remoto” [5].

The core lesson is named “Don’t throw away your mobile!”. Two CNR researchers explained how new materials can promote circular economy. The second webinar, a private lesson given to the classes, deepened the topic of materials used in electronic devices. The title, “Don’t throw away your mobile!”, recalls the fact that mobile phones are widely accessible devices which exploit many innovative technologies. The topic is introduced by a google search of “raw materials in electronic devices” which shows the most relevant criticalities in the RM supply chain: scarcity in the Earth crust, provenience, pollution, prices, and ethical issues. Then, we speak about the properties of materials used in various sectors of the semiconductor industry: electronics, photovoltaics, lighting, signal transmission through fiber optics. The main scientific topic of the lesson is the substitution of indium tin oxide (ITO) in transparent conductive electrodes and the application of a novel two-dimensional material, graphene [6]. Since the pathway aims at linking science with citizen education, a “context-based” educational approach is appropriate in order to raise interest in the audience [7]. Finally, the class performed an experiment in which two glass slides played the role of resistors in a circuit made up of a battery, a LED and the resistor (i.e., the glass slide). The light in the LED is brighter when the ITO-coated slide is inserted in the circuit, meaning that its electrical conductance is higher than the conductance of graphene. This experience opens to a discussion about the need of further research in graphene technology in order to transform a research result into a commercial product.

The learned contents are re-elaborated by the pupils with comments on the contribution of the proposed scientific topics to Sustainable Development Goals (SDGs) of the Agenda 2030. In this paper we make a re-examination of the topics treated in the reports made by the pupils.

2. Results and discussion

2.1 State of the art before the pathway

In order to have a better evaluation of the background knowledge among high school students, it is useful to report on the results of a survey prepared by the pupils of two pilot classes, who attended the lesson a couple of weeks in advance with respect to their peers [8]. The survey was made up of 27 questions covering several topics concerning RMs. 433 pupils aged between 13 and 18 years took part in the survey. We can comment some of the answers, see Figure 1.

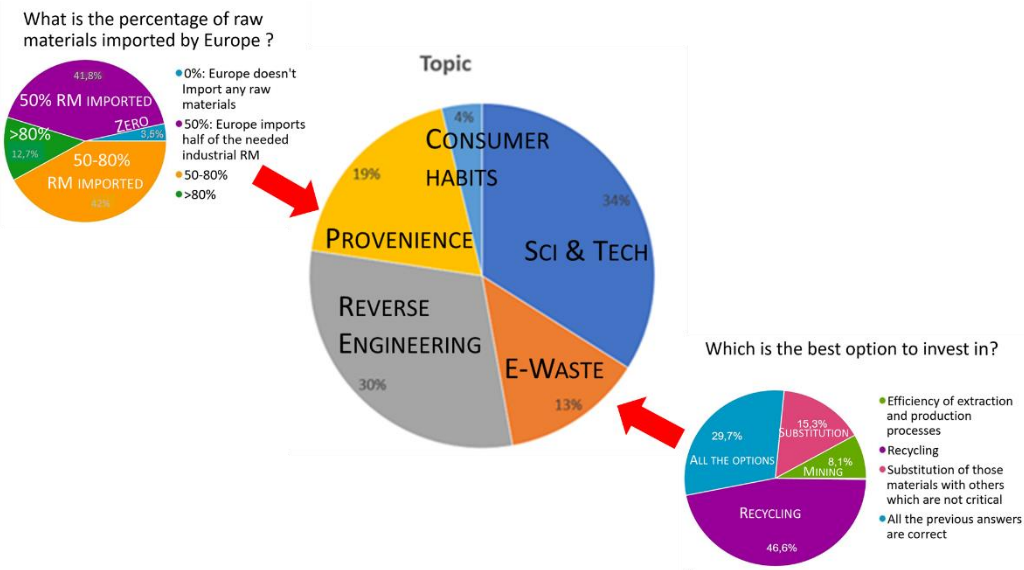

Fig. 1. Interest in the topics emerged from dissemination materials created in 2016-2019. This analysis testifies the suitability of the proposed topic to citizen education

The correct answer to the question "what is the percentage of raw materials imported by Europe?", i.e., ">80%", was given by 14% of the audience. This indicates that pupils' awareness about criticalities in RM supply was limited before taking part in the project.

Pupils' favorite solution to RM issues, represented by the question "Which is the best option to invest in?", is Recycling, chosen by 47% of the audience. The focus on recycling is probably related to the feeling of empowerment towards the topic: indeed, recycling is something that most people are used to in everyday life and is perceived as something possible. Other solutions are perceived as a prerogative of scientists and engineers.

However, though good recycling practices are widespread for materials like glass, paper and plastics, in most cases electronic devices are bound to lie in a drawer at the end of their lives. An examination of the dissemination products created through the years 2016-2019 by pupils attending the lesson "Don't throw away your mobile!" attests the coherence between the answers given before the pathway and the topics of the dissemination products created to explain the topic. Though the predominant content is related to the materials that constitute electronic devices, many works contextualize the scientific topic in the lifecycle of materials, with major interest in material provenience and device recycling. The focus on provenience is attributed to the surprise and concern of the pupils in discovering that they underestimated the percentage of imported raw materials; the focus on e-waste is coherent with the expectations put on recycling before the project. These considerations testify the suitability of the topic to citizenship education.

2.2 Dissemination products

The pupils were asked to comment on the pathway with focus on the following topics:

1) identification of the SDGs related to raw materials;
2) effectiveness of the communication strategy of the RM@Schools project and possibly proposals of alternative communication activities;
3) personal interest in the treated topics.

The analysis of the reports made by two classes allows to comment on the perception of raw material issues among pupils, about the possibility of improving the communication strategy, and on the hybrid teaching mode (remote and on site) set up to face the COVID-19 restrictions.

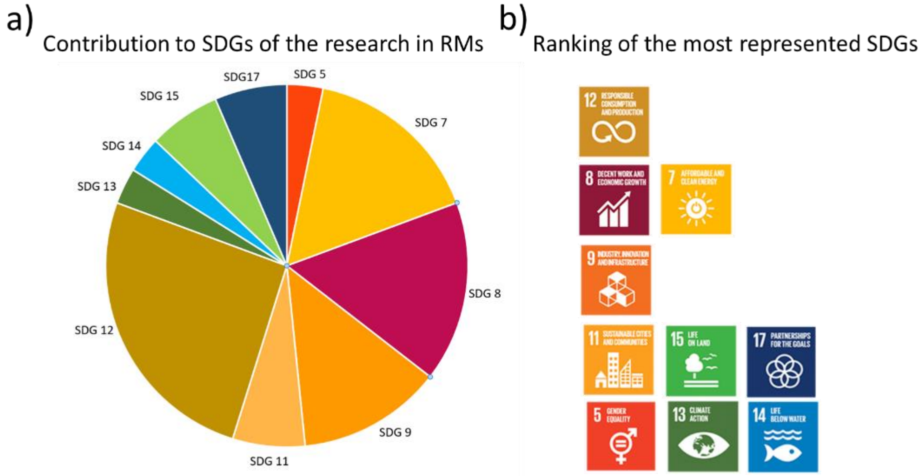

Fig. 2. Pupils' opinion about the achievement of SDGs connected with research on RMs. (a) pie chart; (b) ranking

All the pupils found one or more SDGs benefiting from the illustrated research. SDG 12, i.e., responsible consumption and production, was identified by almost all of them.

The correlation with SDG 7, affordable and clean energy, was identified by many pupils because the scientific core of the pathway, ITO substitution, is a research issue for photovoltaic devices (silicon heterojunction and thin film solar cells). The lesson "Don't throw away your mobile!" also shows the clear link with SDG 8, decent work and economic growth. The continuous recall to research provided an element for connection with SDG 9, industry innovation and infrastructure.

We can make several remarks with respect to point 2. First of all, most of the pupils made positive comments on the presence of actual researchers in their classroom. In fact, speaking about research fosters a more positive storytelling of the whole RM problem, focusing on the solutions that are being setup, explained with a certain dose of critical thinking, that can be better communicated by professionals of the sector. While the constructive character of the pathway was generally appreciated, one pupil evaluated this analytical attitude as less effective in raising awareness of RM importance among youngsters with respect to more emotional description of future treats. Though this comment would suggest a different communication strategy, it is coherent with the reports of the others classmates.

Most of the students find that on-line communication, like the public webinar that started the pathway, and communication through socials, is suitable to involve as many youngsters as possible. However, many of them regretted the possibility of attending conventional face to face seminars, which usually allow for a more direct discussion with the public. In this respect, showing the experiment in presence, though appreciated by the pupils, cannot be evaluated as a definite compensation, because hands-on activity of the students was forbidden for security reasons.

Despite the limitations, the students showed good interest in the proposed topics. In particular the pathway raised curiosity about graphene technology and applications in sensing.

3. Conclusions

We analysed the messages resulting from the reports made by pupils of secondary schools after participating to citizenship pathways focused on raw materials and their key role in new technologies and electronic devices. The goal of the lessons was to make pupils aware of the importance of the research in the field of critical raw materials. The students were asked to comment on the contribution of scientific activities connected to RMs to the achievement of the Sustainable Development Goals (SDGs) of the Agenda 2030 and to comment on the effectiveness of the communication activity of the RM@Schools project in raising awareness among youngsters. The analysis evidences that i) the objective of framing a scientific topic as a possible solution to a social issue has been reached; ii) most of the pupils consider social network as the best way to communicate to youngsters; the live experiment that complemented the pathway is effective in catching pupils' interest about new technologies contributing to social development; iv) despite the lower appeal of the hybrid pathway setup to face the COVID-19 restrictions, the learning objectives have been reached.

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A Systematic Review of the Use of BBC Micro: Bit in Primary School

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Abstract

This paper is a systematic review of the literature on the use of BBC Micro:bit in primary education, including twelve empirical studies published from 2016 – 2020. This literature review's goal was to investigate studies on the effects of using BBC micro:bit for learning. The Goal, Question, Metrics (GQM) approach was adopted as it represents a systematic approach for defining and evaluating a set of operational goals using measurement. Informed by the established systematic review method, the present study undertook the review in three main Phases: Planning, Conducting, Reporting. The relevant data are grouped into four categories. Students and teachers adopt a favorable attitude towards micro:bit, show enthusiasm, and find it interesting. Students consider that it encourages creativity and can help them understand conceptual and procedural knowledge related to computational thinking and problem-solving. The small number of the available literature, especially on the primary education level, demonstrates the need for more empirical research. The lack of any summarization of existing research makes the systematic synthesis of this data essential as it will contribute to more comprehensive knowledge. A meta-analysis was performed to ensure the validity and reliability of the results.

Keywords: BBC micro:bit, primary school/education

1. Introduction

Education is called to qualify students for the knowledge that will enable them to proceed from the simple consumption and use of technological products to their critical analysis, even giving their technological solutions [1-2]. In this context, there is a growing interest in small programmable devices that can be used to teach computational thinking and problem solving [3]. BBC micro:bit is a programmable device and was originally introduced for purely educational purposes. It is a portable, low-cost device and a new, innovative and promising tool.

2. Method

2.1 Goal – Research questions

The increasing use of this device reflects the importance of its creators' project and the importance of the further investigation. The systematic review is expected to present findings in both the teaching and learning process. The following research questions guided this review:

- What experiences have been recorded regarding the use of the micro: bit by primary school students?

- What experiences have been recorded regarding the use of micro: bit by primary school teachers?
- What capabilities of the micro:bit can be exploited in primary school and what obstacles have been observed during its implementation in practice?

Our systematic review includes three stages: planning, conducting, reporting [4]. The research field mapping began with searching for necessary information about the BBC micro: bit from the official website on its features, capabilities, and current data from its release and use. The research questions were then identified, and the following search string according to the Boolean system was derived: (micro: bit OR microbit) AND (learning OR teaching OR learn OR teach) AND (primary school OR education OR elementary school).

This string began to be used in December 2020 in international online databases (ACM, ASEE, ERIC, Google Scholar, IEEE XPLORE, ProQuest, SCOPUS, Springer Science, Taylor & Francis). The research concerns sources written in English that have been published since 2016 (when the release of the micro:bit board started) until 2020.

Besides, the search concerns sources that have been published in reputable journals and have free access. The keywords could be included in the article title, summary, keywords, or even within the manuscript.

Specific inclusion and exclusion criteria were established, and the PRISMA Statement was applied to collect, identify and analyze source data [5]. The Goal, Question, Metrics (GQM) approach was adopted to define and evaluate research objectives systematically and using measurement [6]. The relevant data are grouped into four categories. Firstly, studies that present both students' and teachers' experiences, secondly studies that describe the possibilities or any barriers that may result, thirdly studies related to the effects on skill development and its possible connection with increasing motivation for programming.

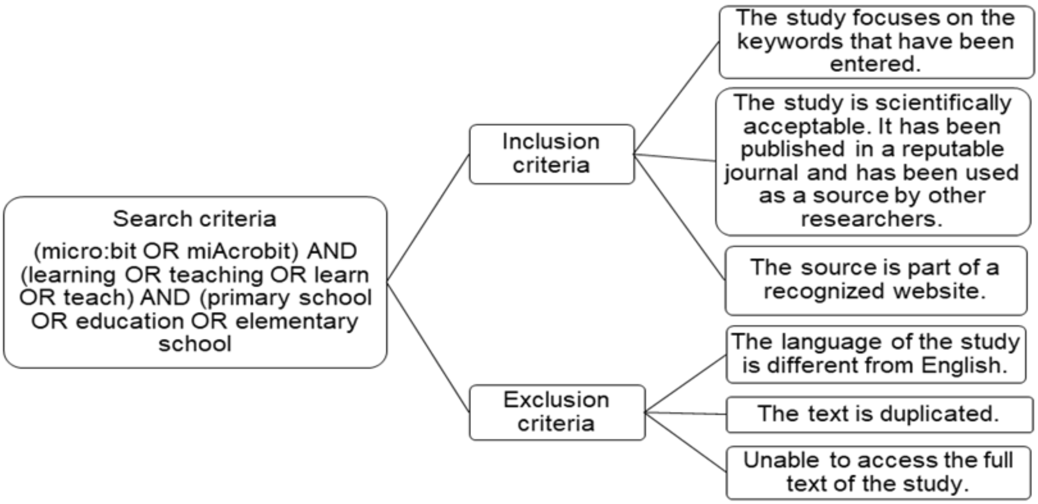

Fig. 1. Criteria for search, inclusion, and exclusion [4]

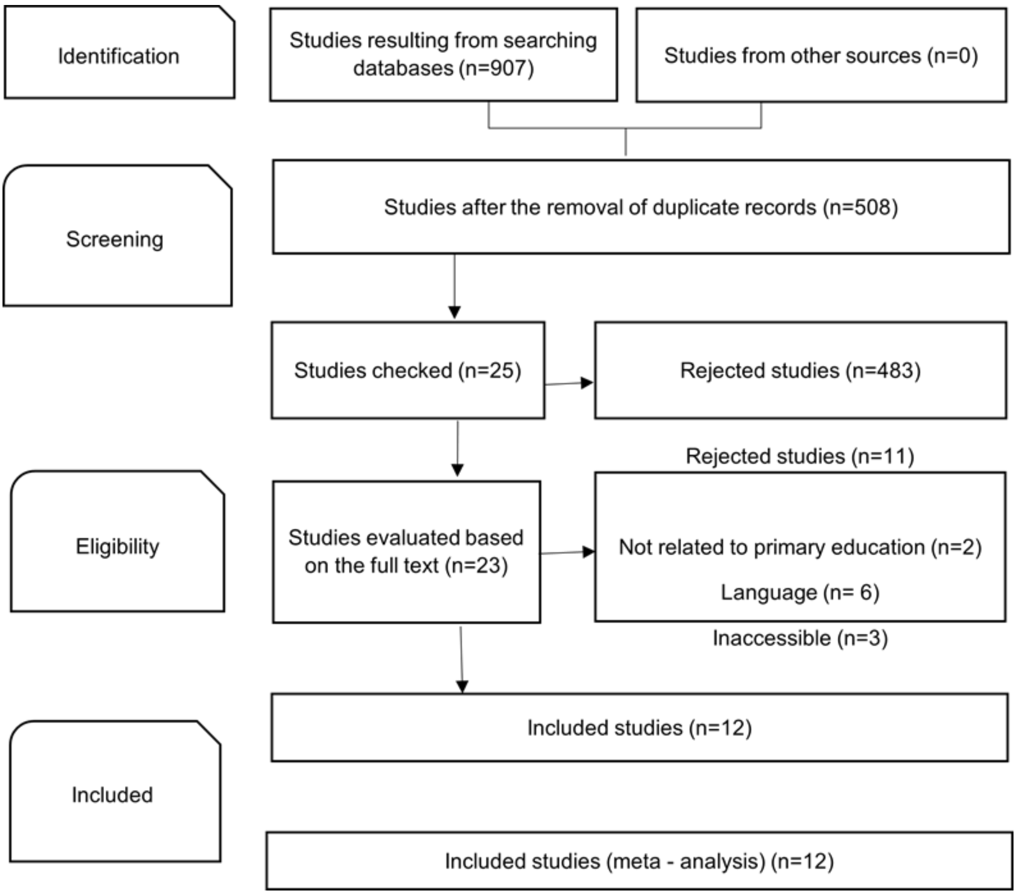

Fig. 2. Study selection phases [5]

3. Results

3.1 Student's experience

Particularly interesting and easy to use described the micro:bit by students, who view its integration positively into the learning context. They are actively involved in learning, have fun using such a tool, and feel satisfied during the learning coding [7]. Most students commented positively on the ease of use and usefulness of Micro:bit about understanding programming concepts and developing coding skills [3]. Starting with simple activities and gradually increasing the required level of knowledge, advanced concepts and skills can be taught [8].

It is also crucial for students to understand both the usage of building blocks in a technological solution, their role and understand the logic that governs the code, how to control the blocks and the flow of information that determines the solution's operation.

Distinguishing all these parts will help to generalize this understanding in other cases as well [1].

Results show that students approach micro:bit in various ways [9] depending on their capabilities. Novice students approach coding through trial-and-error when more advanced students are aware of the coding process and can use the appropriate functions and blocks to get the desired result. [1-2]. Students also seem to associate the use of micro:bit with STEM lessons [10]. From their participation in activities with micro:bit, opposed views of students emerge. Some feel that the device has limited capabilities, and therefore, there is a limit to what they can learn from it [3].

3.2 Teacher's experience

Teachers seem to be experimenting with the implementation of various activities in which they utilize the capabilities of the micro:bit device. Most teachers' starting point was activities from the official website, while there are cases where teachers develop their original material or learning sequence [10]. This reflects the lack of confidence in teachers who prefer to start using a tried activity before developing their initiatives.

Teachers consider it essential to connect small programmable devices such as this one with everyday life to highlight their usefulness, contribution to learning and strengthen students' motivation [10]. Moreover, many teachers show great interest in further engaging with more advanced designs through micro:bit related to various topics and courses [11].

3.3 Possibilities – barriers

Various technical characteristics allow the teacher to differentiate the students' level of challenges concerning their needs and abilities [9]. Students often have problems with coding when using text-based programming languages. Block-based programming languages, as in micro:bit, alleviate writing problems and difficulties [12]. The teachers also mention practical difficulties [10]. The coding of micro:bit is usually done through online compilers (Microsoft MakeCode, python.microbit.org), so a reliable connection to the Internet is required [13]. Alternatively, some compilers do not require an internet connection but are not so easy to use. Besides, difficulties arise from teachers' lack of knowledge in computer science and programming languages [7].

Students report that by following activities offered by the website and step-by-step guidance, they do not understand the essence of what they are doing [10]. The shape of the blocks facilitates and guides students on how to combine them but is not enough to help students understand what blocks represent programming concepts, so generating code based on block shapes is challenging. Understanding and handling programming material includes procedural and conceptual knowledge that refers not only to the material itself but also to a general understanding of the concepts.

3.4 Impact on skills development and motivation in coding

Several students report that micro:bit allowed them to collaborate [10] with gamification elements [7] but also work individually [8]. micro:bit can be used as tool for developing problem-solving and programming skills and creativity and a pedagogical approach to STEM education. teachers [12, 14].

Teachers describe the Micro: bit as an excellent motivation tool [12] but, there are cases of high-capable students that seem less enthusiastic due to the device's limited capabilities and not so advanced technology in their opinion. Moreover, some teachers noticed a decrease in the motivation of the students over time. micro:bit's integration in teaching seems to depend on the confidence and the level of knowledge of the teacher [8].

4. Conclusion

The use of micro:bit favors the positive attitude of students who find it fun and easy and are more likely to increase their involvement with it [9]. Despite the limited sample, the findings provide a clear picture of the experience in the use of BBC micro:bit [9]. It cannot be taken for granted that specific programming materials such as micro:bit automatically develop students' understanding of programmed technological solutions in everyday life [1, 15, 16].

The BBC micro:bit initiative is essential in encouraging physical computing in classrooms [11]. Pupils link the use of devices such as micro:bit with the interdisciplinary approach to STEM courses, language learning, art, demonstrating the potential impact of the device in the curriculum [8].

Students' contact with technology is essential to develop adequate skills to study and analyze existing programmable technological solutions (PTS) and design new ones (in our case with the micro:bit). As the use of micro:bit increases over time, there is room for more studies to better comprehend such devices in education [8]. Teachers facing this curriculum change need extra guidance on effectively teaching these new concepts to their students [2].

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AI-Based Stem Education: Generating Individualized Exercises in Mathematics

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Abstract

During the COVID-19 pandemic, the trend towards self-directed learning at universities received a strong boost. However, some students show considerable deficits regarding their self-learning competences. These become especially apparent in the first semesters, creating gaps in the students' knowledge which will not only slow down their progress in later semesters but may even lead to their dropping out of university altogether. For this reason, several approaches in the field of mathematics teaching attempt to prevent knowledge gaps from the very first week of studies, usually by employing educational instruments such as peer feedback or corrected homework. Despite these efforts, dropout rates in STEM subjects *remain high. We propose to address this problem with an instructional design based on AI algorithms which create mathematical exercises, tailoring their degree of difficulty individually to fit each student's skills and speed. Our hypothesis is that this individualized training will keep students from feeling overwhelmed and increase their motivation to study. As the exercises depend on many parameters to determine the appropriate degree of difficulty, they are adjusted iteratively, based on final or intermediate results of previously processed tasks and Learning Analytics data through Bayesian optimization.*

Keywords: AI-supported task creation, STEM Education, Personal Learning Environment, Bayes optimization (BO)

1. Introduction

Higher education has never been as accessible as today, with more and more students enrolling in university. Many of them, however, will quit within a few semesters.

Despite their high standing in both economy and society, STEM subjects present an especially high dropout rate. At German (technical) universities focusing on applied sciences, about 34% of students quit without obtaining a degree. With a dropout rate of 41%, electrical engineering shows the highest turnover within the student body.[1]

But what makes all these students abandon their lessons? One of the reasons might be an insufficient number of teachers and tutors to offer individual support.[2] At the same time, several projects in the educational sciences show that first-year students often struggle with a lack of competence regarding self-directed learning.[3] Representative studies also confirm that – at least at German universities – students feel especially overwhelmed by the task of applying scientific methods to self-directed learning.[4] In addition to all this, the prerequisites for successful studies are different for each academic subject. Some fields require first-year students to be independent in their pursuit of knowledge, while others allow for a slower transition from pre-organized school life to self-organized higher education.[5] Taking into consideration how differently schools prepare students for this, so-called "directive" forms of tutoring turn out to be highly efficient, as they allow tutors to direct the learning process in accordance with the student's skill levels.[6]

Today, most German universities use digital Learning Management Systems (LMS) such as Blackboard, Moodle, ILIAS, or D2L. These systems are not only used to present content, they are also versatile management tools, allowing teachers to create exercises, organize and evaluate their classes, and communicate with students.[7] However, LMS are also criticized for perpetuating a behaviouristic approach to learning. It is still the teachers who create the curriculum, conveying only a very limited scope of the flexibility modern technology in education might allow.[8] As a unilateral approach to teaching cannot take into account heterogeneous knowledge, even well-structured seminars may lead to knowledge gaps, as students fail to keep up.

This lack of flexibility, however, also leads us to one of the possible applications of Artificial Intelligence (AI) in higher education. Deep neural networks are what makes AI indispensable for many applications in image recognition and speech processing. For predictions based on small datasets (5-1.000 data points, typical for applications which simulate human perception), Gaussian processes (GP) are state-of-the-art.[9] Bayesian optimization (BO) is usually employed to optimize parameters when using such small datasets.[10] With an iterative process, BO captures more data, thereby allowing us to choose parameters which promise reliable predictions based on GP or suggesting further exploration to improve the robustness of the model. In higher education, GP models are already in use [11,12,13] but neither for the creation of exercises nor with BO to improve their performance.

In this paper, we address one of the most important reasons for the high dropout rate in STEM subjects: Mathematics. Using BO to adapt the difficulty of mathematical exercises to the skill level of each student, we propose an approach to differentiation which will allows for individual support, directing students with prior knowledge towards more difficult tasks while allowing students with gaps in their knowledge to practice the basics.

2. Concept

This concept has been developed as part of a design-based research project. It focuses on the creation of an AI-based tool for mathematical exercises which is meant to help students in STEM study mathematics and – in the long run – reduce the dropout rate. Our approach is both iterative and cyclical, i.e., the concept is refined by several iterations of application, each followed by a cycle of exploration, re-design and empirical evaluation.[14,15]

This paper outlines the development of a prototype and our assessment of the risks and potential of AI-based applications in higher education. First, we take a closer look at the AI architecture necessary for this project, then we focus on the students' side of the endeavour: How can an AI-based tool gain acceptance as a learning aid – and is there a risk of AI discriminating against students?

2.1 The technology behind the tool

Mathematical exercises are easily scaled to make them more or less challenging: Change parameters such as the number of variables or types of calculation involved, and the difficulty changes accordingly. We envision to use this parameterization for an AI tool which matches exercises to students' skill levels.

First, we task the AI with predicting the probability of a student correctly solving a certain exercise. This way, teachers can use simple tasks to introduce their classes to new topics, and then increase difficulty to match individual speed and skill. The advantages of such differentiation are obvious: Working on exercises tailored to their knowledge ensures that students see constant progress and stay motivated – the risk of frustration due to overly complex tasks is dramatically reduced. At the same time, the AI creates an efficient feedback loop, automatically correcting the students' work, recognizing gaps and providing appropriate follow-up exercises. If new aspects of an exercise seem too hard for a student, the system will automatically switch to repetition.

