Development of digital teaching scenarios on advanced STEM topics for teacher education

Dimitris STAVROU

University of Crete, Department of Primary Education, 74100, Rethymno, Crete, Greece

Abstract. STEM Digitalis project aimed at the development of blended and distance learning environments for pre-service science teachers in advanced STEM topics. Consequently, five teaching scenarios about contemporary scientific topics have been developed, to facilitate pre-service teachers' conceptualization of STEM learning and to provide them with learning experiences, supporting the development of their digital competencies. Three contributions of the proposed symposium are focused on the implementation of the teaching scenarios, focusing on the use of digital technologies for teaching STEM topics in blended and distance learning environments, while the fourth contribution discusses insights of these implementations into pre-service teachers training programs.

Introduction

The COVID-19 pandemic forced institutions worldwide to quickly transition instruction from face-to-face forms to distance or blended learning settings. Most of the academic institutions, staff members, and students were not prepared for this quick transition, due to their limited or lacking knowledge and skills about blended or distance learning environments, as well as the corresponding teaching methodologies. Further challenges arose in the STEM courses, which usually consist of hands-on activities to engage students in scientific practices, enhancing apart from their scientific understanding, inquiry, and practical skills, including skills in data collection and processing and operation of scientific equipment, etc. Because of the universities' operation suspension for a long time during the pandemic, many questions have emerged related to how prepared higher education is in case another global or even local crisis appears in the future. It is controversial whether higher education (infrastructures, staff members, students) could support an effective shift of the face-to-face learning environment to an appropriate distance or blended learning environment for science courses [1].

Consequently, many attempts have taken place in the last years related to the development of online and/or blended digital teaching material and learning environments in the context of STEM courses in higher education, in cases where physical presence is not possible. However, if online teaching is approached from a pedagogical point of view, it is supposed to have a positive impact on teaching and assessment strategies [2]. In the literature, various pedagogical and instructional strategies (such as gamification, interactive models, virtual environments, etc) that could effectively support the engagement of learners in meaningful knowledge construction, are proposed. Both synchronous and asynchronous online learning experiences could be enriched by online digital tools, improving student learning and providing high-quality and collaborative learning environments, due to their multimodality and availability [3].

According to the above, the Erasmus+ project "STEM Digitalis" (https://stemdigitalis-project.eu/) is a partnership of five academic institutions and its aim was the development of blended and distance learning environments for teaching advanced STEM topics to pre-service primary and secondary science teachers. More specifically, the project objectives refer to formulating guidelines and teaching material to equip pre-service science teachers with knowledge and skills not only related to the use of digital tools (e.g. interactive videos, data loggers, virtual and augmented reality apps, etc.) but also related to the efficient integration of such tools in teaching and learning of advanced STEM topics.

Symposium format

The symposium will consist of four contributions Three contributions are focused on the implementation of the teaching scenarios, focusing on the use of digital technologies for teaching STEM topics in blended and distance learning environments, while the forth contribution refers to the insights of these implementations into pre-service teachers training programs. More specifically, during the symposium the discussion will focus on i. the educational use of various digital tools in online and distance science learning environments, ii. the innovative characteristics and features of digital technologies and iii. examples of good practices concerning teaching and learning strategies that promote meaningful use of digital technologies for teaching STEM topics in pre-service teachers training programs. Particularly, the four contributions are the following:

- *"Pre-service science teachers' views on the use of digital tools in the context of a Climate Change scenario"*
  Through this contribution, the structure of the climate change module will be presented with a focus on the integration of the specific digital tools, designed by the University of Crete group. In addition, the pre-service science teachers' views about the significance of the integration of digital tools in STEM learning environments intended for climate change teaching will be presented and discussed.
- *"Interferometry in a Virtual Surrounding"*
  This contribution reports on the digital products developed by the Leibniz University Hannover team of the STEM Digitalis project with a focus on the VR environment. Part of the results will be presented related to the significance of the students' experimentation through a Michelson interferometer.
- *"Ocean Batteries and Energy Farms: A Digital Scenario"*
  This contribution focuses on sustainability through renewable energy harvesting and storage, presenting a digital scenario on Ocean Batteries and Energy Farms, developed by the University of Groningen group. Findings related to teachers' reflections on engineering and technological aspects of the scenario will be presented and discussed in the symposium.
- *"Influence of STEM Digital scenarios on pre-service teacher professional learning"*
  This contribution examines the influence of STEM Digital scenarios on pre-service teacher professional learning through the discussion on the role of both the teacher and the technology in facilitating the successful implementation of a digital scenario in primary and secondary classrooms.

