STEAM in Computer Science Studies

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Abstract

STEAM (Science, Technology, Engineering, Arts, Mathematics) is defined as an active learning approach which integrates multiple disciplines from the acronym [1] and employs problem-based learning to solve real-world problems using technologies [2]. It aims to develop creativity, critical thinking, collaboration, communication skills, and therefore, better prepare students to meet labor market needs. Classified as a student-centered learning approach, STEAM facilitates students' engagement in the learning activities. However, there is lack of reusable and easily modified STEAM-based teaching tools at the university level. Thus, the STEAM-Active project [3], which is developed under the Erasmus+ programme, provides university teachers with e-learning course on STEAM methodological approaches, bibliographic review, protocol for designing teaching-learning sequences (TLS), collection of TLSs for socio-scientific-technological problems. Two TLSs "Cycling Tour and Tourism" and "Enjoy Sailing in Greek Islands" were piloted at Kaunas University of Technology, Lithuania during the 2023 fall semester. After adapting the TLSs to meet the course learning outcomes, time limitations, and students' prior knowledge, they were implemented as group projects of the master level course "Artificial Intelligence and Decision Making". 5 groups of international students developed mobile or web applications taking into account sustainability, circular economy, specific environment, and customers' needs. In order to meet the learning outcomes of the course, all the applications included artificial intelligence-based solutions for either data analysis, route optimization, or providing recommendation. Students faced the challenges of working in groups, choosing the proper technologies, and creating strategies to increase users' engagement. A clear perspective of the application possibilities helped students to gain skills for practical problem solving.

Keywords: *STEAM, problem-based learning (PBL), teaching-learning sequences (TLS)*

1. Introduction

Creative problem-solving, collaboration, ethics, ability to consider various perspectives and integrate different technologies are important skills necessary to prepare university students for the labor market. All these skills are fostered by employing STEAM methodology in the educational process [4, 5]. STEAM combines the disciplines of Science, Technology, Engineering, Arts, and Mathematics [1]. Although multiple STEAM definitions exist [6], STEAM is usually classified as a student-centered active learning approach that focuses on real-life problems [2], usually in the ones that occur in the students' environment [7]. Integration of arts to solving science, engineering, and mathematic problems by using technologies result in meaningful students' engagement in learning by doing [4]. STEAM education facilitates a holistic approach and addresses social barriers arising from gender, race, socioeconomic and other disparities [8].
It has been noticed that the university engineering teachers lack reusable and easily modified STEAM-based teaching tools. The STEAM-Active [3] project aims to fill this gap by educating the current and future teachers on STEAM learning approach and providing the fully prepared, reviewed and tested teaching-learning sequences for socio-scientific-technological problems. Because of the multiple existing definitions of STEAM, in the scope of the STEAM-Active project, STEAM is defined as an problem-based learning (PBL) methodology which covers at least two disciplines of the acronym, focuses on the real-life context, and takes into consideration transversal axis, namely, circular economy and fighting gender inequality. The content created during the STEAM-Active project consists of the bibliographic review on STEAM application in education, protocol for teachers, E-learning course on STEAM in engineering education, examples of teaching-learning sequences (TLS) [3]. The project is developed under the Erasmus+ programme and unites 7 contractual partners from 5 countries.

In this article, the results of piloting two TLSs at Kaunas University of Technology, study programme "Artificial Intelligence in Computer Science" are presented and the challenges which occurred during the process are discussed.

2. Teaching-Learning Sequences

Teaching-learning sequences (TLS) guide teachers and students throughout the learning process by defining the principal components. In the scope of the STEAM-Active project, TLSs are designed for implementing problem-based learning approach. The TLS structure, proposed in the STEAM-Active project [3], consists of the following elements:

- General data (study programme name and level, subjects involved, integration type, etc.);
- Description of the context (project topic, resources, ECTS, required prior knowledge and expertise);
- Possible strategies to integrate transversal axis of gender equality, circular economy, team-working and detailed description of their application in the TLS;
- TLS details, such as main guiding question, learning objectives, demands, and pathway;
- Matrix to provide relationship between different stages of the TLS (learning pathway, objective, learning demand, methodological needs, activities);
- Detailed description of activities;
- Scheme of evaluation.

All TLSs suggested in the STEAM-Active project are reviewed and tested by the project partners. The TLSs "Cycling Tour and Tourism" and "Sailing in Greek Islands" were provided by University of Peloponnese (Greece) and piloted by Kaunas University of Technology (Lithuania). Both TLSs cover technology, engineering, and arts disciplines by the means that students have to research, choose and apply technologies, consider best engineering practices to create resource-efficient, user-friendly and engaging application for the practical problem. The main guiding questions define the goal of the TLSs and are provided in Table 1.

Table 1. Main guiding questions of the TLSs.