The AI aims to provide exercises which students will correctly solve with a probability of σ. To ensure long-term success, the parameter σ must be empirically based on factors such as student motivation. For this, we suggest σ≈80% as a starting point. Motivation should always be a priority as it determines whether or not the training sessions are completed. In order to keep students engaged, the first exercises introducing them to new topics must be especially well-designed – and to do this, we need high-quality GP models to create an a-priori model from little to no datapoints.

When a student S first works on an exercise E, there is no data the model could use to predict the outcome. There is, however, data from other sources: We suggest using datapoints from other students S' who have already worked on exercise E. At the same time, we compare the performance of students S and S' by comparing their work on other types of exercise E'. This data may then be compared with the results of past semesters or even other universities – provided, of course, that the students' anonymity can be guaranteed.

In this context, Learning Analytics help us understand the data surrounding the learning process. This, in turn, helps us support the students – with prediction, intervention, recommendation, reflexion and iteration.[16] Identifying and supporting students who are at risk of dropping out[17] improves these students' odds of graduating and the overall quality of education.

Fortunately, universities provide researchers with an abundance of data which can be used to drive Learning Analytics. To name just one example: A Technical University in Germany may use the LMS ILIAS for the seminars "Mathematik 1-4". This means that around 200-250 students in Electrical Engineering and Computer Engineering use this system every year to download scripts and notes, work on exercises, and communicate through group forums.

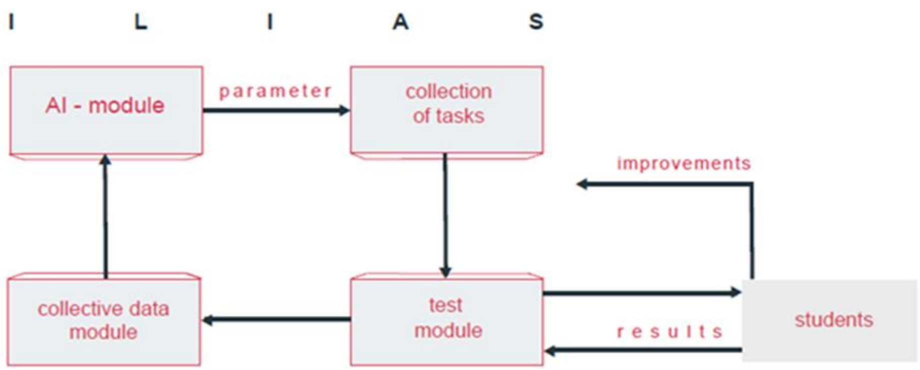

Fig. 1. Visualization of the research design

2.2 The educational concept behind the AI tool

When it comes to digital education, AI is regarded as one of the most groundbreaking technologies of our time.[18] German universities, too, are starting to integrate it into their educational concepts[19], albeit usually in the form of third-party solutions such as chatbots or assistance systems. Considering the amount of sensitive user data collected by these applications, the number of on-site solutions is still surprisingly low.

Compared to international competitors, the German education system has only just begun to tap into the potential that is AI in education. Possible reasons for this slow advance are – among other things – open questions regarding ethics and data protection. Some, for example, argue that the human perspective makes education what it is today, and that it would be unethical to let machines evaluate students. Others worry about the potential for discrimination: If the machine does not need to explain why it does what it does – could its seemingly objective results not be abused to discriminate against certain people or groups? And then, from a purely legal point of view, there is also the issue of information privacy: If AI is to be integrated into higher education, the students' right to data privacy must be protected at all times.[17,20]

Furthermore, German universities have not involved their students in the debate on AI. As a study conducted by the Institute for Internet and Democracy shows, neither the students' opinions nor their acceptance play any role in the universities' current concepts for AI-based educational programs.[20] At the same time, though, it seems safe to assume that the students' opinions on AI will prove crucial for its successful application in this field.[21]

These aspects – ethics, data security and acceptance – are to be studied with our AI-based tool. We are already collecting data for the seminars "Mathematik 1-4" (Prof. Heiss, Prof. Lange-Hegermann), reviewing, among other things, student interaction with the software, polls included in our prototypes, and interviews with focus groups to gauge the students' reaction to the AI. A longitudinal study (mixed methods design) accompanies this iterative and cyclical collection of data.

3. Conclusion

With the number of students enrolling in university on the rise and with different subjects demanding very different levels of self-organization, there is an increasing demand for e-learning concepts to support students at risk of falling behind. The concept presented in this paper offers a new perspective on the application of individually tailored exercises. Our project focuses on the often dramatically different levels of skill and experience first-year students display, as they are strongly linked to the pace at which these students acquire knowledge during their first semesters at university.

By offering individual tutoring in the first semesters, we hope to decrease the dropout rate in STEM subjects and improve the overall quality of tutoring. At the same time, our project is also meant to provide new data on the possible applications of AI in higher education – which, as research on AI as an educational tool progresses, may be used to lay the empirical groundwork for the development of new models and prototypes.

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Analysis of Plant Reproduction Representations in Austrian Biology Textbooks

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Abstract

Understanding plant reproduction is an important goal in science education since plants build the basis for many ecosystems. The presented project analyses the representation of this topic in Austrian biology textbooks in secondary schools. This analysis is embedded in a multi-perspective research project, investigating educational aspects of plant reproduction following the Model of Educational Reconstruction. The textbook analysis includes 18 different biology textbook series from the 5th grade in which plant reproduction is typically taught in Austria. The textbook analysis focuses on the representation of core ideas of plant reproduction and on aspects relevant for the development of students' conceptions, such as the use of terms, examples, and metaphors. Results show that all textbooks represent plant reproduction in much detail, including all processes of sexual reproduction. The results also indicate potential difficulties for students, such as the use of misleading terms, examples, or metaphors. Moreover, only few books include the advantages and disadvantages of the different pollination mechanisms and most books discuss the variety of plants and pollinators insufficiently. This could lead to difficulties in understanding how mechanisms and adaptions developed from an evolutionary perspective. The presented results provide direct implications for teaching plant reproduction and for a beneficial use of textbooks.

Keywords: Biology education, Educational Reconstruction, Textbook analysis, Pollination, Plant reproduction

1. Introduction & Theoretical background

Understanding reproduction of plants is an important goal in science education.

Plants are essential for almost every ecosystem and play a crucial role in preservation aspects, as food, and in fighting climate change. Despite their importance, plants and their relevance are often overlooked, which is described as "Plant blindness" [1]. Plant blindness affects learning on several ways: Teachers devote little time on teaching about plants [2], schoolbooks contain less information about plants than about animals [3] and students are less interested in plants than in animals [4]. In addition, studies prevailed that students have difficulties in understanding various aspects of plant reproduction such as the connection between flowers and fruits [5].

To improve learning about plant reproduction as a central botanical topic, we have started a research project, focusing on various educational dimensions of plant reproduction (scientific backgrounds; students' conceptions; teachers' perspectives; analysis and development of educational material). To connect all aspects of this project, the Model of Educational Reconstruction [6] was chosen as a framework. In this paper, we focus on the analysis of textbooks as educational materials, since these textbooks are important, widely used, and therefore potentially powerful resources for teaching.

The aim of this study is to systematically analyse the contents on plant reproduction in Austrian school textbooks based on three main research questions:

- *Which contents about plant reproduction are represented in Austrian school textbooks from the 5th grade and how are specific terms and examples used in these books?*
- *How are the sections on plant reproduction structured?*
- *How does the content in these sections about plant reproduction relate to students' conceptions and scientific backgrounds?*

2. Methods

The main analysis was conducted in spring 2018 and included 18 different Austrian textbooks for the 5th grade (list of all analysed books in [7]), representing almost all textbook series used in Austria [8]. The 5th grade (children aged 9-11) was chosen because the national curriculum for this grade refers to structure, function, and biology of plants [9]. Even though the topic "plant reproduction" is not mentioned explicitly in the curriculum, all analysed schoolbook series included reproduction of (flowering) plants as a part of a separate chapter about plants. The analysis focused on the complete chapter about plants, any other potential information about plants in other chapters was not analysed.

We analysed the school textbooks adapting a method of Roseman, Stern & Koppal [10], which uses a concept map representing the key ideas of a topic. Therefore, we first developed a concept map including major aspects of plant reproduction based on existing scientific overviews. In addition to the map, general questions about examples, metaphors and the structure were answered for each book. This method was then tested independently by two researchers with nine schoolbooks in a testing phase. The agreement of the testing results between the researchers was very high and only minor differences existed, which were solved in a consensual discussion. The same map was also successfully applied in a parallel project to analyse science content in scientific books [11].

After the testing phase, one researcher systematically analysed each schoolbook and all contents included in the book were marked in a separate map. After this step, all topics which were absent in a schoolbook were deleted from the map and topics mentioned only implicitly were set semi-transparent. This improved readability of the concept map also simplified further comparison between the schoolbooks. The progress from the initial map to the application of the method by hand and the simplified version of the map for one schoolbook is included in the appendix (see appendix 1). All results where then transferred in a table to support further comparison.

3. Results

The analysis allowed detailed insights into every schoolbook (see [7] for the complete analysis in German). In this paper, we will focus on the most important outcomes from six areas (a)-(f) and we will also provide an overview showing in how many books certain aspects occur (numbers in brackets).

(a) General structure: The chapters on plants cover between 13-24 pages, representing approximately 10% to 20% of each schoolbook content for 5th grade.

Typical contexts inside the plant chapters include early bloomers (15x), useful plants (10x) and plant families (8x). Many books (11x) follow a clear chronological order when describing the processes of sexual reproduction (pollination, pollen tube growth, fertilisation, seed development, seed/fruit dispersal, germination of seeds). The seven remaining books interrupt explanations or switch between different topics or examples.

16 books also include asexual reproduction. Despite this representation of both sexual and asexual reproduction, the biological importance of sexual recombination is stated in one book only.

(b) Flower structure & specific terms: All books provide a detailed description of the (hermaphrodite) flower structure, which is often represented by a cherry flower (10x) or an abstracted "model" flower (6x). Other examples (tulips, snowdrops, apple) are used only in few books. All books provide appropriate definitions for most terms and use terms consistently. The only exceptions are the (wrong) synonymous use of the terms *carpel* and *pistil* (5x) and a lack of differentiation between *pollen grain* and *pollen* (12x).

(c) Pollination: 17 books refer to pollination by wind and by animals. However, advantages or disadvantages of these ways of pollination are mentioned in only one book explicitly and in six books implicitly. Self-pollination is mentioned in 10 books with some books even referring to mechanisms which reduce self-pollination. But none of the books refer explicitly to positive aspects of self-pollination. Typical botanical examples in the context of pollination were the same as in the description of the flower structure with few additional examples to illustrate phenomena (*Primula*; *Salvia*; *Corylus*). The books include the following examples for animal pollinators: insects in general (18x); (honey)bees (18x); bumblebees (9x); butterflies (5x), birds (4x), bats (4x), flies (3x), ants (3x). Relevant morphological differences between insects such as different mouthparts are only addressed in five books. The main reasons for animals to visit flowers described are foraging (18x) and being attracted by colour (12x) or scent (8x). None of the books differentiate between flower visitors and pollinators.

(d) Pollen tube growth, fertilisation, and seed development: All books describe the growth of the pollen tube and the following fertilisation process. Nearly two thirds of the books (11x) also mention the competition between different growing pollen tubes. All books describe the relation between flowers and fruits, which is often illustrated with images showing the development of a fruit. Most texts describe that the ovary alone builds the fruit. Most books (14x) use cherries (*Prunus*) to illustrate the development from the flower to the fruit. Additionally, some books compare the development of different flowers to show the relation between flowers and fruits (7x).

(e) Dispersal of fruits and seeds: All books include information on dispersal types with a clear focus on the vectors wind and animals. In addition, seven books include a broad morphological classification of fruit types, six books include a smaller selection of fruit types. The examples of plants which are often mentioned in the context of fruit and seed dispersal are: dandelion (*Taraxacum*) (15x); touch-me-not (*Impatiens*) (14x); burdock (*Arctium*) (12x); maple (*Acer*) (9x); poppy (*Papaver*) (9x), violet (*Viola*) (8x); lime tree (*Tilia*) (6x); All other plant examples are mentioned in fewer than 5 books. Most books do not only refer to animals in general in the context of seed/fruit dispersal, but also refer to specific groups: birds (13x); ants (12x); squirrels (4x); mammals in general (4x) and mice (2x).

(f) Synonyms & Metaphors used: In the context of pollen, many schoolbooks mention that they contain either “sex cells” (“Geschlechtszellen” in German) or “seed cells” (“Samenzelle” in German) (4x). Typical metaphors in the context of pollination describe a “transport” of pollen from one flower to another by insects (6x), describe “travelling” (of pollen grains) (3x), or describe pollination as a “work” or a “task” for insects (2x).

4. Discussion

(a) The observed link with useful plants in many books is a good approach to connect to students’ interests in useful plants [12]. Presenting the processes of sexual reproduction in a complete chronological order is important to show how the processes of the life cycle are related to each other, which has been reported as a major difficulty for students [5], [13]. The importance of sexual recombination should be highlighted, since this importance is fundamental for explaining the variety of flowers and pollination mechanisms.

(b) The number of terms in the context of floral structure is considerably high [11], which makes precise definitions and a consistent use of these terms very important for learners. The terms for the female parts of a flower are particularly difficult, since one or more carpels can be involved in the formation of one pistil. The oversimplification “carpel equals pistil” could lead to further difficulties in understanding morphological fruit types.

The visualization of different flowers and how they develop to fruits could be an effective way to improve understanding (see (d)).

(c) It is important to discuss advantages and disadvantages of the different vectors involved in pollination and to highlight the advantage of cross-pollination. This is fundamental to understand the (co-)evolutionary development of flowers and animal pollinators. Another prerequisite to achieve a co-evolutionary understanding is to see and understand the diversity of both flowers and animal pollinators. Most books contain few examples on both sides and hardly describe specific interactions and adaptations.

Surprisingly, ants are mentioned as pollinators in three books, even though they do not play a significant role in pollination, but rather in seed dispersal (*Viola*). This could reflect a confusion of pollination and seed dispersal, which is also observable in students’ conceptions [13]. It would also be important to differentiate between flower visitors and pollinators, since not every visiting animal is a pollinator [11].

(d) All schoolbooks represent pollen tube growth and fertilisation in much detail. Even though the processes are visualized, the process of double fertilisation includes many inherent difficulties from a scientific perspective [11], which is a challenge for the young learners from 5th grade (aged 9-11). Analyses of students’ conceptions in Austrian students show that the process of pollen tube growth is almost absent in students’ descriptions about plant reproduction [13]. A possible solution is to highlight pollen tube growth as a vivid and fascinating process and to add experiments or models to make this process visible. Illustrating the development of different flowers to fruits should be added in all books, because it highlights the connection between flowers and fruits and shows how floral parts transform.

(e) The schoolbooks focus on the ecological aspects of dispersal, which is understandable regarding the complexity of morphological fruit types. The examples include almost all types of dispersal via wind (*Taraxacum; Papaver; Acer; Tilia),* animals (*Prunus; Arctium; Viola*) and self-dispersal (*Impatiens*). However, the examples could lead to a misleading impression of the quantity of these dispersal forms – explosive mechanisms (in *Impatiens*) and seed-dispersal through ants (in *Viola*) are fascinating but rather exceptional ways of dispersal. An explanation could be the focus on early bloomers in many books including *Viola* as an example.

(f) Finally, the term “seed cell” (“Samenzelle” in German) for the male sperm cell inside the pollen is misleading and can contribute to the mixing of pollen and seeds, which is observable in students’ conceptions. The metaphors “transport”, “pollentaxi” or pollination as a “task” should be avoided or at least critically discussed, since they suggest a deliberate transfer of pollen, which might support students’ ideas of a deliberate pollination, which is observable in students’ conceptions [14].

In summary, the quality of all books was suitable for the 5th grade. The study provides insights of possible sources of misunderstanding in the context of plant reproduction and could, therefore, be highly relevant for teachers, schoolbook authors and educational researchers.

It shows that teachers need to discuss certain aspects (terms, examples, metaphors) contained in schoolbooks critically, particularly regarding existing students’ conceptions and difficulties. The results also imply the necessity to highlight the diversity of the involved organisms and to provide opportunities to discuss (evolutionary) advantages/disadvantages of structures.

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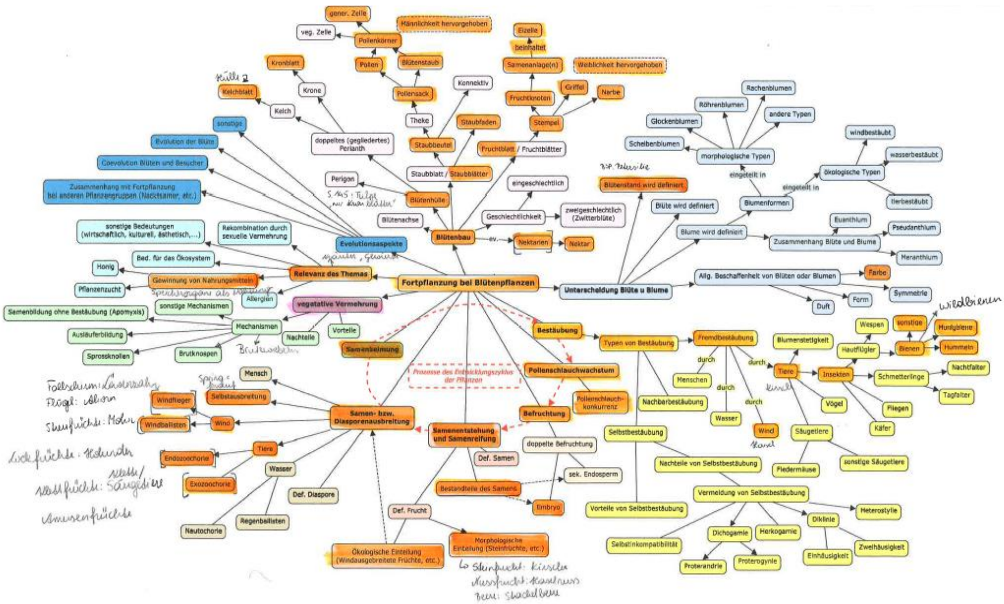

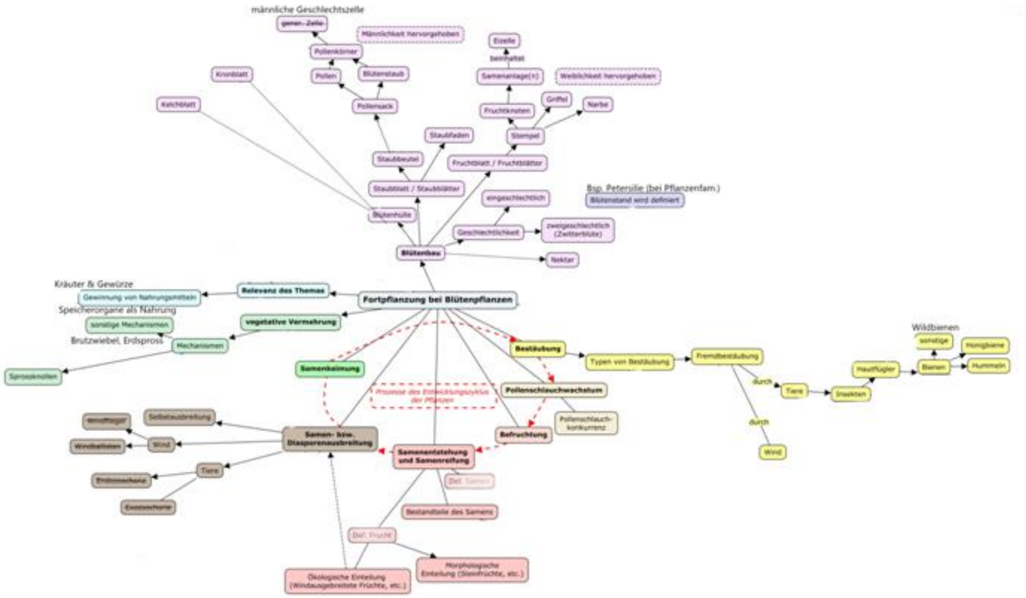

Appendix 1. Concept map for the textbook “Gemeinsam Biologie 1” [15] before analysis (top) and after the removal of concepts that were not found in the respective textbook. Concepts mentioned only implicitly are formatted semi-transparent.

Application of Cloud Technologies in Science Education

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Abstract

The use of cloud computing in science education is an emerging trend that enables access to online services anywhere, assuring scalability and cost savings in contrast to the conventional computational structure that requires both hardware and software to be physically kept on organizations' premises with requisite technical support. Cloud computing, accessible via a network, provides a variety of virtual resources (hardware, software, and services) to provide science teachers and students with tools to use virtual computing resources (Virtual Machines) for lectures and labs on demand depending on their needs. Universities are already using cloud computing to outsource email services and data storage, or adopt high scale massive open online courses (MOOCs), but it remains largely underused and can offer many other e-learning services that are computer-intensive and well-suited to online education (including video streaming, simulations or virtual worlds). Cloud computing also brings new technical risks related to security, compatibility and/or interoperability. Adopting cloud technologies in science education presents new challenges to educational institutions how to identify such opportunities for pedagogical uses. Cloud computing is a significant alternative for educational institutions that is still underutilized, but its advantages hugely outweigh the disadvantages and adopting the new applications in science education is an exciting opportunity not to be passed over. This presentation will define the basic cloud computing concepts, models, benefits and risks. We will explore some applications of cloud technologies in undergraduate STEM education at CUNY (City University of New York).

Keywords: science education, cloud computing, e-learning, online education

1. Introduction

While information and communication technologies (ICT) applications for online and distance education have a long tradition and can hardly be defined as an innovation, the coronavirus outbreak in 2020 induced a paradigm shift in the entire educational system worldwide by reforming the teaching and learning practices practically overnight.

Suddenly, the whole stream of education – a mix of traditional (in-class) and online education – became fully online. Both educators and learners had to learn new platforms, on the fly, and adapt the educational practices and pedagogy to match the new reality.

Indeed, attempts to use the Web as media for undergraduate, graduate and post-graduate education had been made since the late 1990s but it was the COVID-19 pandemic that made it a necessity. Nevertheless, the need for online schooling was formed by social and technological factors long before the pandemic. On the technological side, the main driving force was ICT development (Wi-Fi, 5G, Web 2.0) allowing the sustained transfer of large amounts of digital data and manipulation of these data in real time. In addition, the availability of cheap and powerful Web-enabled devices gave life to the concept *Bring Your Own Device* (BYOD), liberating education from solely in-class format. On the social side the propel came from movement for liberating education by offering free online educational content via Massive Open Online Courses (MOOCs) and providing affordable and free educational materials via Open Educational Resources (OER) repositories. According to the National Center for Education Statistics, even before the pandemics more than 70% of American educational Institutions used some form of distance and online learning [1].

The support for intensive e-learning with OER requires educational infrastructure with high elasticity and agility. That is even more true for science education which is based on staged engineering design. In addition, science education benefits from real-time collaboration and peer-learning. However, expanding local infrastructure is expensive and time consuming, while implementing cloud computing can add elasticity and agility to existing infrastructure by providing needed resources (computer power, storage) on demand, on-time, at reasonable price and under strict quality of service obligation.

Consequently, many educational institutions seek to establish hybrid local-cloud learning environments, in which the cloud guarantees expandability of the infrastructure, but the steering of the educational process remains the university's obligation. In this paper we will review the main characteristics and features of cloud computing and the applicability of various cloud frameworks for science education in a context of principles of STEM education.

2. Cloud computing concepts

Cloud computing is a business-oriented model of computing in which the users rent or subscribe for the needed resources (computational power, storage and applications/software) from the cloud provider, who in turn ensures the quality of service (QOS) necessary to guarantee reliability, availability and performance of rented/subscribed resources. That feature is fundamental for technology heavy-learning, when the success of a course depends on stable and educational infrastructure. In the core of the cloud are virtualization of necessary resources and virtualization of implemented services. The latter are the handlers which allow users to access the cloud resources: storage/disk space, computational power, applications/software.

Consequently, cloud services include: Software as a service (SaaS) – allowing users to apply software installed on virtual computer by vendor and not locally; Platform as a service (PaaS) – permitting users to employ different hardware and software platforms; Desktop as a service (DaaS) – providing local desktops; Big Data as a service (BDaaS) – allowing virtual storage; and Infrastructure as a service (IaaS) which is an analog of Data Center on-demand. According to Metz [2], four different deployment models for cloud computing have been outlined by NIST: Private cloud, Public cloud, Hybrid cloud, and Community cloud. In higher education the mostly widely used services are DaaS, PaaS and SaaS along with data services.

3. Application of cloud technologies in science education

In this section we will explore some cloud frameworks used in science education.

Since the type of education is a governing factor, we will evaluate cloud frameworks in terms of their response to the principles of STEM education to integrating technology, reaching across disciplines, and bringing project-focused tasks [2].

3.1 Via basic cloud frameworks and video conferencing communication tools

Many large cloud providers support specifically developed educational cloud frameworks combining popular tools and services suitable for education. The simplest frameworks are in fact expansions of already popular office suite software enriched with features that enable support sharing and collaboration. Google's GCP offers Google Workspace (previous G-Suite). Microsoft Azure offers Office 365 Education with similar functionality. Other popular cloud office type frameworks are Zoho Office suite, Hancom Office, LiveDocuments and some others. These frameworks support manipulations of documents, presentations, data sharing, communication, team work, and some assignments and class management. Because of the native support for sharing and collaboration, these frameworks are appropriate and often used for learning when students work on individual assignments as part of group projects and the results are summarized in a shared report. For example, Weibel [3] describes the use of Google Drive for an online physical chemistry learning laboratory to communicate basic data and applications and to support a shared lab journal; in addition, students can assess the final results and make comments on the content. E-mail is used for submission of final lab report. Apart from their simplicity and gentle learning curve the main advantage of office-like frameworks is their applicability to basic education in different science disciplines, support for project-based tasks and direct integration of technology in education. However, office like frameworks is not the best match for high tech models of learning like inquiry-based learning, game-based learning or flipped-class learning.