References

[1] J. Dillon and L. Avraamidou, Towards a viable response to COVID-19 from the science education community, *Journal for Activist Science & Technology Education* **11**(2) (2020) 1–6. doi: 10.33137/jaste.v11i2.34531

[2] D. A. Cook and Y. Steinert, Online learning for faculty development: A review of the literature, *Medical Teacher* **35**(11) (2013) 930–937. doi:10.3109/0142159X.2013.827328

[3] J. F. Eichler and J. Peeples, Online homework put to the test: A report on the impact of two online learning systems on student performance in general chemistry, *Journal of Chemical Education* **90**(9) (2013) 1137–1143. doi: 10.1021/ed3006264

Pre-service science teachers' views on the use of digital tools in the context of a Climate Change scenario

Athanasia KOKOLAKI, Eleni BOTZAKI, Emily MICHAILIDI, Dimitris STAVROU

University of Crete, Department of Primary Education, 74100, Rethymno, Crete, Greece

Abstract. The present study explores the views of pre-service science teachers about the integration of digital tools in STEM learning environments which are intended for climate change teaching. The study took place in the context of the Erasmus project "STEM Digitalis". A digital teaching scenario about Climate Change was developed and implemented with pre-service science teachers. The findings indicate that pre-service science teachers recognize a variety of possibilities of digital tools in the teaching of cutting-edge STEM topics, supporting the cultivation of skills related to scientific practices and a deeper understanding of scientific content.

Introduction

In recent decades, climate change has been increasingly intensifying with significant societal and environmental impacts which are expected to escalate [1]. Consequently, citizens have to be climate literate to make informed decisions and take climate actions. Particularly, they need knowledge about climate change phenomena and their multidimensional consequences, as well as skills and attitudes to be able to critically evaluate information, argue, and make decisions about mitigation and adaptation action plans [2]. Climate Change Education is the key for citizens to cultivate their climate literacy, with a focus on the appropriate knowledge and skills.

To reach the above, school education could contribute to cultivating climate literacy. However, teachers need to be prepared and equipped with the necessary knowledge and skills to formulate an effective STEM learning environment, that could support climate change teaching. To enhance the effectiveness of a such learning environment, a variety of digital tools could be used. Thus, teacher education could prepare pre-service science teachers to be able to use digital tools in the teaching of cutting-edge STEM topics, such as Climate Change. Furthermore, this part of teacher education could be enhanced by the participation of pre-service teachers in the corresponding learning environments with the integration of digital tools [3].

Theoretical Framework

The research in the Digital Technologies field reveals the possibilities of tools in teaching and learning processes, especially in Science Education and by extension in STEM education [4], contributing to formulating dynamic, interactive, and inquiry-based learning environments [3]. Specifically, digital technologies (modelling tools, sensor software, etc.) can effectively support teachers' efforts to conduct inquiry-based teaching in their classrooms and lead learners to a deeper conceptual understanding of scientific ideas, as well as encourage them to engage in STEM fields and become familiar with scientific processes necessary for an inquiry. Examples of digital tools that could be used are interactive videos, mobile applications, serious games, etc., offering also an increase of the engagement and interest of learners, supporting problem-based activities, and cultivation of interpersonal skills (communication, collaboration, etc) [4]. However, there is a lack of findings about how pre-service science teachers' views on the use of digital STEM learning environments [5]. Based on the above the research question that guides the present study is: *What are the views of pre-service science teachers about the integration of digital tools in a teaching scenario about Climate Change?*

Methods & Findings

In the context of the "STEM Digitalis" project, the University of Crete (UoC) developed a digital teaching scenario about Climate Change, which consists of three units and has integrated a variety of digital tools such as mobile apps, Unity 3D software, H5P tools, etc. Particularly, *Unit 1* focuses on the drivers of climate change through a Unity 3D-based serious game and an integrated interactive video experiment. The task of the game is the collection and comparison of data about the temperature and carbon dioxide through decades, guiding the users to conclude how they correlate. *Unit 2* refers to CO_2 emissions by anthropogenic activities and is based on interactive maps that provide data related to them per country. Additionally, a mobile application has been created for the calculation of users' CO_2 footprint based on their daily activities (transportation, household devices). In Unit 3, a digital "treasure hunt" is organized, in which participants collaborate in solving riddles and find the information that they need to support the perspective of one of the stakeholders during a negotiation about a socio-scientific issue. The digital teaching scenario was implemented in a summer school organized in Crete in 2022 and addressed to pre-service science teachers. Data from the implementation was used for the scenario's update, which was integrated into an open-access platform and implemented again in online seminars, to check its final version.

Data was collected through questionnaires focused on the views of pre-service science teachers about the integration of digital tools and the audio-recorded meetings during the implementation of the scenario. Due to the explorative nature of the study, qualitative methods of content analysis were used.

