New Perspectives in Science Education
International Conference
NEW PERSPECTIVES in SCIENCE EDUCATION

Experimental Escape Games with Digital Enrichment - An Innovative Format in Science Education

Isabel Rubner[1], David Ditter[2], David Weiser[3], Sarah Lukas[4]

University of Education Weingarten, Germany[1, 2, 3, 4]

Abstract

Escape games are innovative formats that are both motivating and have great potential to integrate subject-specific content and train future-oriented skills (21st century skills, future skills) in a fun and entertaining manner. Here, we present the integration of experimental escape games in chemistry education. They are carried out in the Chemistry Teaching and Learning Laboratory at the University Education Weingarten and developed further for the application in schools. The aim is to increase students' motivation for scientific topics and interest in STEM subjects, and to consolidate the application of knowledge acquired at school. In addition, 21st century skills (creativity, collaboration, interest, engagement and self-regulation) are promoted by embedding them in a game-based context. In the escape games, experimental approaches and solutions are essential to achieve the goal. Some of the escape games are digitally enhanced and guide the students (e.g. Actionbound, H5P) or digitally enhanced with different technologies as needed (AR, explanatory videos, etc.). In this contribution, the development, testing and evaluation of this innovative teaching method is presented.

Keywords: *game based learning, Escape Games, Digitalisierung, STEM*

1 Introduction

Young people's interest in science is still low. One way to attract students is to embed science topics in motivating contexts. In this respect, game-based elements offer great potential, especially if they are enriched with practical experiments and digital components. In addition, game-based learning offers good opportunities to organize learning content in a practical way. They also demand application-related knowledge, which is still rarely practiced in schools. As experimentation is at the heart of chemistry, it is useful and valuable to go beyond the theoretical transfer of knowledge and realize the consolidation and transfer of knowledge in the context of practical experiments. Digital learning environments and enrichments have the potential to reach groups of students who are sometimes not primarily interested in science. Here we present an approach in which experimental escape games with digital enrichments are developed, tested and evaluated in the Teaching and Learning Laboratory of the University of Education as part of the Science4Exit project. In addition, the sub-project Science4Exit School Escape Games is designed for use in schools.

2 Learning in game-based contexts

2.1 Gamification - game-based learning

Gamification can be considered business-related according to Deterding et al [1]. Gamification is defined as "... the use of game design elements in non-game contexts". This means the integration of game-based elements in non-game contexts. This could be as simple as visualizing a progress bar when loading an update or giving feedback on the extent to which a profile has been completed. According to Oliveira and Bittencourt [2], the process is analyzed more specifically in terms of problem-solving strategies. Game mechanisms and game strategies are central to problem solving. The definition is as follows: "The process of making activities more playful". This is the basis for game-based learning.

The use of gamification in non-gaming contexts promotes several areas. In addition to promoting motivation (Gears & Braun, 2013), increasing engagement (Reeves, Cumming & Anderson, 2011), increasing participation (Barata, Gama, Jorge & Gonçalves, 2013; Vassileva, 2012) and promoting well-being (Oprescu, Jones & Katsikitis, 2014), gamification can also be used to promote learning (Cheong, Cheong & Filippou, 2013) and collaboration and interaction (Raftopoulos & Walz, 2013). The latter are particularly relevant as 21st century skills in today's world [5].

2.2 Escape rooms - escape games

In an escape room, the initial objective is to get out of a room in which the group has been trapped within a certain amount of time [3]. For safety reasons this format cannot be used in a chemistry laboratory, but the basic idea can still be used. The terms Escape Game or Exit Game are more appropriate for the Science4Exit project and the term Escape Game will be used in our context for standardization purposes. The use of escape games in education is often referred to as an educational escape game [4]. In general, they contain tricky problems or tasks, the solution of which leads to the next problem [5]. These tasks have a clear technical reference, so that the focus is on consolidating or transferring specialist knowledge through the application of knowledge. In this respect, different elements can be integrated into escape games. Escape games can be purely digital, purely analogue/haptic or hybrid.

3 The Science4Exit project

3.1 Presentation of the project

The aim of the Science4Exit project is to increase students' interest in science and to consolidate their applied knowledge. To this end, we focus on the development, testing, optimization and evaluation of experimental escape games with digital enrichment [6]. Students should also consolidate their experimental and digital skills as part of the escape games.

The Science4Exit project is designed for use in teaching and learning laboratories and has since been extended for use in chemistry classrooms (Science4Exit$_{school}$). As part of the project, classic and innovative chemistry topics are prepared and offered as escape games for school classes.