Video conferencing software has emerged as a worldwide standard for conducting remote lectures. The most popular are Microsoft Office Education level 2 Teams, Cisco's WebEx, and Zoom Video Communications. Their learning curve is not steep, but may require training to use such features as whiteboard and break rooms to name a few.

However, apart from factors like insufficient network their main shortcomings are security issues, background noises, and limited pedagogical resources [4].

3.2 Via advanced cloud educational frameworks

The STEM learning principles mentioned above require project-based lab work, strong collaboration among peers and engineering design of learning process. The central challenges for online hands-on science education are how to assess the learning outcomes beyond using quizzes and how to present a wide scope of lab activities. For the latter, the cloud frameworks focused on virtualization, such as Amazon Virtual Computing Lab (VCL) or Apache VCL are the best suited. For instance, Ali and Ullah explored the features of different 3D virtual lab for theoretical chemistry courses [5]. In biology, Abramov and his colleagues use virtual reality for biotechnological lab development [6]. Other services such as Data Simple Storage Service (DS3) and Elastic Compute Cloud (EC2) are often used in design of online courses in computer science and mathematics. IBM's education frameworks InfoSphere and BigInsights support Apache Hadoop on cloud and are being used in courses in Big Data.

3.3 Via third party advanced frameworks

Third party frameworks are specialized implementations designed to support different models of advanced education. The most popular cloud application is JupyterHub which plays a significant role in democratizing research-based post-graduate education. Many research universities have already adopted JupyterHub to provide access to high performance computing resources via cloud for graduate and undergraduate education.

For instance, Georgia State University has deployed JupyterHub for their instructional cluster, Data Intensive Computing Environment (DICE), which was adopted into Big Data

Programming and Scientific Computing courses [7]. Ngo and colleagues used JH framework to design cloud classes in parallel and distributed computing on the undergraduate level [8]. A similar project called "Open Research Infrastructure" is in progress at the CUNY High Performance Computing Center.

4. Application of Cloud Computing at CUNY

Application of cloud technologies is vital to increase collective leaning and improve quality of education across the City University of New York (CUNY), a conglomerate of 26 colleges and more than 100 institutes and research centers. Apart from Office 365 Education, CUNY provides Dropbox, Dropbox Paper, and Adobe Creative Cloud to all CUNY students, faculty and staff. The distance teaching CUNY switched to at the end of March, 2020, uses Zoom for Education to allow faculty to conduct lectures. In addition, the different campuses use basic cloud frameworks for the needs of online education and research. The flagship City College of New York (CCNY) received an NSF grant to develop a cloud processing of latency- and capacity-sensitive mobile applications across network domains and testbeds. A cloud-based lab is a pilot project currently developed at the e-Learning Center at the Borough of Manhattan Community College (BMCC). The College of Staten Island (CSI) developed a *Physics For Everyone* cloud assisted course – lectures, problem-solving exercises, and labs – to be launched in Spring 2021.

5. Conclusion

Cloud based science education can provide teachers and students with tools for lectures and labs on demand depending on their needs. Adopting cloud computing in science educations – via office-like suites, virtual labs and/or specialized frameworks – is an emerging trend that enables educational institutions with new opportunities for pedagogical use and tools to provide e-learning.

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Digital Challenges in Education Crisis – Case Study of ESTGL

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Abstract

The continual advances in technology are changing the way students learn, connect and interact every day.
The coronavirus pandemic (COVID-19) has paralyzed life around the world, reporting restrictive measures (that include avoidance of social interactions and the prohibition of circulation between national and international territories) that were considered non-essential activities like factories, services and including all the education institutions.
It predicted that in coming years approximately 75 per cent of all new jobs will require qualifications and skills in the areas of science, technology, engineering and mathematics (STEM).
STEM is an approach to learning and development that integrates the areas of science, technology, engineering and mathematics. Skills developed by students through STEM provide them with the foundation to succeed at school and beyond.
This research project focuses on anticipated needs for skilled workers and strategies, including the scaling up of investments in Information and communication technologies (ICT) education and training, more efficient management, concerned the wellbeing of students and teachers.
During the state of emergency, teleworking is mandatory as the work function and classes are compatible with e-learning and homework. This research project focuses on anticipated needs for skilled workers and strategies, including expanding investments in Information and communication technologies (ICT) education and training and more efficient management of student and teacher well-being.
The study carried out in a higher education institution located in the northern region of Portugal, with approximately 700 students from all over the country and islands.
The methodology used was documentary, through indicators of student satisfaction and success, result of the reports of engineer courses during 2019-2020.

Keywords: ICTs, STEM, higher education, pandemic crisis, teachers, students

1. Introduction

The coronavirus pandemic (COVID-19) has paralyzed life around the world, with several countries reporting school closures. The urgent imperative to ‘move online’, caused by the recent COVID-19 pandemic (World Health Organization, n.d.) [1], has added to the stresses and workloads experienced by university faculty and staff who were already struggling to balance teaching, research and service obligations, not to mention the work-life balance (Houston, Meyer and Paewai 2006 [2]; Houlden and

Veletsianos 2020) [3]).

In the EU 150, million people have little or no digital skills. With 20% of the recovery and resilience fund for # digital transition, what measures to combat digital inequalities?

On the other hand, for qualifying workers who are lefted behind?

Pandemic effects can generate demotivation and dissatisfaction, or even discomfort, since it is an activity and structure built based on relationships, in largely face-to-face relationships, which make the pedagogical act a moment of interaction and sharing.

We are still not sure whether such a loss will translate into a reduction in human capital availability, with negative effects on productivity growth, innovation and employment, including lower future earnings for groups of students directly affected by the block.

Digital Technology looks closely at one significant facet of our rapidly evolving digital lives: how technology is radically changing our lives as teachers and students.

Strategies in the era of Digital Disruption will provide you and your team with the tools, concepts and perspectives necessary to respond correctly to the digital transformation, and to turn its threats into opportunities with which to improve your performance and that of your organization.

Many institutions have opted to cancel all face-to-face classes, including labs and other learning experiences, and have mandated that faculty move their courses online to help prevent the spread of the virus that causes COVID-19.

During the state of emergency, teleworking is mandatory as the work function and classes are compatible with e learning and homework. This research project focuses on anticipated needs for skilled workers and strategies, including expanding investments in Information and communication technologies (ICT) education and training and more efficient management of student and teacher well-being. Guy Ryder Director-General of the International Labor Organization (ILO (2020)) says the key role that male and female teachers played in responding to and recovering from the pandemic recognized their role "to ensure that an entire generation of students can reach their potential and the importance of education to stimulate economic growth".

It is necessary to draw attention to the importance of looking at the work of teachers, in this pandemic, as an important work. For this professional group and for the great responsibility that governments and social partners have towards these professionals with regard to the protection of their health, safety and well-being, the security of their employment and the commitment to improvement.

Tara Beteille (2020) [4] in an interview said that "teachers must be equipped to assess students when they return to school so that they can identify what essential content and skills have been lost and need to be rebuilt – as well as detect warning signs of abandonment".

Hélène Landemore (2020) [5] said that "One of the most far-reaching transformations in our era is the wave of digital technologies rolling over – and upending – nearly every aspect of life. Work and leisure, family and friendship, community and citizenship have all been modified by now-ubiquitous digital tools and platforms." Santos (2020, p. 13) [6], draws attention to the new idea of normality. In fact, the reality we live in is an exceptionality of exception, and reflecting on this time of abnormality is extremely complex, because "The problem is that the chaotic and elusive practice of days is beyond theorization and demands to be understood in sub-theorizing mode".

Lucy Bernholz (2020) [7] said "We must consider whether and how our networks of digital communications accommodate and protect individual rights to expression and association in ways that also protect privacy and resist corporate or state surveillance."

Solve in relation to both the current moment and in the near future, the feeling that one is at risk, can only through effective physical isolation and the absence of contact with eventual carriers of the virus, which generates an enormous sense of distrust and uncertainty.

As we can see in the Technical report by the Joint Research Centre (JRC), the European Commission's science and knowledge service (2020, p. 4) [8], "a few selected EU countries consistently indicate that, on average, students will suffer a learning loss".

From their analysis, we can report three important reasons to this problematic matter.

"First, there is evidence showing that quarantined students tend to spend less time in learning compared to when schools are open. Second, many students confined at home due to COVID-19 may feel stressed and anxious, and this may negatively affect their ability to concentrate on schoolwork. Third, physical school closure and the lack of in-person contact may make students less externally motivated to engage in learning activities" (JRC, 2020, p. 4). These new frameworks reflect the realities of modern strategy, introducing concepts that were unknown a decade ago, and then challenging executives to use them on case studies that will have relevance to their own circumstances.

We can conclude that in all the high education tasks, strong school leadership will be key. Countries will need to devote the necessary financing to achieve these goals – and they will need to bridge digital gaps – if they want a generation of flourishing young people.

Instructional design (ID) and learning design (LD) can be characterized as 'a process, or series of suggested steps, that teachers can use to plan, implement, and evaluate their instruction' (Carr-Chellman 2016: xiv) [9].

To promote transnational cooperation and share good practice in the field of innovation for science education.

It is predicted that in coming years approximately 75 per cent of all new jobs would require qualifications and skills in the areas of science, technology, engineering and mathematics.

2. STEM a New Away of Education

The global economy is changing. Current jobs are disappearing due to automation and new jobs are emerging every day because of technological advances. What is STEM education? It's widely accepted that the acronym STEM stands for "science, technology, engineering and mathematics. Through STEM, students develop key skills including problem solving, creativity, critical analysis, teamwork, independent thinking, initiative, communication, digital literacy. According to the National Science Teachers Association (NSTA), "*A common definition of STEM education […] is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy.*"

STEM is an approach to learning and development that integrates the areas of science, technology, engineering and mathematics. As the current emergency remote teaching (Hodges *et al*., 2020) [10] situation invoked by the COVID-19 crisis is also new to the students, teachers must take into account the time and effort they need to regulate themselves in order to adapt to the new learning situation.

There are two ways to improve some solutions:

a) one way of doing so, is to make self-regulation a part of the assessment, for example, through self-reflections or portfolios;

b) another wat is to propose self-paced, asynchronous activities (always within a pre-defined timeline) as part of the students' learning process and indicate clear ways of assessing students' participation.

3. Case Study – ESTGL/PV

The method used for this exploratory study was a report analysis, based in administrative documents that were validated. The study carried out in a higher education institution located in the northern region of Portugal, with approximately 700 students from all over the country and islands. It's a faculty that has an important course that can interact with the others – Engineer and Telecommunications. The methodology used was documentary, through indicators of student satisfaction and success, result of the final pedagogical reports of both courses. Comparisons made with the homologous situation for the year 2019/2020. The present article focuses on the pedagogical preparedness of university students and teachers with no or little experience in online teaching. There is no doubt that STEM empowers individuals with the skills to succeed and adapt to this changing world. The continual advances in technology are changing the way students learn, connect and interact every day. Skills developed by students through STEM provide them with the foundation to succeed at school and beyond. How those it happened in ESTGL? Is important to analyze how students develop key skills including: problem solving, creativity, critical analysis, teamwork, independent thinking, initiative, communication and digital literacy. From a sample of 55 students in Engineer and Telecommunication Course, in the academic year 2019-2020, made an assessment submission 79,2%. In Unit Credits (Ucs) average attendance (%): 66.6. Success with enrolled students 73.4 and failure in relation to subscribers 26.6. Access specifics: Mathematics or Physics and Chemistry and Mathematics.

The forced digitalization of teaching and learning during the COVID-19 pandemic is clearly one of those emerging topics (Jandrić and MacLaren, 2020) [11].

Fig. 1. Legend – STEAM in ESTGL (Scientific areas)

Scientific Areas that can be worked on digital – TIC (%):	All of them have already been done in the academic year 2019-20 and 2020-21 with the availability of content in Moodle as well as teaching via platforms Colibri or Teams (due to covid19)
Math	16,7
Physics	9,4
Computing	20,0
Electronics	22,8
Telecommunications	23,3
Languages	1,1
Economic and Business Sciences	2,2
Project	4,4
Total:	100,0

4. Conclusions

The Educational Institutions of high education announced changes in the organizational structures.

The post-COVID-19 phase will offer many opportunities to "Build Back Better" that is strengthen quality and equity in school systems. Countries will need to devote the necessary financing to achieve these goals – and they will need to bridge digital gaps – if they want a generation of flourishing young people.

We can conclude that in all the high education tasks, strong school leadership will be key. Countries will need to devote the necessary financing to achieve these goals – and they will need to bridge digital gaps – if they want a generation of flourishing young people.

As the International labor organization director said, there is no doubt that our new report on homeworker's calls for better protections for the hundreds of millions of people working from home globally.

Pandemic effects can generate demotivation and dissatisfaction, or even discomfort, since it is an activity and structure built based on relationships, in largely face-to-face relationships, which make the pedagogical act a moment of interaction and sharing.

Collier (2020) [11], said in her article Higher Education After Surveillance "is *aiming to analyze current surveillance practices in the higher education sector (including broader educational technology, policy and other spaces) and trying to understand what post-surveillance futures might be desirable and how to work toward these"*.

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Enhancing STEM Education for the Online Environment

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Abstract

Innovative strategies for communicating science are necessary in the current global environment where many institutions are seeing an increased need to address educational needs through online platforms. Traditionally, many skills within STEM disciplines have been reinforced using a hands-on, applied approach in the laboratory setting. Recent worldwide events forcing many in STEM fields to transition to online environments present an opportunity to take advantage of rich data sets and available online tools to enhance learning and scientific curriculum. Strategies and best practices are emphasized here to assist science educators with the transition to the hybrid, blended, or virtual classroom and aid in the preparation of science teachers who must be ready to teach in a multitude of platforms [1, 2]. Several examples within the biological sciences are used to contrast a more traditional approach with virtual counterparts to demonstrate how these resources can improve learning and cognition.

Keywords: STEM, Science Education, Applied Learning, Innovative Strategies

1. Introduction

Recent worldwide events continue to challenge the existing paradigm of the face-to-face lecture modality of education, but this transition can be considered a pivotal opportunity to embrace existing and emerging technologies capable of ushering in innovative ways of communicating knowledge. Quality STEM education has been recognized as critical to economic growth and security [3]. Rapid growth in the nature and scope of online learning continues to strengthen the focus of flexible and virtual learning platforms. Asynchronous, synchronous contact and hybrid models are being utilized to facilitate teaching and learning in the STEM fields, and can be tailored to the learning styles of individual students. Flexible models for online academic courses allow educators to become decision makers, participating in the curriculum and delivery of their courses. These educators are incorporating a multiplicity of creative learning resources tailored to the interest and academic needs of their students. Numerous tools are available to assist educators in integrating scientific curriculum into the online environment. These can be software driven and include apps and programs, data driven to include integration of available data sets for real world application of conceptual ideas, and coordinated networks to encourage the sharing of ideas, tools, and data sets. Below we will expand on the incorporation of these tools within STEM disciplines, with particular examples from the biological field.

Many educators have exhibited a reluctance to transition to online platforms because they believe they do not offer the same effectiveness at teaching learning outcomes as the face-to-face model [4]. When we compare the two modalities, the main differences exist in the areas of learning activities and communication, so we will emphasize ways that instructors can take advantage of the online interface to deliver a broader range of content and more effectively communicate with their student audience. While the majority of the strategies and best practices suggested in this paper can be applied to a variety of subjects within the STEM disciplines, this paper will outline the options for science educators to expand their knowledge of software and data driven strategies to enhance learning and communication. Examples in learning resource collections and coordinated educator networks are shared to promote exploration of available content sources in online settings.

2. Software Driven Strategies

Science education has already experienced a reformation in the mid-19th century with a shift away from the traditions of memorization and recitation and towards the applied nature of these disciplines with the emergence of labs [5]. With recent limitations to face-to-face communication, the STEM fields are experiencing another challenge to standard practice and are improvising the marriage of hands-on practice with technological advances. Particular attention must be devoted to collaboration among virtual lab partners generating innovative web learning activities that can be shared and strengthened through synergistic lab activities.

The modern era of a pocket-sized personal computer has ushered in a new generation of students self-trained in the art of independent, self-directed learning.

Students of the modern era demonstrate an enthusiasm and adeptness in their flexibility to adapt to emerging technological tools. As educators, it is our responsibility to meet that willingness with a revision to our own standard operating procedures taking into account the advantages and best practices for engaging students through independent learning strategies.

First, we can and should consider utilizing a primary textbook that incorporates an online learning component, particularly if it is appropriate for the proposed subject. In the biological sciences, Mastering (Pearson), Achieve (Macmillan Learning), or Connect (McGraw-Hill) platforms are used by publishers to provide learners with access to an e-text and electronic note-taking options. These paired options can allow students to study at their own pace, and often include dynamic modules that adapt to student performance.

These tools help students to direct their studying towards areas of weakness. These platforms also offer reporting options for educators, so they can assess learner performance and detect areas where there are breaks in knowledge transmission.

Electronic mobile applications (apps) that allow users access to computer software on mobile devices such as phones, tablets, or watches also show incredible promise for allowing educators to bridge the virtual distance and share additional content with relative ease. Websites can also be critical for facilitating the dissemination of course material or data. There are many websites with associated apps geared toward sharing tutoring videos in different subject areas. Examples include Kahn Academy and Crashcourse. Websites like Go-lab (golabz.eu) have made an effort to make available laboratory projects for STEM disciplines [5]. Some particularly useful applications in the biological sciences include Seek, an application that pairs with the website iNaturalist and encourages students to identify and document different organisms. There is a plethora of organismal-specific applications that can be very helpful for students learning taxonomy and identification and include apps like iBird, Merlin Bird ID, and Audubon for birds, Roger'sMushrooms for fungi, Leafsnap and Floraquest for plants to name a few.

Laboratory applications, like Frog Dissection and Anatomy, can be incredibly helpful for virtual anatomical dissections.

In addition to what to study, virtual technologies can also be used to better communicate information about how to study. Examples include Crashcourse that has a whole series of videos devoted to providing student study skills. Flashcard applications can be used to assist with memory recall and some of these have downloadable decks that students can use for desired content. Applications like Evernote or OneNote can be used to assist and organize electronic notes.

3. Data Driven Strategies

With the emergence of a global sharing of data comes an incredible opportunity to teach our students how to use this data to ask questions and obtain real answers. In the Biological Sciences, there are many opportunities for real-world data to be mined from online sources to support research and laboratory activities. Examples in the genetic world include sources like the National Center for Biotechnology Information (NCBI), a clearing house for genetic repository data such as PubMed, Gene, BLAST, Nucleotide.

In the life sciences, there has been a recent push to immortalize existing natural history collections at natural history museums, zoos, botanical gardens, universities, and herbaria through digitization. This effort is providing a rich source of electronic data for students to explore and analyse in class projects and research. Gapminder and data.gov provide massive data sets on everything from weather to demographics for students to explore and analyse.

4. Coordinated Educator Networks

Educator Networks are designed to facilitate collaborative and mentoring relationships among educators. Faculty mentoring networks have been created to assist educators with the implementation of specific teaching practices with a targeted goal.

Examples include the Ecological Research as Education Network (EREN), a community of researchers from across the globe that brings together individuals at different institutions for a coordinated research effort in undergraduate research institutions. Often, these colleges do not have an abundance of research facilities or funding and this collaboration allows for individual faculty to pool resources in order to promote research activities among their undergraduates. Quantitative Undergraduate Biology Education and Synthesis (QUBES) is a network of individuals and organizations committed to accelerating STEM education reform with an emphasis on teaching quantitative skills. The Network for Integrating Bioinformatics into Life Science Education (NIBLSE) is another amazing resource maintaining and developing learning resource collections to share resources, lessons, activities, labs, applications or modified versions of existing lessons and labs. Many of these networks exist to bridge gaps and encourage educator connections to help with the challenges of changes in education today.

5. Conclusion

The above examples in the biological sciences serve to raise awareness and support innovative strategies for meeting the needs of learners in our evolving global environment. Collaborative, interactive technology will engage students in the biological sciences providing a wealth of innovative experiences to challenge them and strengthen investigative and critical thinking skills. As science educators gain insights into available online tools and updated approaches to teaching, they will experience further reformation shifting away from traditional methods. Technological advances and state-of-the-art software coupled with well-designed mobile apps have the potential to strengthen collaboration and shared knowledge, enabling the incorporation of adaptive and dynamic learning tools. These accomplishments allow educators to challenge students to high ideals and motivate them to gain the knowledge and skills that they need to meet the challenges of our transitioning global environment. In response to the emergence and rapid growth of virtual learning platforms, there have been significant advances in curriculum development incorporating technology and enhancing STEM education in the online environment. Recommendations for future research focus on the ongoing development of online platforms incorporating engaging activities in the biological sciences and other STEM fields to improve coordinated learning resources and curriculum in the virtual classroom. By emphasizing collaboration and strengthening networks, the options for science educators to expand their knowledge and positively impact student learning are substantial and will provide powerful benefits to online instruction in the biological sciences as well as other STEM disciplines.

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Evaluation of Student Understanding of Uncertainty in Level 1 Undergraduate Physics Laboratories

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Abstract

In recent years, work has been undertaken at Durham University to investigate how student understanding of uncertainty in experimental measurements changed throughout the course of the instruction they had during their first year of undergraduate laboratories. Measurement uncertainty can be thought of as a threshold concept, which students need to pass through before they gain a full understanding of both measurements and uncertainties, allowing them to transition from the point to the set paradigm. Students were surveyed both pre and post instruction to see how their understanding had developed and deepened throughout the course of the year of study. A particular focus was placed on assessing student understanding of repeat measurements, and the agreement of measurements. Following the period of instruction, the sophistication of answers provided by students to the survey, showed a statistically significant improvement as measured by an optimal pooled t-test, as the survey responses consisted of a mixture of both unpaired and paired data. However, misconceptions still remained, particularly when looking at students' understanding of repeat measurements.

Keywords: Physics Education; Undergraduate Experimentation; Uncertainties

1. Introduction

Laboratory work has long been held as playing a central role in scientific study. Griffin purported in 1892 that '*laboratory has won its place in school; its introduction has proved successful. It is designed to revolutionise education*' [1]. Science education was then heavily influenced by a progressive movement, promoting a learning by doing approach.

In the 1960s, laboratories became re-established as a core part of the scientific process. They have a number of goals including: to arouse interest and curiosity in science; the development of scientific thinking and the scientific method; and to develop practical abilities [2]. In addition to the above, laboratories in the early stages of a degree also focus on concepts and models, but are often less concerned with a procedural understanding. Millar *et al*., break down procedural understanding into three areas – the purpose of performing an experiment, the ability to manipulate laboratory equipment and having an appreciation for the reliability of a set of results [3]. In the twenty-first century, we hope that our teaching enables students to adopt a constructive approach to learning, allowing the learner to accommodate and assimilate new knowledge.

1.1 Threshold Concepts

Threshold concepts can be thought of as 'conceptual gateways:' an academic hurdle that, once cleared, opens up a previously inaccessible way of thinking. Meyer reports that threshold concepts are distinguished by five key criteria [4]:

- Transformative – once understood, there is a significant shift in subject perception;
- Integrative – a threshold concept exposes previously hidden interrelatedness;
- Irreversible – it is unlikely to be forgotten without significant effort;
- Boundary-defining – it will likely outline a specific conceptual space and serve a limited purpose;
- Potentially troublesome to learn – the knowledge is usually counter-intuitive.

If a student has an incomplete understanding of a threshold concept it is likely to have long-lasting repercussions, forming a barrier, preventing application in any unfamiliar contexts and stunting their further educational progress.

Measurement uncertainty is central to experimental Physics; students having a thorough understanding being widely regarded as essential for strong academic progress in this field [5]. The ability for students to assess the reliability of a set of measurements and use this information to guide experimental procedure is a key skill for achieving success in the laboratory. Lubben, Buffer, Allie and Campbell characterise data handling via the point and set paradigms, defined below [6]:

The point paradigm is characterised by the underlying notion that each measurement could in principle be the true value. As a consequence, each measurement is independent of the others and the individual measurements are not combined in any way.

The set paradigm is characterised by the notion that each measurement is only an approximation to the true value and that the deviation from the true value is random. As a consequence, a number of measurements are required to form a distribution that clusters around some particular value.

Students can be between these two paradigms, in what is known as a state of liminality as described by Meyer and Land. The work of Lubben *et al*., reports that, whilst students generally display characteristics of both paradigms, the overall goal of teaching should be to move students wholly into the set paradigm, and in particular to be able to give their reasoning in the set paradigm. For example, they would be able to reason, in an appropriate way, why the mean is the best estimate of a quantity's true value.

Meyer's criteria for threshold concepts can be applied to show that measurement uncertainty is one such concept; students need to pass the threshold to fully reason and understand this topic. Below explains how measurement uncertainty fits into the definition of such a concept:

- Transformative – A good understanding of measurement uncertainty will transform a student's thought process and success in a laboratory setting. When the threshold is crossed, uncertainties become seen as intrinsic to measurements, and are an assessment on data quality;
- Integrative – many previously studied concepts must be combined and fully understood when looking at measurement uncertainty, for example random and systematic error, repeat measurements;
- Irreversible – once fully grasped, students will see data as a spread of results, with the uncertainty characterising the data's reliability;
- Boundary-defining – a more general approach must be taken, regarding the topic as a boundary to quantitative analysis;
- Troublesome – accepting that measurements are inherently uncertain, and that there are no perfect scientific process troubles physicists, who start their

academic journey from the position of requiring exact statements, rules and clarity.

In this work, an investigation into measurement uncertainty as a threshold concept is reported, in the context of Level 1 (first-year honours) undergraduate physicists at Durham University. The definitions of Hughes and Hase (2010) [7] are used: *'an accurate measurement is one in which the results of the experiment are in agreement with the 'accepted' value.'* whilst a *'precise measurement is one where the spread of results is 'small', either relative to the average result or in absolute magnitude'*. Hence accuracy is affected by systematic error and precision by random error, and in experimental work, random errors should be minimised.