Findings

Findings show that pre-service science teachers recognize many possibilities related to the integration of digital tools in the teaching of cutting-edge STEM topics, such as Climate Change, supporting the cultivation of skills related to scientific practices and a deeper understanding of scientific content e.g. through the interactive video experiment. Indicatively, they also consider that digital tools could effectively engage them in the context of an everyday life topic, enhancing their interest e.g. through mobile apps that support the negotiation of socio-scientific issues.

Conclusion

Pre-service science teachers recognize a variety of strengths and limitations for each of the digital tools that were used in the Climate Change digital teaching scenario, such as serious game interactive experiment, mobile app and AR app. The implementation of the digital teaching scenario to pre-service science teachers helps them to consider the significance of the integration of digital tools in STEM teaching and prepares them to be able to choose the appropriate digital tool depending on the desired learning goals.

References

[1] H. O. Pörtner, D. C. Roberts, H. Adams, C. Adler, P. Aldunce, E. Ali, ... and Z. Z. Ibrahim, *Climate change 2022: Impacts, adaptation and vulnerability*. Geneva, Switzerland: IPCC, 2022.

[2] I. M. Otto, J. F. Donges, R. Cremades, A. Bhowmik, R. J. Hewitt, W. Lucht, ... and H. J. Schellnhuber, Social tipping dynamics for stabilizing Earth's climate by 2050. *Proceedings of the National Academy of Sciences* **117**(5) (2020) 2354-2365.

[3] D. R. Sokoloff, P. W. Laws, R. K. Thornton, RealTime Physics: active learning labs transforming the introductory laboratory, *European Journal of Physics* **28**(3) (2007) S83.

[4] N. C. Skinner and P. F. Preece, The use of information and communications technology to support the teaching of science in primary schools, *International Journal of Science Education* **25**(2) (2003) 205-219.

[5] M. B. Ibáñez and C. Delgado-Kloos, Augmented reality for STEM learning: A systematic review, *Computers & Education* **123** (2018) 109-123.

Interferometry in a Virtual Surrounding

Gunnar FRIEGE, Dirk BROCKMANN-BEHNSEN

Leibniz Universität Hannover, IDMP, AG Physikdidaktik, Welfengarten 1, 30167 Hannover

Abstract. This article reports on the digital products developed by the Hanover-based working group of the STEM Digitalis project. Special attention is paid to a VR environment in which students can experiment with a Michelson interferometer. Selected results of these experiments will also be presented.

Project STEM Digitalis

The aim of the project was to develop and test content and strategies for blended learning scenarios in STEM subjects [1]. The focus was on the development of digital tools for challenging STEM topics. Five universities were involved in the project: University of Crete (lead), Dublin City University, University of Groningen, Tallinn University and Leibniz University Hannover. The project ran from 2021 to 2023. At Leibniz University Hannover, the upper secondary school topic "Interferometry" was worked on.

Innovative Digital Tools

Amongst the newly developed digital tools for variable use in school lessons and higher education were interactive screen experiments (IBE) on various types of interferometers like the Michelson interferometer [4] or the Sagnac interferometer [3], Podcast series including 10 episodes with researchers being interviewed about interferometry [4], a silent video on the ultrasonic interferometer [3] and Geogebra simulations. But the highlight was a virtual reality environment with experiments on the Michelson interferometer [2] which will be described in more detail in the next section.