School classes can visit the teaching and learning laboratory Ex^3 Lab at the University of Education to play an escape game on different topics, supervised by teacher students specializing in chemistry. The teacher students gain valuable practical experience in guiding and supervising students in a reduced complexity environment. The teacher students are also videotaped during their supervision in the Ex^3 Lab. Video vignettes (short scenes) of relevant scenes are then created from the recordings. The supervision and work with the video vignettes are part of a Master's course.
The development of further escape games or building blocks for escape games will also take place as part of a course in the Master's programm, so that the teacher students are actively involved and engage intensively with the technical content, experimental possibilities, and digital implementation in the creation of escape games.
Another component of the Science4Exit project is the Exit AG. Students who have visited the Ex^3 Lab are invited to participate in the design of further escape games as part of a research/exit group. This allows students to explore their topics and interests and develop digital elements or experimental modules according to their interests.
Supervision in the Exit AG is provided by academic staff from the University and student teachers.
The diagram Figure 1 shows how the different areas are linked:

Figure 1 Project structure Science4Exit

3.2 Development of the Escape Games in the Science4Exit Project

In the Science4Exit project the escape games are designed in such a way that the game flow is as smooth as possible and that subject-specific content is deepened and applied and subject-specific transfer is achieved. The orientation and focus vary according to the topic and the grade level.
The escape games are all embedded in digital learning environments (e.g. Actionbound, Genial:ly, H5P) and are played independently in small groups. A central feature of the Science4Exit project is the use of digital technologies such as digital learning environments and extensions such as AR, VR or explanatory videos, which create additional levels for the understanding process.

3.3 The Escape Game „Stranded“

Figure 2: Students playing an escape game, wooden box with material

To illustrate how we work, here are some insights into the escape game “Stranded”. Stranded on a desert island, a crate is washed ashore. The animated character Bill guides through the escape game, which is placed in the Genial:ly learning environment. In the course of the game, students use the contents of the box (see Figure 4) to solve different challenges and experiments.
For example, they have to produce drinking water from salty, contaminated water by separation and purification methods. This is done by decanting, filtering and evaporating the water to recover it. They are given various berries to work with, which they first must analyze to see if they are edible. This is done by examining the color composition of these berries using paper chromatography. Colored cones are used as berries (fig.3). A defective torch (3D print, homemade) with a broken circuit has to be supplemented with conductive material in order to have light at night. After several other experiments, they finally manage to leave the island. In this way, the students consolidate various aspects of material separation and properties that they have learned in class and apply them in a new context.
Other escape games deal with topics such as acids and alkalis or energy supply and storage.

Figure 3: paper chromatography with Skittles

One of the project’s key objectives is the development of key competences in students. Participation in the Escape Games promotes the acquisition of skills that go beyond the mere subject

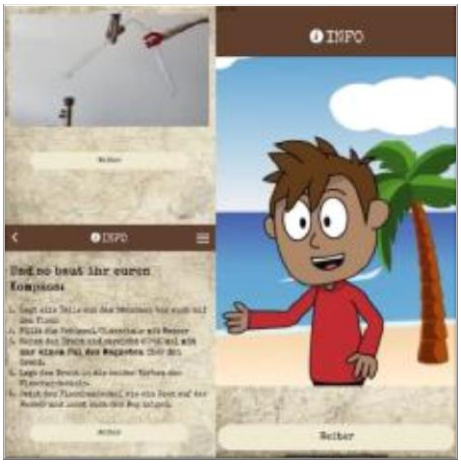

Figure 4: Wooden box from the escape game "Stranded", making fire with fire steel, instructions, Bill figure

knowledge, and add critical thinking, problem solving, creativity and teamwork (21st century skills) [7].

3.4 Results

The qualitative feedback from all participants, the teachers in the neighboring schools, as well as from the students, was consistently positive. This was also confirmed by the quantitative data collected to accompany the escape games in the school laboratory. Using a questionnaire at two measurement points (before and after the escape game), 61 students answered questions about their motivation, perceived competence (in the experiment and in the escape game in general), communication and perceived pressure. The five-point scales ranged from -2 to 2, so that a data value in the positive range indicates agreement with the named construct.

The data show a significant increase in the areas of planning experiments ($t[60] = 4.42$, $p < .001$), communication with classmates during the escape game compared to school lessons ($t[60] = 1.86$, $p<.05$) and perceived competence in the escape game ($t[60] = 2.85$, $p < .01$, see also Table 1). Motivation did not improve significantly, but scores were relatively high to begin with. Competence in conducting an experiment also did not change as a result of participation in the Escape Game.