2. Methodology

Eight probes, surveying a variety of measurement uncertainties, were given to undergraduate students at Durham University registered in the Discovery Skills module, PHYS101 during the 2019-20 academic year. This laboratory-based module is taken by all first-year physics students and also students studying for a degree in Natural Sciences from both the first and second year. It also includes a lecture-based course on error analysis, with learning of this topic supported through each problem sets and as specific tasks completed within the practical laboratories. The survey was given before any instruction had been given, when students' only prior knowledge of experimental work and measurement uncertainty will be from UK A Levels, or equivalent. The probes chosen were based largely on those of Lubben and Miller (1994) and aimed to assess student understanding of a variety of key issues that arise in measurement and uncertainty work [8]. As a number of the probes were related, with information in some of the later probes potentially having the effect of making it easier to answer some of the early probes more fully, the survey was given in such a way that the questions had to be answered in a fixed order, and once an answer was completed, it could not be altered.

Consequently, the results should more likely reflect the deep understanding of students, rather than what they are able to repeat when prompted.

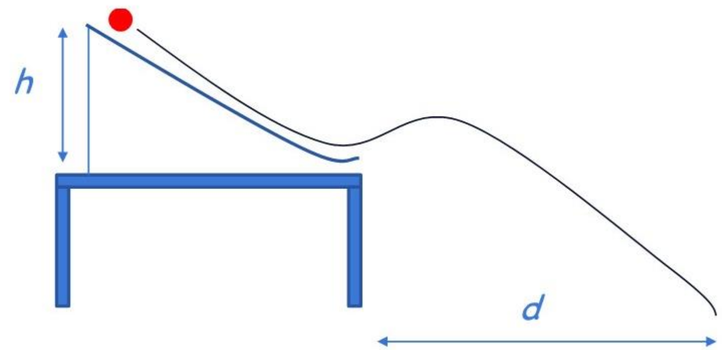

Fig. 7. The set-up that was used in the survey's experiments, with the ball dropped from a height h, before travelling a horizontal distance d, which is then measured

The probes all considered an experiment where groups of studentss roll a ball down a slope, clamped to the edge of a table. The ball is released from a height *h,* leaves the table horizontally, and then falls on the floor some distance, *d* away as shown in Figure 1.

The probes test a variety of measurement and uncertainty phenomena, at a level appropriate for first-year physics students. For example, looking at reasons for making repeat measurements, how final results should be presented, and then the notion of agreement between values obtained from the same experiment by two independent groups. All questions, provided a multiple-choice answer that students selected, followed by a free-text area for reasoning to be explained.

Following completion of the survey by students prior to their teaching instruction, responses were coded thematically using a modified version of a scheme developed over previous years. For student responses covering key themes in multiple categories, a 'tick all that apply' approach was used in order to best reflect the overall trend of student thought. Following completion of the pre-test, four students from the year group took part in thirty-minute interviews, to enable the coder to more fully understand student responses and to allow a more detailed probing into key misunderstandings. In addition, during the interviews students' prior knowledge was also discussed from their learning during, for example, A-Levels at school. In particular, this allowed a probing of their knowledge of the key terms already mentioned, namely 'accuracy' and 'precision'.

Towards the end of the academic year when the students had undertaken all of the work in support of the learning outcomes associated with measurement and uncertainty, students were asked to complete the same survey again. The responses to the post-survey were then thematically analysed in the same way as those for the pre-instruction survey.

To compare the data between pre and post-tests, seven of the answers were given a numeric score in order to investigate overall learning gain. The scores were based on the explanation's sophistication: a mark of one was awarded, if the answer surpassed a given sophistication level, and zero was given otherwise. For example, when looking at the agreement of two sets of results, low sophistication would correspond to "their means are close/far apart," whilst a high level of sophistication would be represented by answers like "the measurement means are not in agreement as they don't lie within three standard errors of each other." This allowed the mean scores and associated standard deviations to be found for the whole survey and for specific sections of it. Because this data was a mix of paired and unpaired data (some students had completed both surveys and others only either the pre- or post-survey), scores were compared using an optimal pooled *t*-test [9], providing a weighting inversely proportional to the variances of the estimates.

The mean scores of the pre and post-test, μ_1 and μ_2 were calculated, and the weighted difference in these means was then compared, through the test statistic, $T_0 = \mu/S_\mu$ to the relevant *t*-distribution table.

3. Results and Discussion

A total of 90 students completed the pre-survey, 51 the post-survey whilst 20 completed both, with a similar gender split being seen across both surveys. Around 80% of the students were registered on the Single Honours Physics programme, with the remaining 20% comprised of the students undertaking this module whilst reading for a degree in Natural Sciences.

3.1 Repeat Measurement Probe

The first two probes focussed on the making of repeat measurements and whether students would choose to do this or not. In these probes, students were asked to decide which statement they agreed with from: taking a few more measurements; taking one more measurement; or taking no more measurements, and then to explain their answer.

In the pre-instruction survey, irrespective of which statement the students chose, six main ideas were provided for the reasoning as shown in table 1. Following instruction student responses were seen to improve, with 33% of students being able to link the idea of repeating measurements to obtaining the standard error, whilst no student mentioned this in the pre-test. The general sophistication of written answers improved from statements like 'so that a mean can be calculated' to 'the more measurements taken, the smaller the standard error.' Interestingly, in this probe a large number of students still argued that repeats are needed to improve accuracy!

Category	Description	Pre-Test	Post-Test	Change (%)
RD 1	Repeats needed to calculate mean	50	43	-7
RD 2	Repeats needed to improve accuracy	29	18	-11
RD 3	Repeats needed to identify anomalies	31	16	-15
RD 4	Repeats needed to reduced uncertainty	41	28	-13
RD 5	Repeats needed to find/increase standard error	0	33	+33

Table 1. Summary of responses to the Repeat Distance (RD) probe, including the level of change seen between pre and post instruction testing

3.2 Probes on Agreement of Data

Four probes were considered here. Students were presented with two sets of data and asked to decide whether the measurements agreed or not, perhaps including having to complete a calculation. Within the probes, some had the same mean, whilst others had different means, but these datasets had similar or different spreads. These probes got more complex as they progressed, and even in the pre-instruction test, student responses became more sophisticated in later questions, since each successive question gave more information, for example the term standard deviation is introduced for the first time in the final probe, and it is at this point a student potentially realises that they have made a mistake in the earlier probes. However, when comparing written answers given in the post-instruction survey, student answers on each probe where in general seen to be more sophisticated than in the pre-test survey. Table 2 shows the improvement in responses for both the 'Different Mean Same Spread' (DMSS) and 'Different Mean Outside Spread' (DMOS) probes. Here, outside spread refers to the fact that the mean of neither data set lies within the spread of the other data set.

Category	Description	DMSS Change	DMOS Change
DM 1	It depends on how close the means are numerically	-46	-28
DM 2	It depends on the means and uncertainty	+21	+4
DM 3	It depends on the means and standard deviations/errors	+31	+38

Table 2. Percentage change for the DMSS and DMOS probes between the pre- and post-surveys

It is from these two probes in the pre-survey that it is possible to draw the most interesting conclusions regarding student misunderstanding of uncertainties. With over half the students on both probes offering simple numerical reasoning, it is clear that students commencing their undergraduate studies have very little appreciation of the content they are soon to learn. By the time of the post survey, all of these probes showed a significant improvement in the sophistication level of responses.

3.3 Statistical Learning Gain

The average of the raw scores obtained by students on the overall test, and also on the questions specifically looking at repeat measurements and levels of agreement, are shown in table 3. The T_o value is also given, with the level of significance which this represents, using the optimal pooled t-test. This shows that, to a significance level of less than 0.1%, students' scores on the survey improved, but that the majority of this score increase comes from increases in the sophistication of student answers to the probes on agreement level rather than on those considering repetition of measurement.

Indeed, the small improvement in the scores for the repeat measurement probes was not even significant at the 10% confidence level. From this, it can be concluded that the answers given by students to the post-test questions on agreement are much more sophisticated, shifting towards standard deviation and error away from a purely numeric comparison. However, despite this large improvement shown in the scores, only around half of the students provided what could be termed a model answer, showing that they had fully moved through the threshold. Correspondingly, for the probes on repeat measurements, many students are still in the liminal state after nearly a year of teaching.

	Pre-Test	Post-Test	T_0	*P*
Total (7)	2.5±1.4	4.2±1.5	6.5	<0.001
Repeat (2)	0.6±0.7	0.9±0.8	1.1	>0.1
Agreement (4)	1.8±1.0	3.1±1.0	6.0	<0.001

Table 3. The raw scores and their standard deviation for the pre-survey and the post-survey, split into overall score and scores on the repeat measurements and measurement agreement sections. The T_0 value from the optimal pooled t-test is included alongside the associated *P*-value.

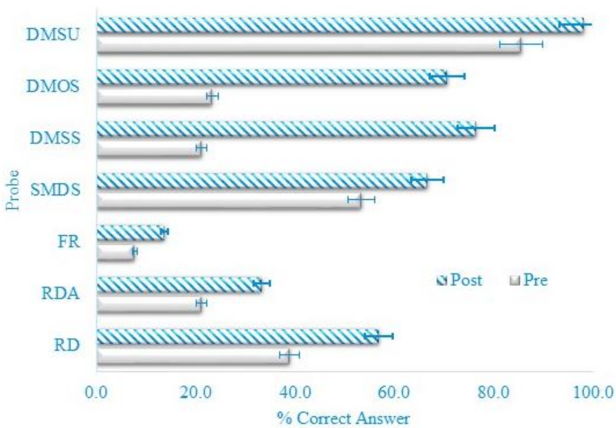

Fig. 8. Comparison of the percentage of students to give correct answers on each prove in each survey. Error bars are given at the 95% confidence interval

By only considering only the paired sets of data, and using a binomial exact test, a similar trend to the increase of the sophistication of the responses given can be seen in figure 2. In particular, it highlights an improvement in percentage of correct answers on all probes, specifically the DMSS and DMOS probes.

4. Conclusions

First year students at Durham University had their understanding of measurement and uncertainty tested both prior to and following instruction. This topic was chosen because it has been postulated to be a *Threshold Concept* for physics students. After the period of instruction, there was a statistically significant improvement in the performance of students, in particular with regards to the agreement of two similar datasets. This suggests that overall, the learning undertaken in the first year undergraduate module is somewhat successful in transitioning students from the ‘point paradigm’ to the ‘set paradigm’ associated with threshold concepts. However, it is clear that many students have not reached a satisfactory level of understanding or exist in a state of liminality. Consequently, further work will be undertaken to enhance the teaching of these key topics at Durham in support of deeper student learning.

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Examination of the Theoretical Framework for Science Learning Material Incorporating Activity of Engineering in Elementary School STEM Education

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Abstract

The national curriculum guidelines in Japan were set as a standard by the Ministry of Education, Culture, Sports, Science and Technology, and the subject matter studied in schools must comply with them. The science curriculum guidelines emphasize the relevance of science in society and everyday life, but in many science lessons, students are learning to solve problems only in the context of science, and not that of society and everyday life. Therefore, we developed a learning material that would cover this aspect, in compliance with the learning contents stipulated in the Japanese curriculum. In this study, we showed the theoretical framework of STEM education that applied to the learning material and clarified how STEM education could be realized in Japanese science lessons. First, based on previous studies, we adopted the context of problem-solving in society and everyday life into science lessons and introduced engineering activities. Next, we chose a model of Learning-by-Design (LBD) proposed by Kolodner as a theoretical framework for STEM education, which fits the purpose of this study. Based on these examinations, we developed a learning material named 'Science MIRAI', which includes Gigo blocks (made in Taiwan), a control box with Arduino for programming, a lesson plan in compliance with the Japanese curriculum, and worksheets. There were three important points in the development of the learning material: (1) selecting the learning contents of electromagnets, (2) adopting the context of separating steel and aluminium cans for recycling, and (3) devising how to introduce engineering, while retaining the science learning contents. The learning plan of Science MIRAI based on LBD enabled students to learn and apply science in the context of problem-solving in society and everyday life, triggered by engineering activities. Furthermore, the results also demonstrated that science lessons incorporating engineering raised students' awareness of science in practice.

Keywords: STEM, LBD, relevance to society and everyday life, problem solving, engineering

1. Introduction

In 2005, an organization supporting the collaboration between industry and academia in education was established In Tokyo, Japan, with an aim of returning the intellectual property of universities (e.g., Tokyo Gakugei University) to society. It was named Tokyo Gakugei Univ. Children's Institute for the Future and has promoted research and development of organized STEM education for school and social education and playgrounds since 2013.

One of the practices promoted in the STEM education project of the Institute is the development of learning materials such as the ‘MIRAI (future)’ series for STEM education in compliance with the Japanese curriculum. ‘TECH MIRAI’ is intended for junior high school students learning technology, and ‘Programming MIRAI’ and ‘Science MIRAI’ are intended for elementary school children. This study will focus on Science MIRAI: a science learning material that incorporate engineering activities. Japan has national curriculum guidelines applied as a standard that are issued by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), and the subject matter studied in schools must comply with them. Recent science curriculum guidelines emphasize the relevance of society and life, but the blueprint is not shown. Thus, in many science lessons, students are learning to solve problems only in the context of science, while pragmatic application in society and everyday life is lacking. Therefore, we have developed Science MIRAI to help students explore science in the context of problem-solving in society and everyday life. It is also in compliance with the learning contents as stipulated in the Japanese national curriculum guidelines.

This study showed the theoretical framework of STEM education applied to Science MIRAI. Furthermore, it will clarify how STEM education was realized in Japanese science lessons.

2. Examination of the theoretical frameworks of STEM education for developing Science MIRAI

It is well known that STEM education integrates multiple disciplines: science, technology, engineering, and mathematics. However, there are various perspectives regarding the integration of STEM education. For example, STEM only means science (or mathematics); STEM means science and incorporates technology, engineering, or mathematics; STEM means coordination across disciplines; STEM means complementary overlapping across disciplines; or STEM means a transdisciplinary course or program [1]. This indicates that the perspective and the framework of STEM education differ depending on its position and purpose.

This study examined the theoretical frameworks of STEM education for the development of Science MIRAI, considering the background of Japanese science education. In Japan, the relevance of science education in society and everyday life is emphasized for raising students’ interest in learning through realizing the significance and usefulness of learning science [2], [3]. In addition, the training of innovators who could solve unexperienced problems in society and life was anticipated in ‘The 5th Science and Technology Basic Plan’ adopted by the Japanese Cabinet in 2016.

Therefore, based on previous studies, first, we decided to incorporate the context of problem solving in society and life into science lessons and introduce engineering activities [4], [5], [6].

Next, we chose a model that would fit the purpose of this study, Learning-by-Design (LBD) proposed by Kolodner [7], as a theoretical framework for STEM education.

Previous studies have examined some STEM education theoretical frameworks [8].

In this research, engineering (i.e., creative activity) was introduced into science lessons (i.e., exploratory activity). Hence, we focused on LBD as the learning model.

LBD’s learning process consists of different two cycles: ‘design/redesign’ and ‘investigation’. These cycles are bridged by ‘Need to do’ and ‘Need to know’.

Investigation is caused by ‘Need to know’. Furthermore, Yata *et al.*, [9] showed that in the context of Japanese subject principles, the engineering process was relevant to each STEM discipline.

Therefore, LBD was considered effective in motivating Japanese students in science learning and hence chosen as a theoretical framework in this study.

On the other hand, we found that there is a challenge in adopting LBD directly into Japanese elementary school science classes. If LBD is introduced as it is while complying with Japanese curriculum guidelines, time will be insufficient. Thus, in this study, we adjusted LBD to practice it in a limited time by reducing and simplifying the engineering activities of each stage with scaffolding. The model is presented in Figure 1 as Adjusted-LBD.

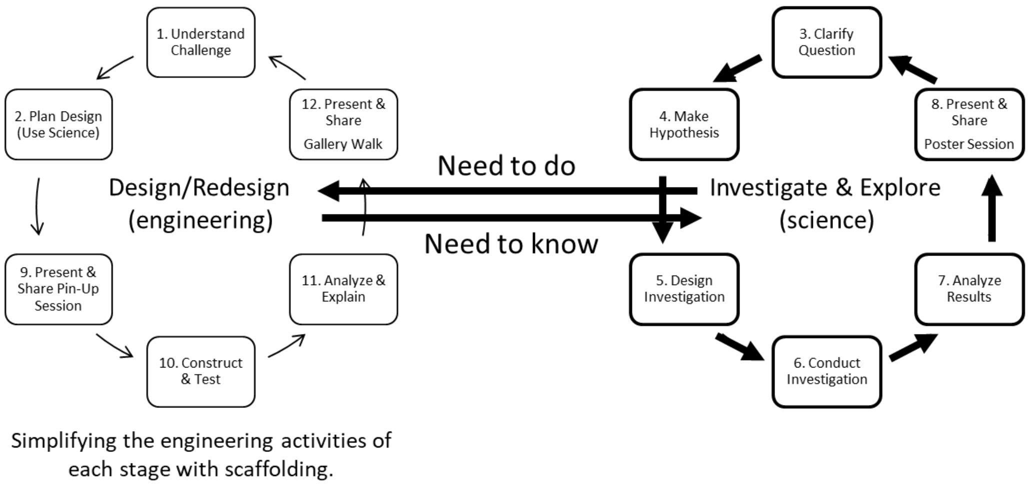

Fig. 1. Adjusted-LBD

3. Application of theoretical framework and development of a learning material

Based on the assessments, we adopted Adjusted-LBD as a theoretical framework and developed a learning material named Science MIRAI for STEM education in elementary school science. It consists of Gigo blocks (made in Taiwan), a control box with Arduino for programming, a lesson plan in compliance with the Japanese curriculum, and worksheets. The development of the lesson plan was based on the following three important points:

Point 1: Selecting learning contents

Some science learning contents may easily adopt engineering activities, while others may not. Thus, we selected engineering activities that are easy to introduce. Specifically, we developed a learning material that conforms to the Grade 5 curriculum on electromagnets in Japan.

Point 2: Adopting the context of recycling

As a context for solving problems in society and everyday life, we chose the context of improving garbage and resources problem, and labour shortage problems due to a declining birth rate and aging population in Japan. Specifically, we planned science lessons incorporating engineering activities: creating lifting magnets and tackling the issue of efficient separation of steel and aluminium cans.

Point 3: Devising how to introduce engineering while retaining the science learning content

The main purpose of the lesson is to study science, and not the engineering activities.

Therefore, we carefully ensured that students would learn the learning contents (e.g., types of magnetic poles; generation of magnetic intensity with an electric current flow; and the effects of magnitude of electrical current and number of coils turns on the strength of an electromagnet) specified in the Japanese curriculum. In addition, we considered the standard number of hours (11-13 hours) that would be assigned to this lesson. Hence, we designed and prototyped simplify engineering activities by presenting a prototype machine (basic model) with its building manual as a scaffolding for 'Challenge 1' to the students so that they could learn within the limited time. Students could revise the basic model and solve problems with less time spent in trial and error.

No model or manual would be presented in the subsequent challenges. Students have to revise the first basic model to solve the next challenge. In this manner, we devised a mode to learn within the specified time by reducing the cost of initial design and trial production.

The main parts of the lesson plan were as follows:

Challenge 1: Separate steel and aluminium cans for recycling

- Consider how to separate cans and make a basic lifting magnet (see Fig. 2)
- Separate steel and aluminium with the lifting magnet

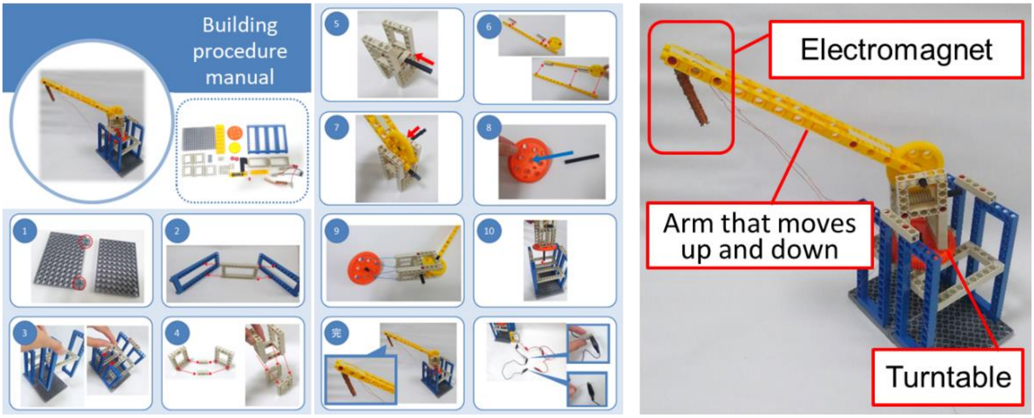

Fig. 2. Basic lifting magnet model and its building manual

Challenge 2: Separate more efficiently

- Investigate the relationship between the number of batteries (magnitude of electrical current) or the number of coils turns and the strength of the electromagnet's magnetic force
- Improve the lifting magnet for more efficient separation

Challenge 3: Operate the lifting magnet automatically using a computer program

In this paper, we focus on Challenge 2 and outline the lesson plan applied in the Adjusted-LBD in order to show when 'Need to do' and 'Need to know' occur and how student back and forth of learning processes (see Fig. 3). Here, 'Need to know' occurs at the stage '2. Plan Design' in the Design/Redesign process, leading to a switch to science exploratory activities.

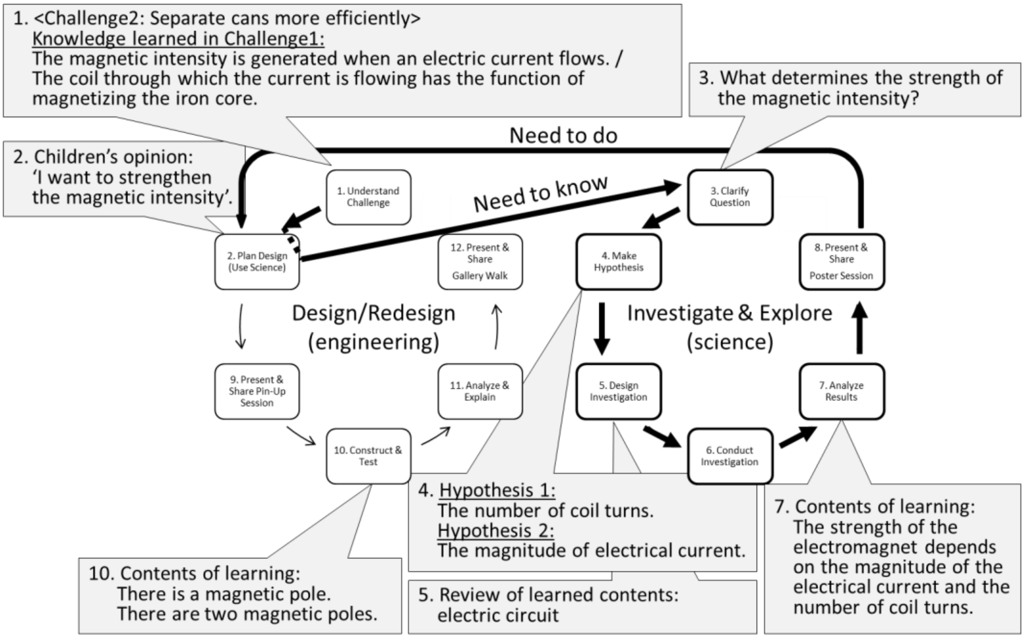

Fig. 3. Learning process of Science MIRAI focused on Challenge2

4. Conclusion

This paper considered a theoretical framework for science learning materials that incorporates engineering activities in elementary school STEM education. As a result, an important point of the theoretical framework was clarified: simplifying engineering activities by introducing scaffolding in order to retain learning contents of science even after introducing engineering. In addition, the results of the test practice showed that the learning plan of Science MIRAI enabled students to learn science in the context of problem-solving in society and everyday life, triggered by engineering activities.

Furthermore, the results also showed that science lessons incorporating engineering raised students' awareness of the practicality of science [10].

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Green Education for a Sustainable Future

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Abstract

Green education can act as a vehicle in order to inspire the next generation of students to pursue a career in science. Empowering youth to create a sustainable future is critical in the process of preserving the planet and in educating future responsible citizens.
With a green education curriculum, a science subject which may be considered abstract is put into a familiar context, relevant to the everyday life of the students. Green education connects abstract science concepts to real world technologies that are responding to environmental challenges. Novel fields such as green chemistry, sustainable engineering/robotics and green biotechnology can be implemented into classroom teaching under the umbrella of green education. In order to support teachers around Europe to integrate green education principles in STEM curriculum, the project Green education for a sustainable future-Green Edu has been created. Green Edu is an Erasmus funded project that brings together universities and schools from Poland, Italy, Romania, Turkey and Greece. An online platform is being developed and will act as a repository of STEM Green education resources, focusing on novel fields of Green chemistry, Green biotechnology and sustainable Engineering and Robotics. The platform integrates micro-MOOC (Massive Open Online Courses/Content) – an innovative approach for developing STEM laboratories that will motivate teachers in the creation of flexible personalized teaching/learning paths and to increase students' interest and involvement, due to the innovative methodology; of their learning. This paper focuses on presenting educational resources developed for primary and secondary education and preliminary results from their implementation in the classroom.

Keywords: STEM education, sustainability, Green chemistry, Green education

1. Why Green Education

Green education or sustainable education is an educational approach that aims to provide students, schools and communities with the values and the motivation to take action for our planet in their personal lives within their community and also at a global scale, now and in the future. Green education aims at building awareness and knowledge of sustainability issues, but also at developing students and schools that are able to think critically, innovate and provide solutions towards more sustainable patterns of living. [1, 2]

2. STEM and Green Education

Green education can act as a vehicle in order to inspire the next generation of students to pursue a science career. Furthermore, empowering youth to create a sustainable future is critical in the process of preserving the planet and in cultivating future responsible citizens. With a green education curriculum, a science subject which may be considered abstract, is put into a familiar context relevant to the everyday life of the students and results in the use of technologies that are solving environmental challenges. [1, 3] Novel fields such as green chemistry, sustainable engineering and robotics and green biotechnology can be implemented into classroom teaching under the umbrella of green education. Recent studies identify a shortage of STEM professionals and the need to engage students at all levels in science to boost the supply of STEM workers. The European Union also focuses on education that promotes the building of 21st century skills (transversal and basic skills, STEM related skills, etc.) from children, youth and every EU citizen. Furthermore, green programs draw students and especially female students, toward STEM-related pathways and careers and inspire them to pursue a career or further education in STEM fields.