TLS	Guiding question
Cycling Tour and Tourism	What problem or project needs to be solved in order to promote cycling as a way of living and integrate it into modern municipalities?
Sailing in Greek Islands	How can we leverage mobile technology to promote sailing tourism in the Ionian Islands, with a special emphasis on encouraging the active participation of women, while providing a comprehensive guide to sailing routes and a rich selection of culturally, touristic, and commercially interesting Points of Interest (POIs) for both male and female participants?

The activities of the TLSs are planned to last for 12 weeks. Groups of students carry out analysis of the infrastructure, state-of-the-art technologies, existing solutions. During the TLS, students design and implement the application, discuss possible user engagement strategies, collect, and analyze stakeholders' feedback, prepare report, and deliver presentation. The general timeline of both TLSs is provided in Fig. 1.

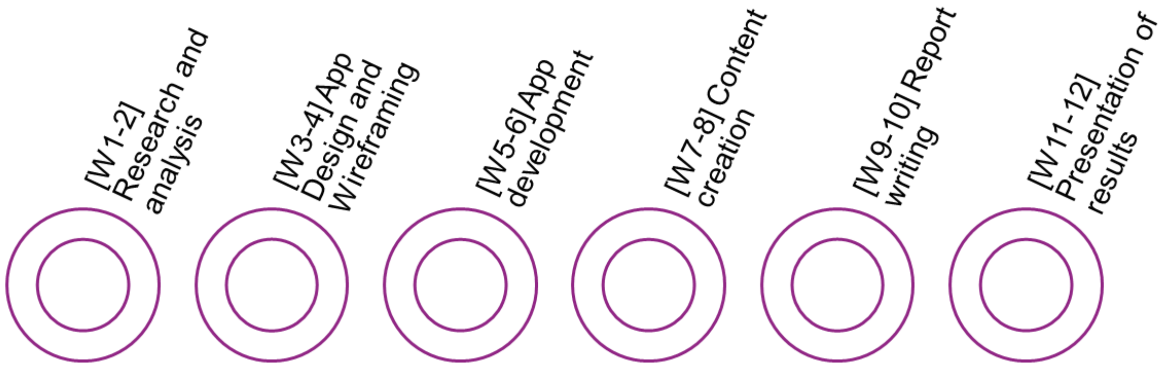

Fig. 1. General timeline of the TLSs "Cycling Tour and Tourism" and "Sailing in Greek Islands", W indicates the week number.

The TLSs were designed for the 3rd year bachelor students of the “Electrical and Computer Engineering” study programme, however, they can be easily adapted according to the time and learning outcomes of the specific course of a similar field. The guidelines on the important points to consider during the adaptation procedure are provided in the E-learning course of STEAM-Active project [3].

3. Implementation of TLSs

Since the TLSs follow the same framework, they both were integrated into master study course “Artificial Intelligence and Decision Making” during the 2023 fall semester in Kaunas University of Technology as a group project. The course is mandatory for the students of the master study programme “Artificial Intelligence in Computer Science”, and it can also be selected by the students of other master and bachelor programmes. In the beginning of the semester, six groups of 4-6 students were made. However, several students left the course and one of the groups was too small to proceed. Thus, the students joined other groups and by the end of the semester, five groups presented their solutions. Three groups implemented the project based on the TLS “Cycling Tour and Tourism”, two groups implemented the project based on the TLS “Sailing in Greek Islands”. The TLSs were piloted in the group with English teaching language, thus, the groups consisted students of various nationalities.
While implementing the designed TLSs, it is very important to adapt them so that they benefit the learning outcomes of the module as well as follow the timeline of the specific course. As the course topics are related to artificial intelligence (AI), the students were asked to use and demonstrate AI-based solutions in their systems. Smart selection of points of interests (POIs), generating personalized recommendations to improve user’s experience, optimizing a route can be examples of AI integration to the application. It should be noted that integration of artificial intelligence complements the STEAM activities for Mathematics. As the learning goals of the course differ from the informatics engineering field of studies for which the TLS was designed, such issues as scaling the app to maintain the increased usage or growing user base were not considered. In addition, the suggested TLS not necessarily fits the timeline or format of the course. In the TLSs, the students are asked to consider engaging stakeholders on the activity of 7-8th weeks. During the implementation of the TLSs, they were asked to present their initial ideas to the stakeholders and collect their feedback in a seminar which was held on the 6th week. Moreover, the final presentations were carried out on the 11th week of the TLS because of the study calendar at Kaunas University of Technology. Each group of students delivered 5-minute presentation and 5-minute demonstration of the main functionalities in the developed systems for the group of teachers working in the AI field and other students. During the course, the students were encouraged to self-monitor their group work by making the minutes of each meeting (list of participants, discussed issues, etc.).