Table 1: Means (and standard deviation) of the constructs surveye in the questionnaire. The scales were five-point and ranged from -2 to 2. A positive value indicates an expression in the direction of the construct.

Scale	Before the escape game	After the escape game
Motivation	1.04 (0.9)	1.09 (0.92)
Planning an experiment	0.15 (0.58)	0.56 (0.81)
Conducting an experiment	1.08 (0.56)	1.12 (0.74)
Perceived competence	0.45 (0.77)	0.82 (0.911)
Perceived pressure	-1.02 (0.95)	-0.95 (1.09)

The Masters Seminar, which aims at developing teacher students' professional skills, is also currently being evaluated. Detailed results are still pending, but the videos and interview data collected during the pilot programm show that teacher students can deepen their knowledge and skills in the development of digital teaching and learning materials. They benefit from the development of escape games by expanding their didactic, creative and technological skills and being able to put them into practice in the Teaching and Learning Lab.

In the peer tutoring course, teacher students reflect on their competences, improve their ability to deal with complex situations, deepen their technical language skills and expand their experimental skills. The seminar provides a practical platform for testing, reflecting and improving their teaching skills, which makes a significant contribution to the professionalization of future teachers.

The practical application of theoretical knowledge and the realization of concepts in a real teaching and learning context enable the different actors to strengthen their digital and experimental skills.

Figure 5 Impressions of the escape game

4. Summary and outlook

In the Science4Exit project, different levels of education are linked in a constructive way, creating a classic win-win situation.

The experimental escape games with digital enrichment offer different starting points for students to deal with scientific topics through the game-based context. In addition to the transfer of learning contents from school and the application of the content in the escape game, several relevant key skills are strengthened. The supervision of the students in the escape games enables them to integrate valuable practical experience into their studies. In addition, valuable aspects of teacher professionalization are strengthened.

In the future, we will develop further escape games in the project for the teaching and learning laboratory and for chemistry lessons. Interdisciplinary STEM escape games will also be explored.

References

[1] S. Deterding, D. Dixon, R. Khaled, L. Nacke (2011): From game design elements to gamefulness: Defining „gamification“. Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments, 9–15. https://doi.org/10.1145/2181037.2181040

[2] W. Oliveira, I. Bittencourt (2019): Tailored Gamification to Educational Technologies. Springer https://doi.org/10.1007/978-981-32-9812-5

[3] Strahringer, S. and Leyh, C. (eds) (2017) *Gamification und serious games: Grundlagen, Vorgehen und Anwendungen*. Wiesbaden [Heidelberg]: Springer Vieweg (Edition HMD - Praxis der Wirtschaftsinformatik). https://doi.org/10.1007/978-3-658-16742-4.

[4] Veldkamp, A. *et al.* (2020) ‘Escape education: A systematic review on escape rooms in education’, *Educational Research Review*, 31, p. 100364. https://doi.org/10.1016/j.edurev.2020.100364.

[5] Tercanli, H., Martina, R. and Ferreira Dias, M. (2021) ‘Educational Escape Rooms in Practice: Research and Experiences’. https://doi.org/10.34624/RPXK-HC61.

[6] Rubner, I., Lukas, S. (2023): Experimentelle Escape Games im Lehr-Lern-Labor Ex^3-Lab des Fachbereichs Chemie. In: Lehr-Lern-Labore und Digitalisierung. Hrsg: Meier, M., Hammann, M., Greefrath, G., Ziepprecht, K., Wodzinski, R.; Springer Verlag, p. 185-189, https://doi.org/10.1007/978-3-658-40109-2

[7] L. I. González-Pérez, M. S. Ramírez-Montoya (2022): Components of Education 4.0 in 21st Century Skills Frameworks: Systematic Review, Sustainability, 14(3), 1493. https://doi.org/10.3390/su14031493

[8] S. Sorge, I. Neumann, K. Neumann, I. Parchmann, J. Schwanewedel. Lehr-Lern-Labore als Vorbereitung auf den Lehrberuf – die Perspektive der Studierenden (2020), In: Lehr-Lern-Labore. Konzepte und deren Wirksamkeit in der MINT-Lehrpersonenbildung, Springer Berlin Heidelberg. p. 285–297, https://doi.org/10.1007/978-3-662-58913-7