3. The Green Edu project

Green Education for a sustainable future – Green Edu, is a European program funded by Erasmus+Action: 2019-1-PL01-KA201-065695. It is a collaboration between 3 Universities and 3 schools, Wyzsza Szkola Biznesu I Nauk o Zdrowiu (Poland-Coordinator), Universita Degli studi di Palermo (Italy), Panepistimio Dytikis Makedonias (Greece), Altindag Ahiler Ortaokulu (Turkey), Scoala Gimnaziala Nr. 16 Take Ionescu (Romania) and Educational Association Anatolia (Greece).

3.1 Aim of Green Edu

The project aims to support teachers across Europe in integrating green education principles into STEM curricula. An online platform will be developed that will act as a repository of STEM green education resources, focusing on novel fields of green chemistry, green biotechnology and sustainable engineering and robotics. The platform will integrate micro-MOOC (Massive Open Online Courses/Content) – an innovative approach for developing STEM laboratories that will motivate teachers in the creation of flexible personalized teaching/learning paths and to increase students' interest and involvement, due to the innovative methodology. The project objectives include: 1.

Support teachers to integrate green education principles in STEM curriculum. 2.

Inspire and improve competence of teachers in order to bring novel topics into the classroom. 3. Embed green education principles in school laboratories. 4. Disseminate green education and create a community of green education in Europe. The project will provide access to lesson plans in national languages that cover state of the art science fields and two educational kits will be available to educators to readily use in the classroom.

4 Green Edu Activities

Green Edu activities aim to inspire students to pursue a career in STEM field and help them connect abstract science concepts to real world technologies that are solving environmental challenges and promote responsible citizenship. Activities are designed in a form of lesson plans that include basic theory and laboratory work. Hands on as well as virtual labs will be designed. Topics will cover novel science fields and encompass a real-life problem in order to engage learners. Activities will be developed for elementary and middle year school students.

4.1 Chemistry

Green Chemistry is the design of chemical products that reduce the use or generation of hazardous substances. The challenge is to provide society with essential products that are economical, sustainable and high performing. From life-saving pharmaceutical drugs to high-performance materials without chemicals and chemical products, our standard of living would significantly decline. Chemistry curricula should be re-designed to be greener and safer. School labs should be cleared from hazardous chemical substances. By supporting educators and students to teach and learn green chemistry, we can inspire students to become tomorrow's responsible science workforce. [3, 4, 5, 6]

4.2 Biotechnology

The Biotechnology field has developed fast and changed over the last decade. Today biology curricula around Europe do not include novel biotechnology techniques due to lack of teacher resources and training. Furthermore, as technology moves fast there is a gap in training that may result in scientific misconceptions from the public especially in the field of genetic modification. Thus, the activities designed will focus on introducing novel biotechnology concepts and techniques into the classroom. The designed activities focus on molecular biology of the plant cell and present students with novel biology topics, such as functional genomics, proteomics, biofuels, textiles, pharmaceutical substances and production economics. Green biotechnology refers to biological techniques to plants with the aim of improving the nutritional quality, quantity and production economics. [7, 8]

4.3 Engineering and Robotics

Green engineering is the design and manufacturing of products and processes that have the least negative impact on the environment possible. From wind turbines and photovoltaic cells to bioclimatic houses, modern technology is a decisive factor in making the world greener. Robotics and automation have a significant role in energy saving and optimizing in production. However, there is still a misconception in our society that robotics does not have a role in a sustainable society and that they deprive people from jobs. Today's educational curricula should include robotics and automation as they will play a major role in the future of production. Activities that connect robotics and automation with sustainable engineering will be developed, aiming at driving students to develop critical thinking skills and becoming the next generation of sustainable engineers. Furthermore, a green engineering and robotics contest will be established. [9, 10]

5. Green Edu Activities in the classroom

The COVID-19 pandemic has affected educational organizations worldwide.

Activities that were planned to be hands on activities in the classroom had to be transferred to an online environment. We implemented two activities of the Green Edu for elementary school online lessons.

5.1 Green Edu Activity – Biopolymers

Through this lesson plan students learn about green Chemistry and polymers. After an introduction to green chemistry concepts and polymers, students are presented with the problem of plastic pollution. They learn about bioplastics and follow the scientific method to make their own plastic ornaments from milk. The lesson plan was addressed to a total of 75 2nd grade elementary school students that were divided into 3 groups, connected online and with the help of the class teacher, the STEM instructors and their parents, they followed the learning scenario. Students had gathered all materials needed for the experiment and were always under adult supervision.

5.2 Green Edu Activity – Our Earth

Through this lesson plan students learn about green Chemistry; our earth and how human activities can affect the environment. After an introduction to green chemistry and the earth, they are presented to climate change, to human actions responsible for this environmental issue and are motivated to use their imagination and think of ways to save the environment. The lesson plan was addressed to a total of 75 3rd grade elementary school students that were divided into 3 groups, connected online and with the help of the class teacher, the STEM instructors and their parents, they followed the learning scenario.After a short presentation about greenhouse gases and the impacts on climate change, students brainstormed about different uses of plastic bottles and were given instructions on how to make a mini composter in their home kitchen and made observations for a 2 week period. In the end, they shared their observations with the rest of the class.

6. Conclusion

As a result of its innovative character, the Green Edu adds important value as though it: i) Green Chemistry is combined with STEM, ii) An online Green educational platform along with a digital repository are created, iii) Guidelines on Green activities and Green lab establishment are provided, along with educational seminars and in person training, iv) Detailed lesson plans are provided as well as educational kits and v) Part of the Elementary School activities were presented online (due to the pandemic) and their impact was recorded using questionnaires and moodle.

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How to Incorporate Local Wisdom and Powerful Ideas into Creation of Innovative STEM Projects for Sustainable Agricultural Development

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Abstract

In Thailand, the National Science and Technology Development Agency (NSTDA), in close collaboration with 10 universities, has been supporting altogether 150 high schools and vocational colleges under the Fabrication Laboratory project to encourage students to become innovators through creative activities. In 2020, NSTDA and its partners launched a national contest under the topic "STEM Project for Strengthening Agriculture for Sustainable Development."
In the contest, four enterprising and outstanding STEM projects out of a choice of 55 were unanimously chosen by the selection committee: Automatic Crab Molting Warning Application, Farmer Bot, Aueng Sae Greenhouse and Solar Herbs. All of which incorporated local wisdom and powerful ideas for agricultural applications. From our point of view, there are three principal contributing factors playing a vital role in the successful implementation of the STEM projects for sustainable agricultural development. Firstly, its suitability for local areas and practicality in solving real problems affecting the community. Secondly, multiple on-site experiments, not only in a laboratory, with results' adjustments and improvements as required to be most practical for the community. Lastly, full support of required equipment and devices from the Fabrication Laboratory such as sensors, 3D printers, and laser cutters for implementation of the STEM projects conveniently. These outstanding selected STEM projects are good examples of Education for Sustainable Development (ESD), as they can motivate and stimulate students to acquire new knowledge and to develop new skills, proper attitudes, and values necessary for shaping a sustainable future from their own local contexts. Furthermore, these STEM projects encourage students to take action and be resourceful through critical thinking, imagining future scenarios, and making decisions collaboratively the skills they developed from their creation of these STEM projects which can significantly help them achieve actual sustainable development in any specific area in the future, not only in agriculture.

Keywords: local context, powerful ideas, STEM project, sustainable development, Fabrication Laboratory

1. Introduction

The STEM Project for Strengthening Agriculture for Sustainable Development Contest is part of the National FabLab2020 Contest, aiming for creating innovations for the community. The thematic areas were divided into 3 categories which are 1) Strengthening Agriculture for Sustainable Development 2) Social Lifestyle and 3) Future

Community.

The objective of this national contest is to encourage students to be innovative makers by using fabrication tools to developed prototypes suitable for their communities and inspire them to develop valuable work by realizing and understanding their communities' problems and conditions.

On the way of formulating a project. Students collaborated with their teachers, engineers and members of the local communities with an aim to solve the community problems. Furthermore, the contest can be considered as a new platform for enhancing their design thinking, design capability and engineering skills to apply for their community and well beyond. Students have an opportunity to develop and practice scientific communication skills, as well as build up on teamwork competency on the national stage in the era of Thailand 4.0 society. STEM projects were submitted from students nation-wide and the nature of the projects were of a wide variety. We aim to investigate the important factors for successful STEM projects for strengthening agriculture for sustainable development.

2. Program design and Methodology

The process of studying factors of successful STEM project for Strengthening Agriculture for Sustainable Development is divided into 6 steps as below:

Step I: Students submitted conceptual project for solving community issues through an online contest and presented them via video clip. There were 55 projects for submitted.

Step II: The committee chose 20 interesting projects from 55 projects by evaluating conceptual project and video presentation clips.

Step III: Twenty teams of students presented their project implementation progress to the selection committee and then the committee made a selection for 4 outstanding projects.

Step IV: The committee visited the students' communities for determining and guiding how useful and achievement of project to local communities.

Step V: Students adjusted their project and then they presented the final project to the committee who determined the winning team.

Step VI: The committee discussed and summarized important factors of successful STEM project for Strengthening Agriculture for Sustainable Development.

3. Result and discussion

3.1 Result

There were 55 projects from high schools and vocational colleges under the FabLab project participating in the "STEM Project for Strengthening Agriculture for Sustainable Development". Contest. In the first round, the committee considered the project background and execution plan as the main criteria for selection process. Twenty projects were selected for entering into the second round. In the second round, the committee considered selecting from the presentation of the prototype inventions and the progress of the development. The selections got through an online form due to the situation of the coronavirus outbreak 2019 (COVID-19). The competitors received some guidance to modify the inventions to be more effective in response to the community circumstances before the inventions can be applied in their respective communities. In the third and final round, the committee attended to the worksite, evaluates and provided advices on some issues. The Board of the committee then selected outstanding work, a total of 4 projects as follows:

Project 1: Automatic notification of crab molting through an application developed by a tema of students from Chulabhorn Royal College Satun.This college situates in Satun Province, in the south of Thailand. Soft crab is an economic aquatic animal in their local community, which is in the vicinity of the sea. The crab molting occur very quickly to detect in time for sale and the crab molting observation rely to local expertise to inspect the laying of the crab with the naked eye for every 3-4 hours. In order to reduce the amount and hour of labor, save cost on employment and also for the more desirable life of the workers, this automatic crab molting alarm monitoring system was created by using the principle of infrared reflection of crab shells. This device can be connected directly to the phone, is portable, as well as being able to view the stored data by visualizing graphs to estimate production and marketing as well.

Project 2: Automated planting and plant caring robot with smartphone controller (Farmer Bot) by Islamic Education Demonstration School Prince of Songkla University, in Pattani Province which is in the southern part of the country. This project was developed because the farmers in their areas lacked information about technology, incorrect maintenance, hence leading to poor quality of their production. This project would like to help the farmers to be more efficient in their work environment, use less stamina and have more free time available to carry out other activities or jobs. The robot planting and caring for plants automatically controlled via smartphones (Farmer Bot) was designed and developed. It has the ability to plant the seeds into planting holes. Fertilize and irrigate the plants, which will follow the instructions from the user via the application with a wireless connection or the robot can be operated automatically. Therefore, growing plants by robots not only provide growth but can increase the survival rate of plants more than 60 per cent in various conditions compare with self-cultivation.

Project 3: Aueng Sae Greenhouse by Mae Sariang Boriphat School.This school is located in Mae Hong Son Province which is in the northern most part of Thailand. Students in this project designed and developed a smart greenhouse for growing orchids. The greenhouse was invented to preserve a critical indigenous orchid species of the community. Its flower can be transformed into perfume. Aueng Sae Greenhouse can control the temperature, humidity, light, as well as the amount of fertilization that is suitable for growth. It has multiple displays and can use the Internet of Things (IoT) system via smartphones. Not only in areas in the northern part of the country where this project was implemented, Aueng Sae Greenhouse can potentially be re-constructed and used for growing orchids in other parts of Thailand as well. Another advantage is this smart greenhouse design can help to prolong the flowering period that is 2 times longer than before.

Project 4: SMEs drying and Processing Herb Machine by Sakon Nakhon Technical College. The Solar Herbs is powered by a solar panel. KidBright board, Thai embedded board was used to monitor, control the temperature and humidity via mobile phone. The machine will dehydrate the herbs to the standard moisture value, conserve its medicinal content and decontaminated from bacteria. This device is currently used in the Thai Traditional Medicine Club, Sakon Nakhon Province and hasreceived a high satisfaction rate so far.

3.2 Discussion

From the analysis of project observation and interviews with the teachers of students who proposed their projects including other personnel involved in the projects. There are three common factors contributed to the 4 successful projects out of 55 projects are as followings. Firstly, the developers can identify project-related problems based on local issues and concerns found in the surrounding neighborhoods of their schools. Students understand the implications of the problem very well which then leads to the collaboration between students and their communities to design and solve such problems. As a result, the projects implemented are suitable for the local community. The participants have learned to plan and set up work procedures, practice designing and developing prototypes then examining with target groups and eventually solving the community's problems. Secondly, a prototype has been tested in the local community several times during developing and testing stages. The results are not just laboratory experiments but an effective solution to issues faced locally and the improvements are made to maximize the advantage of the community. Thirdly, educational institutions have important roles to play during project implementation. Students had a full access to engineering equipment required for researching and developing the prototypes. Machines and tools in FabLab such as laser cutters, 3D printers, computers, sensors and hand tools were made available for use. Through project implementation, students learn to take actions, developing skills through critical thinking, creativity and collaboration as a team. These skills, which are developed through project invention, will help them achieve truly sustainable skills for their future endeavors.

4. Conclusion

The factor of successful project which has high benefit to the community is the suitability for local areas and practicality in solving real problems of each community.

Furthermore, the project should do multiple on-site experiments by not only in a laboratory. And the last factor is the project should have maker facilities to support for implementation of the STEM projects conveniently. STEM project is an excellent tool for developing new knowledge, essential skills, good mindset for shaping a sustainable future from students own local contexts.

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PHERECLOS: Boosting Science Capital and promoting STEAM Engagement with Open Schooling Approaches

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Abstract

PHERECLOS builds upon the theory of science capital [1] and the experience that Children's Universities [2] have made in the Third Mission of universities. They became intermediaries between various actors in the educational and social landscape – as incubators of change. Built around them, PHERECLOS develops innovative Open Schooling models of collaboration in six regional clusters (Local Educational Clusters, LECs), which serve as experimental testbeds for schools and affect the quality of STEAM engagement opportunities in general. Their regional effectiveness will lead to the development of implementation guidelines and policy briefs to enhance the sustainability of the overall approach, which is continuously informed by findings from academic implementation research and a Mentoring Programme for further 40 organisations (TEMPS, Transnational Education Mentoring Partnerships). These models of engagement which can be beneficial for educational establishments and for the social communities in a wider context, provided that the involved actors have the capacity and knowledge to approach them.
PHERECLOS, has received funding from the European Union's Horizon 2020 research and innovation programme (www.phereclos.eu).

Keywords: Science capital, Children's Universities, Open Schooling, STEAM, H2020

1. Introduction

The PHERECLOS project is approximately halfway along its journey, our goal being to develop and pilot innovative models of cooperation in micro-education ecosystems.

The models involve various education providers at the overlapping edges of formal and non-formal education in order to respond to local demands and challenges in education.

The definitions of Open Schooling (OS) [3] speak of a collection of ideas from the 1970's around the idea of a school '*opening up its processes to become more permeable'* while Susan Phillips [4] takes the view that an Open School has one unique facet: the physical separation of the school-level learner from the teacher, and the use of alternative teaching methodologies (often ICT-based). This definition fits with some large-scale initiatives supported by the Commonwealth of Learning that have been in place since 1994, examples of which from Africa and India, dominate searches for the term 'Open Schooling' (e.g., NIOS). More recently, Knudsen & Obro Skaarup [5], defined

OS as the collaboration between schools and local institutions, businesses and organisations on teaching. They point out that under this definition it has been a mandatory part of the Danish public school system since 2014. There are clearly very many interpretations of how 'open' is an open school (involving any/all of open classrooms, open labs, open curriculum), all of which are 'open' to interpretation! For our purposes, we are using a relatively broad definition of 'operating a school in a way that reflects external ideas, topics and challenges and incorporates them in their teaching approaches and everyday school life, and in return, provides the creativity and potential as the assets of their pupils and teachers to the community around them.'

From this definition, we wish to explore how these structures are best developed to boost young people's Science Capital and promote STEAM engagement. Science Capital was defined. as a measure of science-related qualifications, interest, literacy and social contacts with science and scientists [1]. Those with high science capital being more likely to pursue a career in STEM related disciplines. The goal of implementing a STEAM curriculum (Science, technology, Engineering, Arts and Maths) is to provide a holistic education that engages both sides of the brain, develops students' functional literacy and promotes constructivism [6].

The project aims to develop innovative Open Schooling models of collaboration based around six regional clusters spread across Europe and beyond. PHERECLOS stands for Partnerships for Pathways to Higher Education and science engagement in REgional Clusters of Open Schooling. Phereclos was also a Greek navigator and shipbuilder, explaining a number of the nautical references. All aboard!

2. Methods

PHERECLOS is a three-year, Horizon 2020 funded project of the European Commission under grant agreement *No 824630*. The project is being delivered by 15 Consortium partners from 10 countries.

KINDERBURO UNIVERSITAT WIEN GMBH (Lead), Austria
SYNYO GMBH, Austria
UNIVERSITAET INNSBRUCK, Austria
UNIVERSITAT WIEN, Austria
UNIWERSYTET SLASKI, Poland
POLITECHNIKA LODZKA, Poland
EUROPEAN SCHOOL HEADS ASSOCIATION, Austria
KOBENHAVNS UNIVERSITET, Denmark
STICHTING INTERNATIONAL PARENTS ALLIANCE, Netherlands
SNELLMAN-INSTITUUTTI RY, Finland
UNIVERSIDADE DO PORTO, Portugal
S.I.S.S.A. MEDIALAB SRL, Italy
UNIVERSIDAD EAFIT, Colombia
ASOCIATIA UNIVERSITATEA COPIILOR, Romania
TEACHER SCIENTIST NETWORK LBG, United Kingdom

2.1 Local Education Clusters (LECs)

Central to the PHERECLOS approach is the establishment of six Local Education Clusters which will see the interaction of stakeholders and key-actors including schools and businesses that is built upon the model of Children's Universities [2]. These models of science engagement have already proven their ability for creating new forms of awareness for research and STEAM, for having an impact in the regional educational landscape and for becoming agents of change-enhancing formal and non-formal education in their region.

Detailed workplans have been prepared by each LEC using tools developed by project partners with experience in implementation science and advocacy. This approach ensures that a common framework surrounds the diverse approaches being taken by the local LECs which are described in more detail below.

2.2 Implementation Science

A series of online workshops/webinars has introduced LEC participants to the principles of implementation research and to help to establish a common vision regarding the crucial steps in implementation processes and utilization of dedicated templates to assist the LECs in creating their workplans.

One template covered the general description of the LEC (aims, organizations involved, planned activities etc.) and two other templates are based on a widely used aid in implementation science, the *Hexagon Tool* [7]. It allows a better understanding of how a new or existing program or practice fits into an implementing site's existing work context. It is also helpful to figure out strength and weakness of an innovation by considering several indicators of the innovation (usability, evidence, support) and the system (need, fit with current initiatives, capacity).

2.3 Advocacy – Policy Briefs

In order to incentivise a change of policy and practice for Open Schooling in the STEAM context, the project has developed a collection of 'policy briefs' which aim to ensure the long-term and widest possible impact of the project by advocating for upscaling and mainstreaming. From the advocacy perspective consideration was given to the specific needs of a diverse number of stakeholders including teachers, school heads, teacher training students, parents and pupils.

1. The Benefits of Open Schooling on STEAM learning,
2. School Autonomy and Stakeholder Engagement in Open Schooling,
3. School Leaders and Teachers in Open Schooling,
4. Non-formal Education Providers in Open Schooling,
5. Financial Aspects of Open Schooling,
6. Physical and Legal Barriers to Student Participation in Open Schooling.

3. Results

3.1 The Mobilisation and Mutual Learning Platform (MML-P)

Evolving from a static information driven website (www.phereclos.eu), the PHERECLOS Mobilisation and Mutual Learning Platform (MML-P), serves as a central hub for dissemination, mobilization and community. It cleverly combines a public-facing project information element with a 'behind-the-scenes' partnering system to boost engagement and support the establishment of Open Schooling partnerships. The platform provides a variety of tools such as a filterable practices-database, information modules for LEC and TEMP activities as well as a dedicated partnering system for creating new education communities. The platform will help to ensure the sustainability of the project outputs as well as supporting interactions between the Open Schooling community.

3.2 Inspiring Cases

One of the first outputs from the project was a compilation of 63 inspiring cases or practices of Open Schooling in a STEM/STEAM context (https://www.phereclos.eu/practices). This collection will be used as inspiration for our own LEC and TEMP programmes but also serve as a repository for anyone interested in these topics such as teachers, school heads, decision makers, and other stakeholders who may wish to develop future OS projects. With the help of search terms, filters and tags the inspiring practices are easily detectable and the information accessible. The cases also show the great variety of activities, which fit well with the broad definition of OS as part of the PHERECLOS approach. Most of the activities have a STEM-focus, but some include strong connections with humanities and the arts (STEAM). They cover a range from preschool up to upper-secondary level and are broad in terms of scale: small activities with a rather local focus, to large scale, nationwide activities.

3.3 LECs

The six LECs have been established and workplans prepared:

- Austria: Vienna *Large scale approach in urban surrounding (capital city with diverse neighborhoods) – Network of Schools meet Network of Universities*
- Columbia: Medellin *Cross-sectoral design of teaching units to foster active citizenship for changing societies in post conflict areas*
- Finland: North Savo *Transfer of scientific knowledge from university to schools and households in rural remote areas*
- Italy: Trieste *Open Schooling in a City of Knowledge: Inclusive education to prevent school dropout*
- Poland: Lodz *Change of school program and teaching techniques to meet current and future labor market needs*
- Portugal: Porto *STEAM awareness, citizenship, and entrepreneurship skills development according to the 2030 SDG via a cross sectoral educational cluster*

3.4 Transnational Education Mentoring Partnerships (TEMPS)

Ten cross-sectoral Transnational Education Mentoring Partnerships (TEMPs) between differently experienced parties in innovative education development have recently been established. These include at least four partner organisations from two or more sectors in at least two different countries. These partnerships aim to create a STEAM-related mentoring programme between education providers from different countries, which have different levels of experience in the field.

The TEMPS are intended to amplify the individual and institutional learning generated about capabilities and effectiveness of Open Schooling models, notably from within the LECs and share it with a wider range of experts and practitioners. In return, it shall contribute to the accumulation of further insights about practical implementation of collaboration schemes in Open Schooling.

3.5 Open Badges

PHERECLOS is utilizing an empowering concept of digital badges as a future way to award and highlight organisations and individuals for their engagement related to the promotion of Open Schooling. The project has established five core badges, which emphasize different forms of engagement https://www.phereclos.eu/badge/). These badges will help to identify committed experts and practitioners in the field of Open Schooling making them more visible in their communities sharing their badges through various social media channels.

4. Next Steps and Concluding Remarks

Building upon experiences from the LECs, PHERECLOS will develop recommendations for new ecosystems in education, where schools become the central hub of a community to embark on new collaboration strategies. PHERECLOS will extend the incubatory role of Children's Universities for institutional and societal change to the school sector in a collaborative approach that is fostering the mutual understanding of formal and non-formal science education providers to become incubators of change.

Speaking about OS in times of school closures appears to be a contradiction – but PHERECLOS was conceived well before the pandemic and can now be realised as an opportunity, a boat of salvation to transport us all to other, not so distant shores, where we seek to understand how to rebuild our lives and hope that the 'new normal' can encompass an exciting blend of formal and non-formal learning geared towards contextualizing the curriculum for mutual benefit of schools and the wider society with PHERECLOS providing maps and charts to navigate our journey.

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Problem-Based Tuition in Blended Environments

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Abstract

Problem-Based Tuition is a scaffolded form of PBL that we have developed over the past 15 years to deliver an interdisciplinary science (Natural Sciences) degree. We discuss the issues arising in adapting the novel features of the program to a blended delivery in response to the COVID-19 pandemic. One of the key features of the program is the use of structured guided reading, which carries over smoothly to the on-line environment. Others such as the lectures and group facilitation require adaptation. Rather than their use for Q&A following self-study, the previously interactive lectures were repurposed as pre-recorded introductions to the guided reading. Students then have these available for review. We found it important to provide extensive initial practice in the use of the relevant software for group discussions (Blackboard Collaborate and OneNote). The issues arising in the adaptation of group peer-marking will be discussed. We compare our experience with the adaptation to blended learning of a PBL module in a Chemistry degree.

Keywords: Problem-Based, Interdisciplinary Science, Blended Learning

1. Problem-Based Tuition

Problem-based tution (PBT) is our term for a strongly scaffolded version of problem-based learning (PBL) developed for an interdisciplinary science programme (biology, chemistry and physics) at the University of Leicester in the UK [1]. The programme was first presented in 2004 [2] and significantly revised in 2018. The apsects discussed here are common to both implementations. We begin by describing the innovative features of the programme. We then discuss the adaptation to much reduced face-to-face interaction brought about by the COVID-19 pandemic. We compare our experience with that of colleagues delivering PBL in a chemistry degree.

In PBT each module is based around a problem or project, here of an interdisciplinary scientific nature. An example might be to investigate the limits to the speed at which a human can run which include physical (heat and chemical transfer, for example) and biological (metabolism, muscle action and so on) and to write this up in an authentic assessment in the form of a report for athletics governing body. The scaffolding consists of directed reading, and a series of lectures, workshops (classes with problems for group discussion) and individual exercises that frame the student learning. Four core science modules run one at a time in sequence over the academic year. In parallel there are support modules for mathematics, computing and professional skills which are not taught by PBT and for which the adaptation to online is considered briefly at the end.