4. Results

A summary of the applications implemented by the students’ groups and AI solutions integrated in them is provided in Table 2. The main goal for both TLSs was to implement an application to promote cycling / sailing tourism. Thus, the students were able to choose different strategies to achieve the goal. Several groups decided to generate routes on the list of POIs (groups A, B, F), others decided to recommend a route out of existing ones created by the manager or other users (groups C, D). Students were also free to choose the technologies and AI methods. This approach encourages students to look for the most appropriate method or combination of methods. For example, group B delivered an application that combined unsupervised and reinforcement learning methods, namely, K-means and Q-learning. Other groups employed natural language processing methods, image processing methods, similarity-based recommendations, supervised learning, genetic optimization.
During the reflection on the TLS implementation, students mentioned that they faced several challenges related to the implementation of the application. Firstly, students mentioned the lack of ideas on how AI solutions can be integrated to the system although examples have been provided. After questioning, it became clear that this uncertainty occurred due to the shortage of data possible to train machine learning models. Groups chose to overcome this problem in different ways, for example, by using open access data or collecting and preparing dataset by themselves. However, this problem is even more evident for data related to users’ experience as it is not possible to instantly have many natural users of a system. Thus, to demonstrate system functionalities related to users’ experience, students used randomly generated synthetic data. Secondly, the TLS “Sailing in Greek Islands” was

rather difficult to transfer into the local context, as sailing infrastructure and tourism sector is not developed so much in Lithuania compared to Greece. This also results in a lack of relatable students' experience and a low number of sailing experts who would provide field-specific feedback to the students. Finally, the requirement to integrate the transversal axis of gender equality raised a discussion if women and men are properly represented in historical landmarks, art objects, monuments, memorials, and other POIs. This also helped students to understand the importance of developing an ethical AI model.

Table 2. Summary of the applications implemented by five students' groups.

TLS	Group	Description	AI-solution
Cycling Tour and Tourism	A	An application to select a cycling route with customers' interests defined by the uploaded images. The application employs gamification approach as clients get rewards for achieving their objectives (e.g. completing routes)	Convolutional neural network (CNN) for image classification into predefined categories; Random forest for recommendations using users' location and CNN classification result as input.
	B	An application to generate a personalized cycling route by defining level of interest in specific category, such as history, arts, nature, fun activities.	K-means clustering to create "example users"; Q-learning to create a route.
	C	An application to generate a personalized cycling tour related to a specific topic, e.g. women artists. Users' experience is enhanced with starring route recommendations.	Natural language processing algorithms for filtering the descriptions of POIs; Similarity-based recommendations for routes.
Sailing in Greek Islands	D	An application to suggest personalized sailing itineraries and POIs. The application includes interactive features (forums, user generated content) and gamification (rewards, discounts, exclusive access).	Term Frequency-Inverse Document Frequency (TD-IDF) for user feature description. Similarity-based recommendations for routes using cosine distance matrix.
	E	An application to suggest a sailing route with specified categories of POIs.	Modified genetic optimization approach to generate routes.

Almost every group faced the challenges related to working in a group. For example, several students left the course in the first month and one of the groups consisted of only two members. Thus, these students joined other groups that had the same TLS. The integration was successful, and students offered interesting ideas which facilitated the application development process in these groups. Another example of a challenge was related to time management and the sharing of responsibilities, as in one of the groups students began to work individually. At the early stage meeting it was clarified that group members performed the same tasks (e.g., user interface design) and therefore did not spend their time efficiently. After identifying the problem, the students shared their responsibilities and tasks to make the work process smoother.

Despite all the challenges, students provided positive feedback regarding the task. They stated that the process of developing an application improved their practical skills and knowledge of integration of AI and other technologies used in similar system. In addition, finding creative ways to overcome challenges gave self-confidence to face the future challenges. Students were encouraged to develop a system attractive to users, thus, designing a user-friendly interface and planning strategies to increase users' engagement demonstrated their skills of creativity. It also led to the consideration of the system from the user's and owner's perspective to make sure that the balance between the user's engagement and financial sustainability is kept. Students also mentioned that working in a group helped them to improve communication and time management skills, contributed to understanding the importance of responsibility and individual impact to the project. In summary, students' collaboration in implementing practical tasks led to making new friendships and satisfaction with the results, which are the key elements of students' engagement.

5. Conclusions

Two TLSs, namely, "Cycling Tour and Tourism" and "Sailing in Greek Islands" were piloted in the master study program course "Artificial Intelligence and Decision Making" at Kaunas University of Technology. The provided TLSs cover engineering, technology, and arts (creativity) disciplines of the STEAM acronym. The TLS adaptation to the learning outcomes of the course, that is, integrating AI solution, led to also covering mathematics discipline. Although there were several challenges in TLS adaptation to local context and learning outcomes of the course as well as the implementation process, the students' feedback on the task was positive. In conclusion, STEAM activities can be successfully integrated in computer science studies by solving practical tasks, such as implementing a prototype of a recommendation system.

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