By contrast, in the School of Chemistry, PBL is integrated into the lecture-based teaching of a number of core modules throughout the curriculum [3]. Students are assigned to small teams (typically around six members per team) to work on open-ended problems in which they apply their subject understanding to problems with broad societal significance such as environmental, financial and social impact. In one example, year two students have to advise the government of a small European nation on the development of a sustainable energy strategy. Here students communicate the key outcomes of their strategy through (i) a review paper providing evidence-based scientific justification for their proposed course of action and (ii) a press conference presentation addressing the social impact. Students work on PBL problems in weekly facilitation sessions. Support is provided in the form of lectures and workshops (related to the scientific principles and the key transferable skills), directed reading and individual reflective activities.

2. Adaptation to online learning

The adaptation of a course of lectures to delivery online is straightforward, to the extent that it is surprising that it has taken a pandemic to drive this change. It is possible to learn from the experience of MOOCs here to make this adaptation a more interactive experience. In theory, adaptation of a problem-based pedagogy to online learning can be accomplished through virtual group work and virtual workshops. In practice we discover pitfalls in this approach. We discuss these in the context of the two programmes.

2.1 Lectures

The facility to record live lectures (as voice over slides) already exists in all of the university theatres using Panopto software. In PBT these recordings were used previously to address issues of accessibility, to provide students with revision material or as (rather poor) alternatives to attending the live sessions. In the programmes described here lectures were not the prime mode of delivery of discipline content. In chemistry PBL they are used to support the pedagogy (see section 4) and in PBT science we use them to guide the content learning. Nevertheless, although these recordings exist, we did not consider them to be of sufficient quality to substitute for face-to-face sessions.

We have therefore made use of Panopto to generate more engaging picture-in-picture presentations (slides and presenter). The key however is that the recorded lectures are structured and delivered in ~20-minute sections with links to the reading material, and again not as substitutes for the print materials. In PBT the original face-to-face lectures were designed as interactive Q and A with experts, for which the students were expected to come prepared through their prior reading. (In recognition of this structure we labelled these as “expert sessions” rather than “lectures”.) However, for the online version we repurposed the material as more straightforward content delivery, which students watch *prior* to engaging with the suggested reading. The lectures now focus on where we might expect students to need help with or reinforcement of the text book material (or research papers) based partly on previous experience of the Q and A.

2.2 Induction

In semester 1, first year chemists work on a PBL induction activity designed to familiarise them with PBL and to give them the opportunity to form strong social links with other students. The activity was adapted for the 2020-21 academic year to an on-line led approach with a change of timescale (from seven to ten weeks). Students were allocated randomly to teams of four or five and given access to a file sharing tool and a team whiteboard. Teams attended regular online facilitation sessions hosted on Blackboard Collaborate Ultra in a communal PBL room (with breakout rooms used for individual teams). Between these sessions students were given access to their own Collaborate rooms to work on the problems.

The first Chemistry facilitation session included an icebreaker activity and and introduction to the PBL approach. The icrebreaker activity required each team member to introduce themselves to the rest of their group and to tell their favourite chemistry joke.

Once all team members had introduced themeselves and told their joke, the team members voted for their favourite joke which they then told the entire cohort to determine the overall favourite joke. This light-hearted introduction provided students with a memorable way of meeting their team mates.

Students in PBT are assigned to diverse groups of four or five. We use *Blackboard Collaborate* software for online group work with a facilitator moving between break-out groups. We used a two-week induction period comprising a non-credit bearing problem for which students received feedback from academics and peers, allowing students to thoroughly familiarise themselves with the technology and their group members. This was crucial to the success of the later assessed group activities.

2.3 Group Workshops

The level of engagement in chemistry facilitation sessions was generally good with very vibrant discussions taking place in some teams. It is true to say that some teams were less engaged and perhaps the online format made it more challenging for facilitators to intervene when they noticed a team lacking in focus or engagement.

Chemistry students adopted a different approach to the first problem on the development and evaluation of a learning resource [4] from that of previous cohorts in the classroon enviornment. In 2020/21 many groups created online quizzes and videos.

This may reflect the changes to the learning environment.

With one facilitator to five or six groups in PBT we found it to be much more difficult to keep track of the online break out room conversations than in a face-to-face setting, and the online activity can lack any “buzz”. The structure was adapted by requiring each group to record their discussion points in real time in a shared OneNote file that can be viewed continuously by the facilitator and retained as a record of the workshop. The precise psychology eludes us, but this has led to much deeper engagement in the workshops.

2.4 Tutorials

Previously in PBT students completed weekly set exercises individually, which were then peer marked within a group in a class setting. To prevent cheating (groups agreeing to give each member unearned marks) random samples of marked work were checked by academic staff. In the move to online these exercises have been designated as formative and carry no marks, obviating the need for checking. Contrary to the expectations of some academic staff (jncluding one of the authors), this has not led to any diminution in engagement. In fact, on the contrary, the work of preparation for the tutorials has been relieved of the stress of a summative assessment, and the online discussion of group members’ solutions has focussed to greater extent on the learning content.

3. Scaffolding online

In the face-to-face version of PBT students have a handbook (provided electronically) to guide them through the material, with the regular expert sessions to provide pacing.

Moving to online, the now asynchronous lectures no longer served this role. To guide students through PBT online, materials were placed in weekly folders. On Friday afternoon of the preceeding week a post was released guiding students through the activities for the forthcoming week. This suggested both the order of activities and the recommended time on task for each element.

4. Skills

A key feature of the natural sciences programme is the embedding of skills for employability through the problem-based and group pedagogy and the authentic assessments. Skills sessions were retained as an essential component to support development of broader academic skills (for example literature searches and referencing) and to support specific assessments (for example group presentations). In addition, we introduced a new skills session specifically to support students to work effectively outside class in an online setting. The existing skills sessions were adapted from two-hour face to face workshops to one-hour sessions with instructional material moved to online recordings and appropriate activities moved to pre-session preparation.

In chemistry student team work (which took place in facilitation workshops, see section 2.2) was supported by a series of lectures that helped intoduce students to the PBL methodology and assisted their development of key skills (e.g., oral and written presentation skills) that they would need to use in PBL facilitation sessions. These skills sessions were delivered through a combination of pre-recorded material together with live online sessions, which included interactivity activities based on the content of the pre-recorded sessions.

5. Conclusions

PBL becomes more like PBT under online teaching. PBT is largely preadapted to online learning with minor tweaks. Thus, very little (if anything) of the academic content and skills development is lost in moving to PBT on line (although naturally the social interactions are more limited).

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STEM Education in Gülen Inspired Schools through Extra Curricula Activities

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Abstract

STEM education has been one of the most important subjects in college entrance exams in Turkey and therefore it has been an initial target of the private school sector for decades. Through various channels, Turkish Islamic Scholar Fethullah Gülen's and his followers schools, which are named Gülen Inspired Schools according to different scholars [1], have achieved remarkable success in STEM education. Their graduates are now among Turkey's leaders in science and math and are very well represented at the country's top universities, as well as in master's and doctorate programs throughout Europe and in the United States [2]. Through the internationalization process of the movement after the Soviet Resolution, different Gülen inspired schools were founded outside of Turkey and they also followed the same path and expanded this type of STEM education to the world [3]. The purpose of this paper is to examine the methodology of Gülen Inspired Schools in STEM education. A qualitative research design is used to study this issue. Semi-structured expert interviews are conducted with managers of the Gülen Inspired Schools from three continents: Europe, Africa and the US and the experts of the subject. The results show that, in addition to the full-day concept and modern facilities with science labs, these schools conducted three types of extra curricula activities such as tutoring programs for the weak students, preparing good students for science Olympiads and coaching or mentoring students [4]. These types of extra educational activities have a supporting role in the STEM education in these schools. On the other hand, the detractors of these schools described these extracurricular activities as a tool in which Gülen followers conducted indoctrination and missionary activities to gain new followers [5]. Schools defended themselves against these approaches by demonstrating the secular structure of these activities and contribution to their students. Such discussions and the controversial structure of these extra curricula activities are also analyzed from different perspectives in this paper.

Keywords: Gülen Inspired Schools, STEM Education, Extra Curricular Activities

1. Introduction

Higher education institutions and interest in higher education has been an important subject since foundation of the Turkish Republic and the demand for these institutions increased rapidly in the last four decades [6]. Because of this issue, the Ministry of National Education in Turkey founded several central exams, such as High School Entrance Exam *LGS (liselere Giris Sinavi*) or Student Selection Examination *ÖSS* (Ögrenci secme ve yerlestirme sinavi), to select the best students for these schools.

Despite several changes in these exams since its foundation, the STEM courses always have had a crucial role in these exams and schools compete with each other in this sector. What is striking in this competition is the success of the private schools and tutorial centers which were founded by Turkish Islamic Scholar Fethullah Gülen. He saw this trend in the early seventies and motivated his followers to found STEM based private tutorial centers and private schools in Turkey. It is not clear what percentage the GISs share in the total number of private schools in Turkey; however, until recently, the Movement was considered the dominant player in the private market in both primary and secondary education [7]. Later on, the movement expanded these institutions outside of Turkey and founded more than a thousand similar types of STEM based schools all around the world [8]. What is the common features of these schools in STEM education, what kind of methodology did they conduct and how did they expand so rapidly were some of the research questions of the researcher in his PhD studies from 2016 to 2020 [9]. This paper is an expansion of the results of this research and adds several new perspectives to this controversial subject. Unfortunately, because of the political disorder in Turkey after the coup attempt in 2016, all Gülen inspired schools and tutorial centers were closed immediately after the event [10]. Therefore, the researcher of the study decided to focus on Gülen inspired schools outside of Turkey to research his research question.

2. Results

As it was mentioned above, the major difference of this type schooling is its strong structure based on STEM education. The first remarkable feature of these schools in STEM education is their modern facilities with high tech labs. All nine schools have laboratories and they use modern technology like smart boards in their classrooms. In this way, they are promoting research activities, especially in natural sciences, and self-learning in their schools. All participant experts in the field study also highlighted this issue and suggested that quality has a crucial role in Gülen inspired schools and that differentiates them from other schools in their region.

In addition to high technology, the whole-day school concept is another remarkable feature of these schools worldwide. According to different researches and during the visits in three parts of the world, it was observed that all GISs practice a whole-day school model in their institutions. In this way students spend more time at the school and, in comparison to other students, they have more classes.

“For example, a normal public school starts at eight and ends at two, two-thirty…Yes, we have an all-day concept, so we give two math lessons, one morning and one afternoon. Science can be like that. So, we have chance to teach more subjects and to do more exercises because we have more time”. (First School Manager in the US)

Based on these two common features, all participant managers highlighted that extra-curricular activities have crucial role in their STEM education. During these visits and interviews, researcher of the study observed three type of extra-curricular activities based on students’ academic level.

2.1 Tutorial Courses for Weak Students

Private tutorial centers were first founded as institutions of the movement in the seventies, much earlier than Gülen inspired schools, and the movement achieved remarkable success with these institutions in Turkey [11]. It was observed during the research that the followers of the movement use their experience in these centers and made tutorial activities a part of their teaching activity in their schools.

Especially students who are weak in STEM courses are encouraged to attend these extra courses. In Africa, GIS organized these activities by themselves and offered these extra courses on Saturdays or evenings in their dormitories. In Europe, such a kind of schools have cooperation with some private tutorial centers and lead their weak students to these institutions. In the US, the practice depends on the school but it is more and less a mixture of the Europe and Africa approaches.

In these courses, teachers or sometimes older students who are very good in STEM courses explained these lectures to weak students at a slow pace with individual care.

By this way, weak students have more of a chance to ask their questions and better focus on these subjects.

2.2 Consulting and Coaching Activities for Average Students

The second type of common practice in Gülen Inspired Schools are consulting and coaching activities in these schools. These types of activities targeted average students in their schools. In GIS there are one or two people with an education and experience background who are employed for this job and they report directly to the school manager.

These people are called *Rehber* or “PDR” (which means psychological counselor in Turkish).

“For example, we have a PDR (Psychological counselor and guidance) work in our school, and there is no such understanding in other schools. Maybe for the first time there is a PDR in this country who is working in a school”. (Second School Manager in Africa)

The people responsible for this duty cooperate with other teachers, especially class teachers, and conduct their mission. In these coaching sections, class teachers or PDR meet with a group of students, mostly consisting of three or four students, and talk about their grades, their study methods and personal issues which could affect their grades every week or every two weeks. Students talk about their difficulties and try to find solutions for these problems together with their teachers. In these meetings, students also decide on some goals and plan several strategies to improve their grades. Class teachers or PDR follows these decisions and motivate students to achieve their goals.

The second goal of this kind of coaching activities is to find out personal problems or concerns of the students, especially because of adolescence, and help them to solve them before these issued darkens their academic success in their school success.

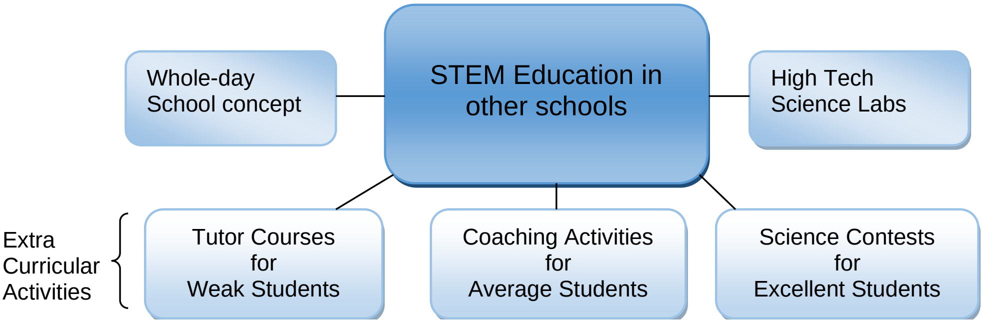
From both perspectives, setting targets and removing obstacles depending on different private reasons, help these schools, especially in STEM education, which needs more focus and concentration.

2.3 National and International Contests for Excellent Students

One of the most remarkable common points of the Gülen inspired schools is their active participation in national and international science contests [12]. In all visited GISs during the field study, many medals and prizes from different contests are located in the most seen parts of the school. As a very concrete example, the third visited school in the U.S. put their students’ picture with Ex-president Obama in the White House at the entrance of their main building. These students achieved a success in a national contest and therefore President Obama invited them to the White House to award their efforts.

It was observed in the field study that GISs mostly select their excellent students from STEM courses and prepare them for national and international science contests. After finding a suitable contest for their teachers and students, GISs post a teacher who has a deep knowledge about the subject, and group of students who have talent in that course and prepare themselves for the contest. Such kind of cooperation will not just increase the knowledge of these students in their strong skills and prepare these students for University studies, besides it will also become a challenge for these students who already have enough above average knowledge. Therefore, management in the GISs take these activities very seriously and they follow these kinds of contests or projects at both a local and a global level for their excellent students, especially in STEM fields.

All above mentioned additional educational activities could also be practiced in other schools too, but the difference in GISs is the attention and approach of the management to these activities. During the field study, all school manager participants mentioned that they have all these three types of activities outside of class and they are all organized by the management of the GISs. The figure below explains the difference between traditional teaching and how Gülen inspired schools cover these activities:



3. Critiques

These three types of additional educational activities cause some criticisms too. The movement's detractors suggested that the schools and their curricula is outwardly secular, which is utilizing *taqiyya* (hypcorism) and that the schools are a front, where behind the scenes in informal classes (*gayrı resmi* in Turkish) and in extracurricular activities, the followers of the movement conduct brainwashing, indoctrination and missionary activities [13]. According to Tittensor, behind the scenes, though, there is a carefully executed informal religious curriculum that is carried out by handpicked proxies [14]. In the same way, some detractors also mention that the other goal of these activities are to recruit new participants and gain new followers for the movement [15].

In contrast to these approaches, especially school manager participants of the study, debated on this issue and said that their goal is to use students' time more efficiently.

According to them, school hours are not enough because of the wide range of their curricula and these kinds of activities are necessary for the students. That is why they only try to expand their education by cooperating with students and their parents after school hours. Besides, they underlined that one of the major factors behind their success is their close engagement with their students in these activities.

Related to this point, Alam also suggested that Gülen's educational discourse is a contribution to western-modern educational system based solely on professionalism, through culture, spirituality, global moral and ethical values [16]. Besides interreligious and interfaith activities of the movement also contradict to these critiques [17]. Why the movement intends to cooperate with Catholic, Protestant and Jewish congregations and why do these congregations accept such an offer, if the movement's educational activities are solely based on expanding Islam and gaining new followers?

4. Discussion

It is very difficult to analyze the mentioned criticisms from different reasons. First of all, there is a lack of research about the Gülen inspired schools, their school concept, their students and graduates [18], especially because a quantitative research method has never been conducted on the students and graduates of the Gülen inspired schools before. Besides, current research which are only based on qualitative research methods conflict with each other. According to Tittensor's qualitative research, the movement is a missionary organization like other Christian churches [19], however depending on Dohrn's qualitative research, she is reluctant to consider the GM's educational engagement as being solely missionary in intent and impact [20]. Similar conflicts were also observed in different studies and depending on the researcher, the place and the time, results are changing, which is a big obstacle to analyze this issue.

All criticism aside, the quantitative growth of these schools in the last four decades inside and outside of Turkey, their successes in STEM based central exams and science Olympiads and also the interest of the parents to these schools, demonstrated that such kind of extracurricular activities help the students to understand the STEM courses.

Therefore, such a concept will be a good example in total or in particular to the other STEM based schools all over the world.

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STEM in the Classroom through Problem Solving on Bacteria and Drugs

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Abstract

The Spanish curriculum for School Science establishes some objectives related to the development of various scientific practices: raising problems, formulating hypotheses, constructing models, designing resolution strategies, analysing results, etc. Furthermore, it suggests the convenience of proposing relevant contexts from a personal and global perspective (environment, frontiers of science and technology, health, and disease, etc.), in order to show the impact of these disciplines in social development. In addition, the evaluation criteria of School Mathematics, the main focus of this work, include use of problem-solving strategies and generalisation of mathematical research, application of mathematisation processes in everyday contexts, and assessment of modelling as a tool for problem solving, being aware of its effectiveness and limitations. Nevertheless, and despite this curricular development, Spanish students scored below the OECD average in Mathematics and Science in PISA 2018. In this contribution, we present a descriptive analysis of the obstacles faced by 16-17-year-old students when dealing with a contextualised problem about growth of bacteria and how two drugs can help to partially eliminate them. In addition, we analyse the potential of a teaching and learning strategy based on modelling, mainly mathematical, to integrate knowledge about different disciplines. The problem allowed students to work on a variety of concepts and procedures: bacteria and viruses, infection models, numerical successions, resolution of logarithmic and exponential equations, graphic representation of functions, etc. During the development of the activity, several intermediate questions were posed to facilitate its understanding and interpretation, delimiting and structuring the problem. The use of the GeoGebra software was also considered.

Keywords: Problem solving, STEM, contextualised problem

1. Introduction

Since 2000, the OECD has been conducting triennial studies on the skills that 15-year-old students must acquire in three areas, reading comprehension, Mathematics and Science, leading to the PISA reports that can serve as a basis for the design of improvement policies. These tests allow reflection on the international learning situation and the exchange of experiences to improve some educational indicators in all participating countries [1]. They aim to determine whether students are able to apply what they have learned in the classroom in different situations, both in their own schools and in real life, which requires reasoning skills instead of well-defined procedures that are only helpful to answer direct questions. [2]. In our context, Spanish students scored below the OECD average in both Mathematics and Science in PISA 2018 [3].

Despite these results, the Spanish curriculum [4] includes objectives related to the development of various scientific practices: posing problems, formulating hypotheses, proposing models, designing strategies for solving them, analysing the results, etc. [5].

Furthermore, teachers are required to propose relevant contexts from a personal and global point of view (environment, frontiers of science and technology, health and illness, etc.), which show the impact of these disciplines in social development. On the other hand, if we focus on the subject of Mathematics, the Spanish curriculum includes the use of problem-solving strategies and the generalisation of research, the application of mathematical processes in everyday contexts or the valuation of modelling as a resource for solving problems, with an awareness of its effectiveness and limitations. In order to understand and promote the interaction between the disciplines of Science, Technology, Engineering and Mathematics, as well as the associated vocations, in the 1990s the term STEM emerged from the field of education, as an acronym for Science, Technology, Engineering and Mathematics [6]. In the STEM framework, apart from understanding concepts about Science, Mathematics or Technology, it is of utmost importance to solve real-world problems by “thinking like” mathematicians, scientists and engineers, and being aware of the interconnections between these disciplines [7].

For all the above reasons, in this paper we aim to analyse the obstacles faced by students when tackling a contextualised problem about the growth of bacteria and the decision to choose between two drugs, a task which integrates knowledge from the previous areas.

2. Method

This research follows a qualitative design to explore how Secondary Education students approach the resolution of a problem contextualised in Science and Technology, in which a variety of mathematical concepts and procedures are involved.

For this purpose, eight 16-17-year-old students from a technological high school in Spain were selected. They were finishing the first year of post-compulsory secondary education and worked in pairs to solve the problem.

2.1 Proposed problem

We proposed the following problem to the students:

On January 1st (Monday) at 0.00 am, one million people were infected with a certain bacterium. Two pharmaceutical companies are trying to combat a situation that could trigger a humanitarian disaster. The first pharmaceutical company has manufactured a drug that reduces the number of bacteria by 62.5% each time it is given; and can be injected every six hours. The second pharmaceutical company has made a drug that reduces the number of bacteria by 72% and can be injected every 24 hours. On the other hand, a laboratory has started to study the reproduction of these bacteria. It has found that at a temperature of 36.5°C (human body temperature), the number of bacteria doubles every 6 hours. Medical research has shown that, if people have more than one million bacteria in their body, they die, but if they are able to keep the number of bacteria bellow that quantity for 10 days, they survive and are immunised for life. What drug would you use to alleviate this infection? Justify your answer.

2.2 Scaffolding

To facilitate problem solving, students were guided to structure the problem in several steps or stages. In addition, a set of questions were provided to promote reflection on the necessary contents, procedures and strategies [8]. These questions were linked to the following four blocks:

Table 1. Proposal of blocks for the problem and associated Mathematics, Science and Technology contents

Block	Mathematics content	Science content	Technology content
I.Reproduction of bacteria (drug-free)	- Numerical sequences - Arithmetic calculations - Exponential functions - Algebraic expressions - Limit of sequences/functions	- Characteristics of living things and levels of organisation - Bioelements and bio-molecules - Research project.	
II.Drug-free life time	- Logarithmic and exponential equations. - Arithmetic calculations - Graphical representation of sequences/functions	- Health and illness - Immune system - Research project	- Computational strategies (GeoGebra)
III.Drug introduction	- Percentages - Arithmetic calculations - Algebraic expressions - Graphical representation of sequences/ functions	- Health and illness - Immune system - Research project	- Medical research - Medical treatments
IV. Survival	- Arithmetic calculations	- Characteristics of living things and levels of organisation - Bioelements and bio-molecules - Research project	

3. Results

Students show a good resolution of the numerical calculations that appear during the problem and a good approach to percentages. Both mathematical notions were already acquired in previous years. In addition, they correctly pose and solve logarithmic equations (Figure 1). In all three cases, these are tasks that require the acquisition of different processes and skills, but not a particular reflection on the problem posed.

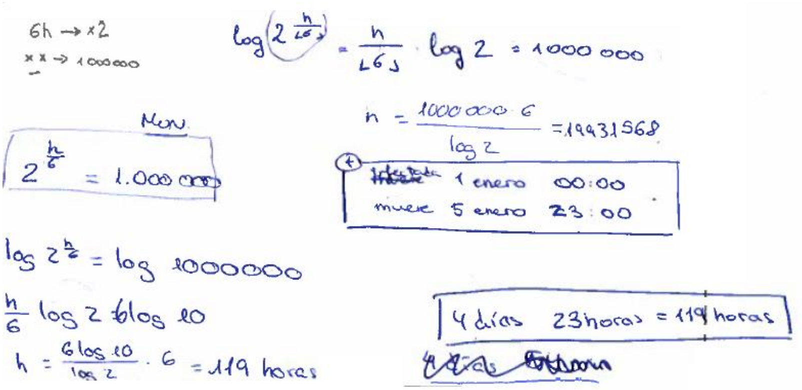

Fig. 1. Approach and resolution of logarithmic equations

Despite being part of a multitude of tasks that pupils of this age have to solve at school, algebraic expressions are not tackled with the rigour they require. Moreover, a great number of difficulties are detected in their interpretation; for example, some pupils incorporate the same number of bacteria in each step of growth and add them to the previous ones, instead of doubling the number of bacteria in each step of growth, e.g., 2x+h instead of 2^h (Figure 2).

Fig. 2. Some proposed algebraic expressions

The greatest difficulties arose when dealing with the notion of limits and, above all, in the graphical representation and interpretation of the results reached in each of the questions posed. Regarding the graphical representation, the students had the opportunity to use the educational software GeoGebra. However, they decided to use paper and pencil instead (Figure 3).

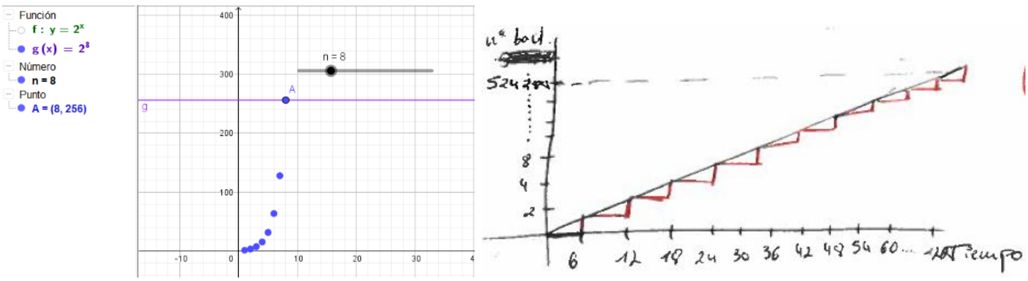

Fig. 3. Expected graphical representation and example of function proposed by a student

The students barely alluded to the concepts associated with Science (Biology), even though they were implied in the context of the problem. They only used the word bacteria to determine the units of the numerical quantities.

4. Conclusions

After carrying out this case study, we can affirm that the students involved in the task were not able to apply what they learn in the classroom to a specific situation that demands reasoning instead of a previously established procedure. This happened regardless of the growing attention of the Spanish curriculum [4] to the development of different scientific practices associated with Science and Mathematics.

Although this proposal was not intended to assess specific knowledge of Mathematics and Science, we were able to observe some obstacles in the integration of these subjects. Among these obstacles, we highlight those related to the graphic representation and interpretation of the results achieved, and the absence of the specific vocabulary of Science that provided context to the problem. Moreover, despite the suggestion to use GeoGebra, the students declined this option and preferred to carry out traditional graphical representations.

Acknowledgements

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The Effect of a Number of SEC Subjects on A-Level Physics in Malta

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Abstract

This study investigates the progression from Secondary Education Certificate (SEC) to Advanced (A) level Physics, and inherent problems for students and teachers in Malta. The four research questions dealt with: (a) the changes in the SEC Physics syllabus in 2012; (b) SEC Physics as foundation for A-level Physics; (c) the sufficiency of skills and knowledge from SEC Mathematics for A-level Physics; and (d) correlation between SEC Physics, Mathematics and English Language and A-level Physics. A mixed methods approach was used: 165 questionnaires from second year A-level Physics students, 16 questionnaires and five interviews with A-level Physics teachers, four interviews with SEC Physics teachers and a focus group with second year A-level Physics students. Teachers considered the 2012 SEC syllabus – following the changes – as an insufficient foundation for A-level Physics, increasing the gap between the two levels. They considered a good grade in and understanding of SEC Mathematics desirable for A-level Physics. Students considered SEC Physics as a good foundation for A-level, and regarded Intermediate Mathematics as the threshold for A-level Physics. Respondents acknowledged the importance of English language skills in understanding A-level Physics questions. The correlation coefficients for SEC Physics, Mathematics and English Language with A-level Physics were 0.54, 0.45 and 0.41 respectively.

Keywords: SEC Physics, SEC Mathematics, SEC English, A-level Physics, correlation

1. Introduction

1.1 Aim of the Research Study

The research study was aimed to elicit the effect of SEC Physics, SEC Mathematics and SEC English Language on A-level Physics in Malta. It involved analysis and investigation of: (i) the changes in the 2012 SEC Physics syllabus; (ii) SEC level Physics as background for A-level Physics; and (iii) SEC Mathematics as preparation for A-level Physics. Finally, the correlations between SEC Physics, Mathematics and English Language and A-level Physics were considered.

1.2 SEC Physics as a preparation for A-level Physics

One expects that SEC and A-level Physics are strongly correlated because they are the same subject at different levels. But, “it seems that students’ experience of the SEC level Physics syllabus may be giving the impression that Physics is an easy subject but when they come to Advanced-level studies they find that Physics is much more challenging than expected. … Teachers and students felt that there is a considerable gap between SEC level and Advanced level in all the major areas of Physics, including practical work, mathematical skills, and the content itself." [4, p. 18] Repercussions can be noticed, especially in terms of student numbers for A-level Physics [7], [8].

1.3 Is SEC Mathematics Relevant to A-level Physics?

Physics is the most quantitative science subject, depending heavily on "many mathematical skills to prove and quantify the different physical laws and principles." [1, p. 682] Moreover, "a good grade in GCSE mathematics is often required if students wish to take A-level Physics." [6, p. 757]

1.4 The Role of English Language in Physics Examinations

Language is crucial for student learning, particularly regarding concepts of Physics. [3] According to the literature, students' proficiency in English and Maltese influences abilities and performance in science examinations. [5] Reading ability is extremely important for student achievement in Physics [9] and there is "a significant positive relationship between English and Physics achievement." [2, p. 199]

2. Methodology

A mixed research methodology with triangulation was used: 165 questionnaires distributed to Sixth Form second year A-level Physics students and 16 questionnaires to Sixth Form Physics teachers; nine face-to-face interviews, five of which with A-level teachers and four with SEC Physics teachers and one focus group with Sixth Form second year students to obtain in-depth opinions from participants going through the 'experience'. The 2017 A-level Physics and 2015 SEC Physics, Mathematics and English Language grades were obtained to compute relevant correlation coefficients.

The five themes of the study emerged.

3. Analysis of Results

3.1 The Changes in the 2012 SEC Physics Syllabus

The changes in the 2012 SEC Physics syllabus included: (i) new themes and grouping of topics; (ii) a new section 'Historical and Science, Technology, Society Connections'; (iii) new learning outcomes, with the removal of some others; (iv) increased weighting (from 15% to 20%) for 'Design and Planning of Experiments' in the written part of the examination; and (v) presentation of 15 experiments or 13 experiments and an investigation for school-based assessment. Moreover, regarding the latter, students were expected to present two experiments from each theme instead of any fifteen.

The study revealed that 68.8% of Sixth Form teachers considered the changes in the SEC Physics syllabus as 'not so helpful' to them and 62.5% considering the changes as 'not so helpful' to students either. Regarding changes in the extent and mode of student preparation for A-level Physics before and after the 2012 syllabus changes, 56.3% of A-level teachers considered students as prepared at 'the same' level while 43.7% deemed them 'less prepared'. Notwithstanding this percentage difference, during interviews, the majority of teachers declared that following the 2012 changes, the SEC Physics syllabus lacked the necessary detail to help students in higher order thinking, increasing the gap between SEC and A-level syllabi. One notes that 63.0% of the students and 81.3% of the teachers concurred that the transition from secondary to post-secondary level was challenging.

3.2 Is SEC Physics a Good Foundation for A-level Physics?

The majority of students (55.8%) believed that SEC Physics is a good foundation for A-level since they considered the two levels as only slightly different. Half the teachers (50%) considered SEC Physics as 'not so good' a foundation for A-level and claimed that some topics could be delivered better. Students, at 63.6%, and teachers, at 81.3%, considered A-level Physics as a continuation of SEC at a higher and harder level. When students were asked about their difficulties, the result was statistically significant.

Considering the six options – (i) discontinuity between SEC and A-level; (ii) understanding concepts, theories and laws; (iii) confusion in the meaning of symbols and symbolic equations; (iv) application of mathematical skills to solve physics problems; (v) language difficulties in expressing oneself; and (vi) none of the above – slightly below a third of students (29.9%) considered that their difficulties in A-level Physics concerned 'understanding physics concepts, theories and laws'. The predominant percentage of teachers (27.7%) agreed with the students by choosing the same option. A further 27.7% of the participating teachers considered that student difficulties stemmed from inabilities in 'applying mathematical skills to solve physics problems.

For 22.16% of the students, the most difficult topics at A-level were Mechanics and Fields. Furthermore, Circular Motion and Rotational Dynamics, Electrical and Gravitational Fields were considered as the most difficult sub-topics (which are not covered at SEC level).

A chi-square test between SEC and A-level Physics gave 133.24 showing a strong statistically significant relationship between the two levels. In fact, most students with grade 1 (95.7%) and grade 2 (77.4%) in SEC Physics obtained grades A, B and C in A-level Physics, and the majority of the students (57.4%) with grade 1 in SEC Physics achieved grades A and B in their A-level.

3.3 Is SEC Mathematics an Adequate Preparation for A-level Physics?

Almost all students (94.5%) and all teachers (100%) agreed that mathematical concepts were important for Physics. Out of the four options (25%, 50%, 75%, and 100%), 39.4% of the students and 50% of the teachers stated that as much as 50% of the A-level syllabus requires Mathematics. In both cases, the student responses resulted to be statistically significant with respect to gender, with the highest percentages attributed to females.

The chi-square test between SEC Mathematics and A-level Physics was 101.52 showing a strong statistically significant relationship. Moreover, 88.5% of the students with a grade 1, 71.6% with a grade 2 and 50.6% with a grade 3 in SEC Mathematics obtained grades A, B and C in their A-level examination.

However, 58.8% of the students did not feel prepared to work out A-level Physics problems with their SEC Mathematics background. While 71.5% of the students stated that they required Intermediate level Mathematics for A-level Physics, 62.5% of the teachers stated that a good grade in SEC Mathematics would suffice for A-level Physics.

However, during interviews, teachers stated that an Intermediate level in Mathematics or a very good understanding of SEC Mathematics would be a bonus because it was difficult to teach mathematical concepts too due to time constraints.

For A-level Physics students, the most difficult mathematical topics included Graphs (43.1%) and Algebra (33.3%), mostly differentiation, integration and trigonometric functions. One notes that these topics feature least in the SEC level Mathematics syllabus.

3.4 The Correlation Coefficients between SEC Physics, Mathematics and English Language and A-level Physics

All teachers agreed that English Language skills were important to study Physics.

Out of the four options – (i) understanding Physics concepts well; (ii) understanding the question properly; (iii) answering by applying knowledge into writing; and (iv) none of the above – 39.8% of the students and 36.6% of the teachers agreed that English Language skills greatly helped the students to 'understand the question properly', with the second most popular reply being to 'answer accordingly by applying knowledge into writing'.

A chi-square test between SEC English Language and A-level Physics gave 67.69, showing a high statistically significant relationship. Moreover, those students who did well in SEC English Language have also done well in their A-level Physics examination: 94.7% of students who obtained grade 1, 84.0% who achieved grade 2 and 60.2% with grade 3 in SEC English Language obtained grades A, B and C in their A-level Physics.

Comparing the three chi-square test values, the largest value (at 133.24) was for SEC and A-level Physics grades and the smallest (at 67.69) relating SEC English Language and A-level Physics. Moreover, the correlation coefficient between SEC Physics and A-level Physics was found to be 0.54, that between SEC Mathematics and A-level Physics resulted to be 0.45 while the value for SEC English Language and A-level Physics was 0.41.

4. Conclusion

Indications from this study show that A-level Physics cannot be regarded as a 'stand-alone' subject. Knowledge of the subject 'per se' does not determine students' performance in A-level Physics, as a number of other factors influence the final result.

Apart from necessarily needing a solid knowledge of concepts and laws covered at SEC level, an A-level Physics student requires the ability for higher order thinking and reasoning, mathematical skills and sufficient English Language competence for proper question comprehension and articulation of the answers.

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The Prospect of Using Automatic Programming Assistant for Providing Direct Feedback in an Online Learning Environment

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Abstract

Formal education systems worldwide were faced with the challenge of shifting from classroom to online e-learning platforms due to the COVID-19 lockdown. The shift forced teachers to spend additional time on digital content management, as well as on individual communication to gain insight into student's cognition and provide feedback. In programming classes, especially at the university level, communication is often asynchronous. Since university students learn at their own pace, they run into issues that a teacher might have anticipated, but at different times and at different rates. Because communication is asynchronous, the need for teacher's feedback disrupts student's learning pace. In this paper, the application of a knowledge-driven feedback-providing automatic-programming Artificially Intelligent Teaching Assistant (AITA) is proposed as a solution to that problem. By using cognitive maps, a teacher could manage knowledge, more precisely, the concepts, the competencies, and tasks that are a part of the programming curricula. Similarly, AITA could manage metaknowledge about student's knowledge of concepts and competencies and would provide specific, direct feedback to students as the result in form of automatically generated programming code. Feedback would range from styling suggestions to fixes. This way, teachers would benefit from time savings, while students would benefit from adaptive learning mechanisms provided by AITA. This paper describes AITA's system architecture and presents the results of pilot testing as an answer to the challenge of shifting from classroom to online e-learning platforms due to the COVID-19 lockdown. This contribution is suitable for an international audience and the abstract content is consistent with the NPSE 2021 Conference guidelines.

Keywords: programming, COVID-19, STEM education, knowledge management, adaptive learning, automatic programming

1. Introduction

During March and the first days of April 2020, countries worldwide implemented the lockdown measures due to COVID-19 pandemic which caused schools and universities to close their classrooms and shift to online e-learning environments as alternatives to traditional classroom environment. As the result, teachers were faced with a time-consuming task of content creation and management because of the shortage of e-resources closely related to the curriculum and/or produced in the official language used in formal education. Even for programming courses, which benefit from the availability of great number of e-resources, teachers at Faculty of Science (FoS), University of Split, Croatia, had to spend significant amounts of time on content management alone. The idea of developing an automatic code generation system was born, driven by the need to generate programming code based on programming knowledge. By using such a system to generate content and serve it in a way that facilitates adaptive learning, teachers would gain time to focus on knowledge and learning management. While system's time-saving properties could potentially benefit teachers, it is its adaptive nature that is the most important feature because it would allow for automatic real-time content generation that would serve as a feedback provider and responder to learner's individual needs. Thus, content would be generated on-demand and as needed, individualizing learner's learning path in the process, while allowing teachers to manage, reuse and share their knowledge.

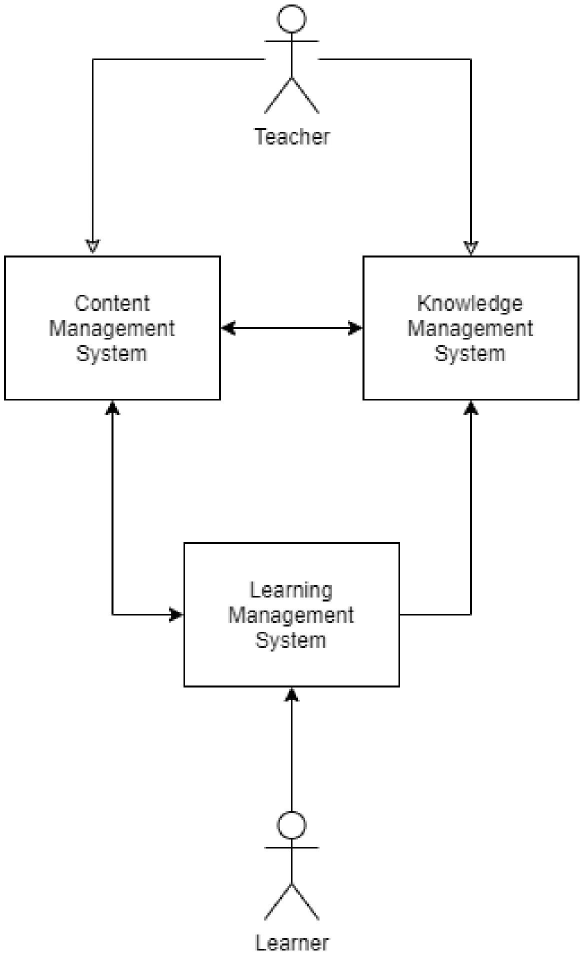

Fig. 1. System architecture of the LORE (Learner Oriented Roleplaying Environment)

LORE is the idea of a system that would be adaptive in nature (Learner Oriented), considering different roles learners take during the learning process (Roleplaying) based on their personality types and other individual parameters that affect their learning habits.

LORE system would consist of three interoperable parts:

- Content Management System – a system accessed by a teacher for managing the curricular content,

- Knowledge Management System – a system accessed by a teacher for managing the programming knowledge presented in a form of a concept map,
- Learning Management System – a system with ability to manage learner's learning path based on programming knowledge, available content and learner's profile.

Even prior to the COVID-19 lockdown, there was a need to include the characteristics of learner into learning scheme generation process, which mostly remained a manual process resulting in static and inflexible e-learning systems [1]. As a response, efforts have been made to generate individualized learning paths based on individual characteristics of the learner [1], such as personality type or learning styles, but also based on misconceptions assumed a learner to be forming [2].

The base activity of any adaptive e-learning system is the learning path generation. According to (Bhaskar, Manju, *et al*., 2010), a learning path is defined as following:

Learning path defines the sequence of learning activities that is carried out by the learner going through learning units in e-learning system. Learning unit is an abstract representation of a course, a lesson, a workshop, or any other formal or in-formal learning or teaching event.

Using the system for automatic code generation with adaptive learning mechanism, we set out to find the answer to the following two questions:

- Is feedback on average more frequently requested by certain Myer-Briggs personality types?
- Are certain programming misconceptions on average made mode frequently by certain Myer-Briggs personality types?

In the proposed system, the content would be partially automatically generated in the form of programming code, while the rest of the content would be prepared by a teacher but served to learners based on their individual needs. This part of the system is an automatic code generator that acts as an Artificially Intelligent Teaching Assistant (AITA).

As part of the knowledge management, a teacher would have to manage concepts and competencies covered by the curricular content by connecting them to form a knowledge map, while mapping them to each atomic piece of curricular content. This way, adaptive learning mechanism could map the learner's achievements to the knowledge map and serve appropriate content based on its metaknowledge of student.

In that way, the system would help manage the learning, yielding helpful analytical data in the process which a teacher could use to start the conversation with individuals about misconceptions they formed.

2. Problematization

During the COVID-19 lockdown, three major issues related to content, teacher and learner have been experienced, and they are the following:

- Content production and management is time-consuming,
- Misconceptions are harder to perceive in an online e-learning environment,
- The lack of face-to-face interaction with the instructor, longer response time due to different times and rates at which learner's access the content, absence of traditional classroom socialization [3].

Based on the observations made during the past two semesters at FoS that were affected by the pandemic, we assume that learner's personality type affects the way they interact with teacher and the content. While extroverts are more open to requesting feedback, which would be granted to everyone in a classroom environment, that feedback was requested and granted on the individual level in the online environment instead, affecting the amount of knowledge introverted students would usually gain without any interaction. Besides that, intuitive learners and feelers were more inclined to forming misconceptions. Both assumptions should be tested and verified in a controlled environment.

Based on intuition, we formed an assumption that, even though learner's personality type might play a significant role in the forming of misconceptions, their lack of precognition might be more influential than their personality type is.

Future studies should include learner's personality types [1, 4], along with cognitive load theory and constructivist theory [5], in order to form a framework for generating individualized learning paths, before a learner accesses the learning unit, but also after their work was assessed. We will set out to find the effects of misconceptions on programming learning path for different types of learners.

The motivation for this type of research lies in the fact that FoS is involved in the programming education of many different groups of students, including Chemistry Engineering, Chemistry, Physics, Mathematics, Computer Science and Polytechnics students, each with a different precognition level, motivations, personality types and learning styles.

3. Conclusion

COVID-19 pandemic significantly impacted formal education systems worldwide, forcing the members of those systems to undergo a lockdown, thus learning and teaching in isolation. This resulted in time consuming efforts to manage e-content, indirect communication, additional efforts to manage learning otherwise done effortlessly within a classroom, making online e-learning environment a fertile ground for misconceptions to be formed. Further studies are necessary to find out how cognitive load of an individual is being impacted in an online learning environment, based on learner's personality type, precognitions, motivation and various other personal factors that might prove to be significant. For this purpose, a system architecture of the system named LORE is proposed. With it, we plan on introducing adaptive learning mechanisms for individualized content serving, with goals of decreasing both teacher's and student's load.

Reducing the load is of major importance since it demotivates both teachers and students from using e-learning systems frequently. Since the pandemic began, the time spent on content and learning management outside the classroom has increased for us at FoS from 2 hours per week for a single course to 1 hour per student per week for the same course. Luckily, it was manageable because we only had 20 students enrolled in the course, but we assume that teachers with much higher loads (higher number of enrolled students and/or number of courses) had even less free time for content and learning management done in a satisfactory way.

Thus, the goal of this paper is to report our experiences using e-learning systems during the COVID-19 lockdown, which is still taking place, to shed light on the major problems within those systems and set the stage for future research based on those observations.

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Training of Science Teachers

Can Teaching on Ticks Increase Learning about Body and Health?

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Abstract

An important part of the biology subject matter in school is the biological processes in the human body and health. In the Swedish curriculum these are present in all years of the compulsory school. Anyhow, students do not have an overall understanding of health and bodily functions. The misunderstandings of the nutritional processes of the human body have been reported by several authors. We have been teaching physiology to preservice teacher and biology students for several years trying to reach a better understanding of processes in the human body. The present study shows teaching of health and body starting with a discussion about ticks and the various diseases they spread in the Stockholm area. Nine preservice teacher students participated in four weeks of biology studies, including ecological processes and organisms' life cycles. The last week was devoted to body and health. The idea was to begin with the circulatory system as students often focus on the various functions of the organ but forget to link it to the blood system. By connecting to the students' previous knowledge of organisms and ecosystems to body and health, we started with an introduction of tics by going out collecting and investigating their morphology and life cycle and continued with a video clip showing how the virus and bacteria are spread through the blood. The following lessons contained function of body systems, nutrition and the immune system. After this the students wrote reflections from three different lessons about their learning and what was surprising. They also wrote a lesson plan for teaching body and health in primary school (year 4-6). At the end of the course, the students had an examination in three parts where one was concentrated on body and health. Results from the reflections and the written exam showed that the students understood the interaction between the different parts of the body better and the importance of the circulatory system, but also between different organisms and how they may affect each other. The inclusion of ticks in the course increased the understanding.

Keywords: Biology teaching, body function, circulatory system

1. Introduction

One part of the biology subject matter in school is the biological processes in the human body and health such as the circulatory system, digestion, respiratory system, how to cure diseases, infection and the importance of nutrients and sleep for the future life. In the Swedish curriculum for compulsory school, one of the overall goals is that "each pupil should have obtained knowledge about and an understanding of the importance of the individual's own lifestyle and its impact on health […]". This is achieved by learning about the importance of sleep, social relations, exercise and food as well as the name and functions of the parts of the human body in primary school. At the end of the compulsory school the knowledge is focused on how mental and physical health are affected and the mechanisms of cells, organs and organ systems and their interactions [1]. Despite learning about health and how the body works throughout all school years, students do not have overall understanding of health and bodily function and what causes diseases. Several reports have shown students misunderstanding of digestion [2, 3], blood circulation [4] and the purpose and function of gas exchange in lungs [4, 5].

We have also experienced that students try to recall the name of the organs but do not know how they interact with each other. When discussing digestion, the knowledge often stops after the uptake of nutrients in the intestine.

Therefore, we have been interested to develop biology courses for preservice teachers and biology students with a holistic view of organs and their function in the studies of health and bodily functions [6]. In order to further improve the understanding of the interactions between different organ systems and their function from a macroscopic view down to microscopic view at the cellular level and illness the course started with a discussion about ticks which may transfer pathogenic bacteria and virus to humans.

2. Course description

Nine preservice teacher students completed a four weeks course of biology containing ecological processes, different organism life cycles and, at the end, health and physiology. The teaching was arranged by inquires and discussions in groups supervised by the teacher. To link bodily function and health to organisms and their life cycles previous taught, the students were capturing ticks and studied their morphology and discussed their life cycle. The students were also supposed to answer questions about two illnesses ticks may cause; Borrelia and Tick-borne encephalitis (TBE). The teaching continued with questions and discussions about antibiotic, bacteria, virus, vaccine and the defence system. To visualize the action by ticks, the teacher showed a short video clip showing how ticks infect a human with bacteria that enter the blood and the circulatory system spreading the bacteria through the whole body. This gave the introduction to questions about the functioning of the blood and circulatory systems and later digestion, lung and respiratory system and the extraction of energy from nutrients.

After the sessions of health and bodily function, students wrote reflections on the lessons answering questions about what they learned and what surprised them. The task was also to write a lesson plan for body and health in primary school (year 4-6). In the lesson plan they should include an area of the subject, how they would perform the teaching and why they chose the subject to teach. The course finished with a written examination including all parts of the course, where one part was concentrated on body and health.

3. Methods

The reflections were analysed by qualitative methods identifying and describing the learning processes and which themes the students regarded as important.

4. Results

The qualitative analysis showed that 2/3 of the students were describing the cooperation between the different organs and how they are connected to each other as an important issue. Some students mentioned that it is more important to have a holistic view than to know the name of the individual organs. Most of them also discussed the important of the circulatory and respiratory systems. What was very obvious is that starting to discuss how Borrelia and TBE are spread in the body gave the knowledge about the blood circulation and how it affects the whole body – in all of the cells. The students where correctly referring to the different processes in the body showing a holistic view (Table 1).

The part in the written examination about body and health consisted of three questions:

1) Describe and explain how blood circulation interacts with the lungs during gas exchange. Why is breathing important for body functions?
2) Describe what a vaccine is and explain how it can prevent diseases. Why is vaccine used against virus more often than against bacteria?
3) Describe the digestion overall and explain why it is important to eat.

Five students answered with elaborate explanations of all questions and received the highest mark. Only two students out of nine did not pass. This was a better result than last year when six out of 15 students failed. The better result from the examination could be due to many factors and it is difficult to draw any strong conclusions, but it may be an indication of a better teaching strategy. More studies have to be done to compare different teaching strategies.

Health	**Organ system**	**Cell function**
It is important to have the knowledge about illness and how to keep us healthy.	I learned that the gut melts the food with the help of enzymes and that it is when it has become small enough that it can be absorbed through the intestinal wall, that it really is in the body.	To see similarities and differences between an animal cell and a plant cell.
When I was studying ticks and how they infect, for the first time I understood the difference between virus and bacteria.	I learned the importance of seeing the whole as I talk about and study the various functions of the body. Without the whole I have a hard time understanding and remembering because there are many parts to remember, if you focus on the whole and learn the connection, this can act as a tool for understanding.	All life on earth is reminiscent of one another. Plants and animals have cells, although they differ slightly. All life on earth needs energy, our primary source of energy is the sun. Everything living on earth belongs together and shares energy and nutrition.
I learned that ticks as vectors for Borrelia and TBE are not only bad but necessary for the ecosystem.	I think it is important to emphasize how important the role of the lung is to the blood and that all the organs of the body work together.	I got a deeper explanation of photosynthesis which I had no previous knowledge of.

Table 1. Examples of students' reflections on what they learned

5. Discussion

It is important for the teacher to create learning situations which start from the students' own experiences in order to improve knowledge in science. The student should not only understand and talk about the world but also experience and connect to their own everyday life [7]. In this study, learning about health and body function started with discussion about ticks and the various diseases they spread in the Stockholm area. It is important that after being in the field, to check for ticks on the bodies of the participants.

The chance to get infected of TBE has increased in the area and health authorities encourages people to vaccinate. The approach was to teach the section on health, diseases and bodily functions through students' own experience of ticks linked to previous studies of ecological systems and life cycles for different organisms. By doing this, the students gained a context where they could continue to investigate the functions of the body organs and how they work together as well to understand the role of oxygen in energy recovery.

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Lesson Study as a Vehicle to Foster Teacher Agency: A Systematic Literature Review

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Abstract

The evidence in support of Lesson Study (LS) as a powerful approach to Teacher Professional learning and Development (PD) continues to grow at a rapid rate. However, despite its widespread use, especially in the area of STEM subjects, researchers have expressed concern that the means by which LS fosters teacher's achievement of agency remain under-theorised. With this in mind, this systematic review of literature sought to uncover the mechanisms by which LS may support teachers to become agentic in the context of STEM education. A total of 32 studies are included, drawing from a range of jurisdictions, contexts and subject areas including science, mathematics and STEM. Drawing from an ecological conceptualisation of agency, thematic analysis is conducted on the included studies, leading to the identification of two major themes: Agency enabling factors and agency constraining factors. These themes enable the development of an emergent theoretical framework for LS and teacher agency. Gaps in literature are also identified, most notably, the dearth of literature in relation to agency and LS. In order to ameliorate such gaps, recommendations for further research include the suggested use of the emergent theoretical framework by those engaging in LS as practitioners and facilitators.

Keywords: Teacher Professional Learning, Teacher agency, STEM Education, Lesson Study

1. Introduction

Lesson Study (LS) is a form of school-based professional development, involving an action cycle whereby a group of teachers collaboratively plan, teach, observe and reflect on a research lesson with a group of pupils [1]. Despite evidence in support of LS as a powerful approach to teacher professional learning in multiple and varied contexts, the mechanisms by which LS foster teacher agency remain under-explored [2]. With this is in mind, this paper presents findings from a systematic review of literature which sought to explore how LS contributes to teachers' achievement of agency. This review drew from an ecological conceptualisation of teacher agency [3] to examine empirical studies across multiple contexts, in terms of how Lesson Study enhances teacher agency in STEM primary education.

2. Conceptual frameworks

2.1 Teacher Agency

Teacher agency describes the capacity to act with competence, purpose, autonomy and reflexivity in order to bring about positive change within teachers' own practice.

According to an ecological model [3], teacher agency is temporal i.e., constructed based on past knowledge, beliefs and experiences (iterational), enacted in the present (practical-evaluative) and oriented towards the future (projective). Factors which can constrain agency include negative teacher efficacy beliefs, lack of availability of resources (e.g., materials, time) and overly bureaucratic leadership structures [3] while enabling factors include school cultures featuring strong horizontal relationships between colleagues, collegiality and sharing of practice [4]. Such cultures also promote teacher autonomy and professional judgement more broadly than overemphasising accountability and further support teachers' achievement of agency [3, 4].

2.2 Lesson Study

The Japanese LS model is a form of school-based collaborative PD [1]. The process is facilitated by an external expert, or Knowledgeable Other (KO) [5]. The role of the KO is similar to that of a coach, whereby they challenge thinking, offer support and guide the group of teachers through the LS cycle. A study of the translation of LS beyond Japan examined the fidelity of various LS interventions in different jurisdictions [6]. This study identified seven critical components which are required in order for a LS intervention to be successful in enhancing teachers' learning:

1. The identification of a broad goal for pupil learning.
2. Teacher planning in collaborative groups drawing on relevant research and resources to create a research lesson.
3. A research lesson taught by one group member and observed by the others.
4. A post-lesson discussion using conversation protocols.
5. Repeated cycles of research using the findings from the post-lesson discussion.
6. The support of an outside expert throughout the process.
7. Opportunities for sharing new knowledge outside the LS group, for example, with other colleagues in their own or in other schools.

For the purpose of this review, these seven critical components of LS are adopted as a conceptual framework in order to examine existing literature on LS.

3. Methodological Approach

Given the focus of the review on teacher agency, a pragmatic epistemological orientation, which sought to ensure that the voices, views and lived experiences of teachers were represented in the selected papers, was adopted. A search protocol was initially devised with terms related to three strands pertaining to LS: "Lesson study" and "agency"; "Lesson study" and "primary" or "elementary" and "Lesson study" and "mathematics" or "science" or "STEM". Further limits were set to refine the search on studies focusing on practicing teachers rather than preservice teachers and academic articles with full text accessible and in English. Limits were also set to include studies from 2000 onwards to focus on the most up-to-date LS research [7]. The search protocol terms were used to create search strings for each area of focus and were then input to the electronic databases of Scopus, Education Source and Web of Science. Manual searches were also conducted in relevant conference proceedings to further ensure that the most current studies had been included. Reference lists from prior reviews were also checked in order to identify older seminal studies [8]. The final stage of study search included the removing of duplicates and screening of the abstracts of the remaining studies to retain only those relevant to the research question.

As the review sought to include studies from qualitative and quantitative domains, a quantitative [9] and a qualitative [10] critical appraisal checklist were adapted and applied to returned studies to methodically examine and assess the validity and relevance of the selected studies' findings. Data on the context, research design and findings, as we all as direct quotes from teachers involved were extracted from those studies (N=32) that scored high in the critical appraisal checklist. The main reasons for exclusion of studies were that they were theoretical in nature, provided insufficient detail regarding the nature of the activities conducted during the LS or were not focusing on teachers' perspective.

The extracted data was thematically analysed [11] by deductive and inductive coding of instances where agency was constrained or enabled, as reported by participants.

4. Findings and discussion

A thematic analysis of data was arranged under agency enablers and agency constrainers categories that served as an emergent theoretical framework to explain how LS can contribute to teacher agency. While the research question sought to identify instances of agency enablement in the separate contexts of STEM and the primary setting, the findings from the review showed that the contributing to agency factors were not subject specific, but rather common across multiple contexts in both primary and STEM education.

Agency enablers which were identified during LS activities were categorised as pedagogical content knowledge (PCK), professional community membership and collaborative expertise. PCK describes the unique knowledge of curriculum, pupils and pedagogical strategies which are required for effective teaching. For example, findings from one study noted that "going through complete Lesson Study cycles results in teachers realising and internalising new PCK and beliefs" [12, p. 228]. Professional community membership describes the way in which LS helps to create a sociocultural learning space for teachers, where they learn through engaging in critical reflective dialogue. An example of this was evident in findings in another study [13, p. 241], where "insulation and isolation" experienced by teachers was ameliorated through engaging with other teachers and KOs in LS. The learning in LS was also attributed to "the constant collegial collaborative interactions between participants and KOs" [14, p. 813], which suggests such interactions foster agency under the category of collaborative expertise.

Agency constrainers which were identified during LS activities included lack of resources and a culture of performativity. The lack of resources was related to "the conditions under which lesson study was conducted, and the lack of educational and school organizational systems set up to support their [teacher participants] efforts" [15, p. 277]. This was articulated by a teacher participant in another study who stated "[f]or this model to be successful, you can't just have a few teachers who are like 'Yeah, great, let's do it'. It has to be supported, by the school leadership and by the system" [16, p. 509]. In relation to an overemphasis on performativity, the purpose of facilitating engagement in LS in some studies appeared to be to further a performative agenda, rather than on the long-term goal of developing teachers' professional practice to support student learning outcomes. It was stated for example that "[t]eachers were concerned that it should not be a 'quick fix', booster programme targeted cynically at teachers in the year before national testing, but a genuine opportunity for professional learning" [17, p. 210]. Similar concerns were expressed in another study [18], which noted participants' association of observation of practice with performance management review, rather than as an approach to deepening teacher learning, as is the case in LS. In the same study it was evident that the attempt was to quantify the impact of LS on short-term gains in student attainment.

A limitation deriving from the agency enabling and constraining factors as described above is that they are broad in nature, and may not be applicable to LS in every context.

However, the emergent framework serves in establishing a theoretical connection between agency and LS, which did not previously exist.

5. Implications for practice, policy and future research

The study findings highlight that, despite the scholarly attention LS is receiving, there is a need for further empirical research to examine how LS may contribute to, or indeed constrain, teacher agency in specific contexts, like STEM and/or primary education settings, where such research is lacking.

The systematic analysis of LS literature also enabled the development of an emergent theoretical framework which seeks to make explicit how LS can contribute to teachers' achievement of agency. Due to its theoretical nature, the emergent framework would merit from further application in the field by teacher practitioners, for example, using it to support critical professional reflection on how LS may, or may not, support their achievement of agency. The framework may also be useful for LS facilitators who wish to foster teacher agency as part of their practice and policy makers who may find the framework useful in guiding LS as a PD approach in curricular reforming.

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The Affective Dimension Implied in Mathematical Problem Solving by Future Primary Education Teachers

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Abstract

Mathematical Problem Solving (MPS) is one of the fundamental competencies to be developed by pre-service primary education teachers. As such, some researchers have shown that the emotions perceived towards MPS can condition the methodologies used by graduates in primary teaching and, therefore, learning of their future students. Therefore, we must understand the affective dimension involved in MPS by preservice teachers. To this end, this work presents a descriptive quantitative analysis based on a validated questionnaire, which was administered in the third year of the Degree in Primary Education of a Spanish public university. The instrument consists of 21 items that must be assessed on a scale of 1 (strongly disagree) to 4 (strongly agree); these statements are encompassed in four domains: nature of mathematical problems, perceived self-efficacy in MPS, attitudes and emotional reactions towards MPS and evaluation of previous training received in the Degree in Primary Education. A statistical analysis was performed, combined with hypothesis testing, to know the influence of variables such as gender or previous background of the participants. Our results show positive attitudes towards MPS (e.g., perseverance or patience), ambivalent emotions (e.g., satisfaction and curiosity, but also fear and nervousness), medium self-efficacy and a mechanical and algorithmic vision of MPS. These results should support the proposals implemented around MPS in the initial training of teachers.

Keywords: Mathematical Problem Solving, Emotions, Attitudes, Preservice Teacher Training, Primary Education

1. Introduction

Since the end of the last century, educational research has highlighted the influence of the affective domain (beliefs, attitudes, emotions, etc.) on the personal and social construction of knowledge [1]. In addition, it has shown that anticipated emotions (either stimulating or depressing) regarding learning activities and proposals can condition achievement [2]. Therefore, science and mathematics education should not ignore this two-way interaction between emotion and cognition [3].

Moreover, teaching methodologies act as variable mediators in the relationship between emotion and cognition. Among them, problem-based learning has demonstrated multiple educational benefits in promoting scientific and mathematical competencies, together with a better conceptual understanding [4, 5]. However, transferring this methodology to classrooms can be challenging. In the particular case of pre-service Primary Education teachers, research on the subject has revealed fundamentally negative emotions of these individuals towards Mathematical Problem

Solving (MPS) [6]. Among them, nervousness, anxiety or frustration predominate [7], which could inhibit them from applying this approach in the classroom.

Therefore, this work proposes an analysis of the affective domain of future Primary Education teachers towards MPS before starting a subject, “Mathematics and its Didactics III”, which puts the focus on these issues. In this way, this study will serve as a starting point for the design and implementation of an effective training proposal around MPS in the Degree in Primary Education.

2. Method

The research follows a descriptive and inferential statistical approach.

2.1 Objectives

Three main objectives are set on the affective dimension of pre-service Primary Education teachers regarding MPS:

1. Characterize their epistemological and educational beliefs, attitudes, emotions, self-efficacy and satisfaction with the training previously received in the Degree.
2. Analyze differences, depending on gender, in perception about MPS.
3. Analyze differences, depending on previous training, in perception about MPS.

2.2 Sample

The sample consists of 62 participants with an average age of 23.1 who take the subject “Mathematics and its Didactics III”, which is framed in the 3rd year of the Degree in Primary Education of a Spanish public university. There are 27 women (43.5%) and 35 men (56.5%); 40 (64.5%) have accessed the Degree directly from the Baccalaureate – post-compulsory secondary education – and 22 (35.5%) have done so through other paths, such as Vocational Education and Training. Among the first, 11 individuals completed a Baccalaureate on Science, while 29 opted for a non-scientific one (Humanities or Social Sciences).

2.3 Instrument

This study relies on a validated questionnaire [7] consisting of 21 items that must be assessed on a Likert scale from 1 (strongly disagree) to 4 (strongly agree). The statements fall into four dimensions with regard to MPS: epistemology (A), self-efficacy (B), attitudes and emotions (C), and evaluation of previous university training (D). These items can be found in Tables 1-2.

2.4 Data analysis

A descriptive statistical analysis through frequencies, means and standard deviations is carried out. In addition, Mann-Whitney’s *U* non-parametric test for independent samples is used in order to answer objectives two and three. The null hypothesis (H0) is set as: “perception towards MPS is not conditioned by the gender/prior training variable”.

A confidence interval of 95% ($p<.05$) is selected to rebut it.

Regarding the third objective, in this study we only compare the individuals who completed a Baccalaureate on Science (n=11) with those who did it about Humanities or Social Sciences (n=29).

3. Results

3.1 Objective 1

Tables 1 and 2 show the percentages of agreement (answers 3-4) and disagreement (1-2) with the questionnaire items, as well as the average values and standard deviations. The least dispersion corresponds to the perception of applicability of mathematical strategies (item 4), procedures that demand perseverance (items 19 and 20) and are favoured by group interaction (item 15). However, future Primary Education teachers conceive MPS as a mechanical and repetitive process (item 3), which leaves no room for luck (item 11).

On the other hand, the greatest dispersion occurs in questions related to self-efficacy (e.g., item 8) and those related to emotions such as calm (item 9) or frustration (item 17).

Table 1. Statistical results regarding dimensions A and B about Mathematical Problem Solving (MPS)

A. Beliefs about the nature of mathematical problems and their teaching	**Ag %**	**Di %**	**Mean**	**SD**
1. Almost all math problems can be solved in a few minutes if you know the formula, rule or procedure that the teacher has explained or that appears in the textbook.	74.2	25.8	2.87	0.61
2. When solving a math problem, the final result is more important than the procedure previously followed.	17.7	82.3	1.95	0.77
3. Knowing how to solve the problems posed by the teacher in class, it is easy to solve others of the same type where some changes have been applied regarding data.	93.5	6.5	3.32	0.59
4. The skills or strategies used in math classes regarding problem-solving have nothing to do with those used to solve problems in everyday life.	14.5	85.5	2.03	0.57
5. I try different ways and methods to solve a problem.	82.3	17.7	2.98	0.63
B. Beliefs about oneself as a solver of math problems				
6. When more study time is spent on maths, better results are obtained in problem solving.	85.5	14.5	3.24	0.69
7. When I solve a problem, I usually doubt whether the result is correct.	79.0	21.0	3.00	0.74
8. I have confidence in myself when I face math problems.	48.4	51.6	2.34	0.80
9. I am calmed and relaxed when I solve math problems.	48.4	51.6	2.39	0.75
10. When I work hard to solve problems, I usually find the right result.	77.4	22.6	2.92	0.60
11. Luck influences successful resolution of math problems.	8.1	91.9	1.85	0.53

Table 2. Statistical results regarding dimensions C and D about Mathematical Problem Solving (MPS)

C. Attitudes and emotional reactions towards mathematical problem solving	**Ag %**	**Di %**	**Mean**	**SD**
12. When I face a difficult problem, I usually give up easily.	38.7	61.3	2.26	0.72
13. When I face a problem, I experience a lot of curiosity about knowing the solution.	72.6	27.4	2.85	0.71
14. I feel anguish and afraid when the teacher asks me “by surprise” to solve a problem.	66.1	33.9	2.69	0.64
15. When I solve problems in a group, I have more confidence in myself.	88.7	11.3	3.13	0.58
16. When I get stuck or blocked in solving a problem, I start to feel insecure, desperate, nervous	80.6	19.4	3.08	0.68
17. If I can’t find a solution to a problem, I feel like I’ve failed and wasted my time.	56.5	43.5	2.63	0.70
18. It gives me great satisfaction to successfully solve a mathematical problem.	98.4	1.6	3.55	0.53
19. When my attempts to solve a problem fail, I try again.	85.5	14.5	3.05	0.58
20. Solving a problem requires effort, perseverance, and patience.	100.0	0.0	3.37	0.48
D. Evaluation of previous training received in the Degree in Primary Education regarding mathematical problem solving	**Ag %**	**Say %**	**Mean**	**Sd**
21. In the Degree in Primary Education, I have discovered other ways to address math problems.	56.5	43.5	2.53	0.67

3.2 Objective 2

The gender-disaggregated analysis reveals significant differences in four of the statements. Men feel more confidence (item 8, U=308.5, p<.05) and less fear (item 14, U=321.5, p<.05) towards MPS. In turn, women value to a greater extent perseverance (item 20, U=349.0, p<.05) and study time (item 6, U=342.0, p<.05) than their male peers.

3.3 Objective 3

The application of the Mann-Whitney test does not reveal significant differences depending on the previous training of the participants, a fact that may be affected by the size of the subsamples (n=11 for the Baccalaureate on Science and n=29 for the Baccalaureate on Humanities or Social Sciences). Nevertheless, in those questions regarding emotions (items 8, 9, 16 and 17), future teachers with a scientific background refer to positive emotions towards MPS more frequently.

4. Conclusions

The analysis carried out has allowed us to obtain a good characterization of the perceptions of pre-service Primary Education teachers about MPS. As such, they show and support an algorithmic and repetitive vision of it (although different strategies may have room), a medium-low self-efficacy (which can improve with time and effort), ambivalent emotions towards these activities (e.g., satisfaction and curiosity, but also fear, nervousness or frustration) and mixed opinions about the training previously received in the Degree. In the case of attitudes (importance of perseverance and study time), these are more positive in women, while men feel more confident and less afraid of MPS.

These results should support the proposals implemented around MPS in the initial training of teachers, seeking to promote a more dynamic and flexible view of mathematical problems, together with the feeling of positive emotions and attitudes towards its learning.

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Using Two-Eyed-Seeing to Integrate Science Teaching and Indigenous Practices in a Graduate Course for Teachers

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Abstract

The Calls to Action [1] from The Truth and Reconciliation Commission of Canada clearly state the need to "educate teachers on how to integrate Indigenous knowledge and teaching methods into classrooms" (p. 7, 62.ii). In an attempt to respond to this appeal, we designed and implemented a graduate level course focused on K-12 science and Indigenous practices, which introduced students to respectful and authentic ways to integrate the teaching of Western Modern Science concepts and Indigenous Science and practices. In the context of the restrictions imposed by the COVID-19 pandemic, the course was delivered online and asynchronously, with a strong hands-on experiential component through curated home-based experiences and investigations. We utilized the Two-Eyed Seeing principle [2], developed by Elder Albert Marshall of the Mi'kmaw Nation, to encourage students to rethink their approach to curriculum integration in ways that emphasize the strengths of a multiplicity of worldviews. In this paper we describe the structure and content of the course, the pedagogical approaches used, the challenges and opportunities afforded by co-teaching online, the intersectionality of our diverse ethnic backgrounds (new-Canadian Latina and settler, Anishinaabe of Eabametoong First Nation, and Canadian Jewish and settler, respectively) and discuss our perception of students' struggles and growth during the course.

Keywords: Indigenization, STEM Education, Teacher Professional Development, Reconciliation

1. Introduction and Situation of Self

1.1 Amy Farrell

In keeping with standard traditional Indigenous (First Nation, Metis, Inuit) and, specifically, Anishinaabe (Ojibwe) practices, I begin this chapter with a respectful introduction and situation of self [3, 4]. I am Anishinaabe, a member of Eabametoong First Nation in Northwestern Ontario, Canada, with maternal ancestral ties to Whitewater Lake First Nation and the Slipperjack Family. My father is of English, Irish, and Scottish descent. I grew up in Thunder Bay, Ontario – in the land of the Sleeping Giant and Anemki Wajiw (Thunderbird Mountain/Mount McKay).

My view of and place within the world, although not always easy, has always been a blend of both of these cultural worldviews and perspectives from my parents. My Indigeneity has influenced my research interests within areas of Indigenous knowledge, culture, and storytelling. Within this paper, there is a principle of Two-Eyed Seeing [2] that describes its usefulness and value within academia. However, I personally do not prescribe to this particular approach as it is a practice I have essentially had to live through and apply in my life since I was born.

1.2 Lilian Pozzer

My journey to become a science educator was paved in collaborations and interactions with a diverse group of people, starting with my undergraduate degree in Brazil, through my graduate studies at UVic and my postdoctorate at McGill University, culminating at my current position at UofM. As an international student in Canada, and later as an immigrant and new-Canadian, I had experienced the challenges and opportunities migrants encounter in their relocation to a new country. In negotiating my identity as a dual-citizen, a professor, and a single-parent for an Autistic child, I have relied on the insights and support my education network has provided me with. Learning to become Canadian involves learning the history of this country, its educational systems, values, culture, and the history of colonization and imperialism, oftentimes told through the perspective of the colonizers. To honour and value the experiences of Indigenous peoples in Canada, I must recognize my positioning as a settler in this land and my responsibility to broaden students' perspectives on science for validation and integration of Indigenous ways of knowing and learning in/as science.

1.3 Richard Hechter

I am a caucasian, Jewish, second generation Canadian, male. Having learned through the lens of Western Modern Science throughout my entire educational trajectory, I taught secondary level science for 11 years before joining the professoriate in 2009.

Stemming from facing anti-Semitic personal experiences, my work is grounded in working with teachers from different ethnic, cultural, and religious backgrounds towards developing relevant and authentic science curriculum and teaching and learning experiences that enrich science phenomena through mitigating othering and racism, while actively promoting belonging, and inclusion in our classrooms.

2. The Truth and Reconciliation Report and Indigenous Education in Canada

The history of colonialism and imperialism in Canada was marked by the residential school system, in which over 150,000 Indigenous (First Nations, Metis, and Inuit) children were forcibly removed from their families and communities and forced to attend these religious schools, from 1831 to 1996. The Truth and Reconciliation Commission (TRC) of Canada sought to examine the long-lasting effects of this system, proposing in its Calls to Action ways in which reconciliation could be achieved. The Executive Summary from the TRC [5], explained that. The residential school system failed as an education system. It was based on racist assumptions about the intellectual and cultural inferiority of [Indigenous] people – the belief that [Indigenous] children were incapable of attaining anything more than a rudimentary elementary-level or vocational education [in which] the majority of students never progressed beyond elementary school. The government or church officials who operated the residential schools...created dangerous and frightening institutions that provided little learning. (p. 144)

In the residential schools, Indigenous children were not allowed to speak their native language, nor practice any of their cultural traditions or ceremonies or spirituality. They were often victims of physical, sexual, mental, and emotional abuse. As part of reconciliation, it is imperative that schools in Canada revive Indigenous languages and culture. As the TRC's *What We Have Learned* [6] states, a part of the reconciliation process "requires...youth engagement about the history and legacy of residential schools, Treaties, and [Indigenous] rights, as well as the historical and contemporary contributions of Indigenous peoples to Canadian Society" (p. 126). Eleven of the TRC's Calls to Action [1] are focused specifically on education.

3. Structure and Content of the Course

The course was taught online for five weeks during Summer 2020. Each week featured two asynchronous classes, one focusing on Indigenous practices and another on Modern Western Science (MWS), organized by themes: The Sky, Prairie Bird and Animals, Plants and Colours, Rocks, and STEM. During the sessions on Indigenous practices, students explored Indigenous ways of knowing and being, and the production and use of different artifacts following Indigenous traditional knowledge. The classes on MWS explored K-12 science activities that intersected with the provincial science curriculum.

Before our course started, students picked up a box of materials for performing the practical activities at home. Course content and assignments were available in the course webpage. Course assignments included (a) weekly posts to our course webpage reporting on the activities performed that week, (b) a contribution to the weekly discussion forum, and (c) the design of an integrated Indigenous practices and MWS pedagogical activity, with a critical discussion of Indigenization of curriculum.

Co-teaching saw our own teaching personalities work to our strengths. This was strongly evident during our live meetings, with our different expertise and positionalities enriching discussions in ways that students may not otherwise experience.

4. Pedagogical Choices for Teaching Asynchronously in Covid Times

Our course was initially designed to take place in-person and mostly outside. With the advent of the COVID-19 pandemic, we became keenly aware of the limitations of virtual learning. We had to modify or completely remove some of the activities initially planned for the in-person course. For example, we had planned to harvest clay on the shore of a local river for making clay pots, and then fire the clay pots in an outside fire.

Ultimately, we modified this activity, providing air dry clay for at-home use instead.

That said, some instructional recordings were completed outside to reflect the original intention of the course. We opted for asynchronous sessions in response to the fact that, at the time, schools were closed and children were at home, which could be problematic for students who were parents (the majority of our students). The asynchronous sessions provided more flexibility for students to complete course-work whenever possible. Asynchronous sessions also meant, however, that we needed to provide very clear and organized instructions for students, and create the connections from one week to the next, so that the course would flow seamlessly. To compensate for the lack of face-to-face interactions and to create both personal and content connections, we produced instructional videos for most activities.

The selection of themes for each week was grounded in the activities we planned for students. This required us to consider the availability of materials students needed to conduct the activities, the time required for its completion, and the connections to both Indigenous practices and the K-12 MWS curriculum.

5. Lessons Learned

Developing a sense of community in the classroom is challenging within virtual settings. We met virtually with our students at the beginning and middle of the course to introduce ourselves and to check on their experiences mid-way through the course.

Students favoured this approach of fewer live virtual meetings, but they were also grateful for the opportunity to have a live class discussion. The discussions we had were lively and interesting, making it clear that we missed the richness of more dynamic interactions and opportunities to talk together. Students completed activities for the week on the Fridays and had until the following Monday to contribute to the discussion forums, allowing ample time to complete the activities and comment on their peers' posts.

Although the discussion board provided opportunities for students to interact, they did not replace whole-class discussions.

During the course, we saw resistance from some students to include other cultural forms of science and to recognize that mainstream science is cultural (i.e., Western-European). One of our main concerns throughout the course was to ensure students understood that integrating Indigenous knowledge into MWS does not mean merging or blending both. We were afraid students might subsume Indigenous science into Western science in their attempts to integrate both perspectives. Our intent was to demonstrate that both Indigenous science and Western science can coexist within the science classroom, with each perspective providing cultural value to science learning. The Two-Eye-Seeing principle [2] provided students a way to value both perspectives. Students feared tokenism, and the possibility of inadvertently crossing boundaries and being disrespectful of Indigenous traditions, which were mentioned as the largest barriers to incorporating Indigenous science perspectives in their teaching. Two-Eyed-Seeing allowed students to approach these two science perspectives, illustrating a way to present the knowledge in meaningful and appropriate ways that do not lead to tokenism.

Co-teaching was enjoyable for the three of us, and we learned more about each other and our different areas of expertise during the planning and delivery of the course.

Beyond the work we have started with this course, we must continue to find creative, meaningful, and appropriate ways to include Indigenous (First Nations, Metis, Inuit) perspectives into the science curriculum, which we hope will become standard practice one day soon.

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