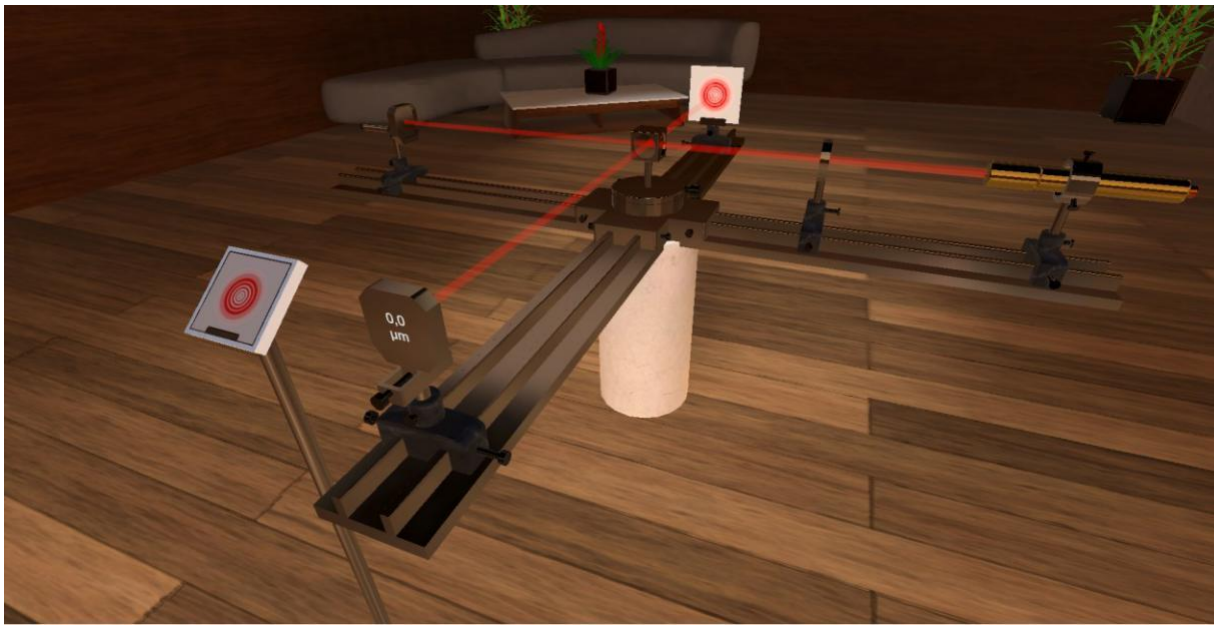

Fig. 1. View of the VR experimental room with the Michelson interferometer.

The Interferometer Building – An Innovative VR Laboratory

The flagship product of the Hanover-based working group of the STEM Digitalis project is a VR interferometer building in which various interferometer laboratories will be set up in the long term. The first room set up for this purpose houses a Michelson interferometer (see Fig. 1). In the meantime, however, the virtual institute has already been expanded to include a gravitational wave detector similar to the planned LISA space detector. The implementation of a Mach-Zehnder interferometer is currently being finalised.

The aim is for students to experiment independently with VR interferometers. Special features of the VR environment are recording and analysing measured values as realistically as possible, getting feedback on the quality of the values obtained and getting acquainted with safety aspects when handling lasers

Selected Results

During the Winter School 2022, the Michelson interferometer was tested on a larger scale in the virtual experimental environment. 43 preservice teachers from Leibniz University were first tasked with determining the wavelength of the laser used and the coefficient of thermal expansion of aluminium. Figure 2 shows the corresponding results.

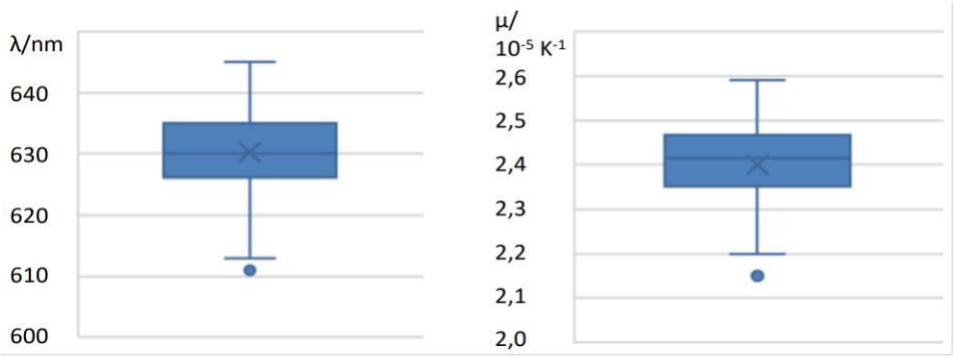

Fig. 2. Results of the experiments in the VR-surrounding.

The median of the students' determination of the wavelength of the laser was 630,3 nm (σ = 6,6 nm), which corresponds to a deviation of -0,6 % from the literature value. The median coefficient of thermal expansion of aluminium was determined to be $2.4 \cdot 10^{-5}\ K^{-1}$. This corresponds to a deviation of 4%. The results show that the VR environment in its existing form is practical and functional.

References

[1] STEM-Digitalis (11.02.2024). https://stemdigitalis-project.eu/de/home_de/. Homepage des EU-Erasmus+-Projekts.

[2] M. Bublitz, *Digitale Experimente in einer Virtual Reality Lernumgebung am Beispiel von Interferometern* (Unveröff. Masterarbeit an der Hochschule), Hannover, 2023.

[3] H. Maas, *Digitale Medien zum Thema Interferometrie. Entwicklung von Materialien für blended learning Szenarien* (Unveröff. Masterarbeit in der AG Physikdidaktik an der Universität Hannover), Hannover, 2023.

[4] K. List, *Entwicklung medialer Elemente zum Thema Interferometrie. Unveröff. Masterarbeit in der AG Physikdidaktik an der Universität Hannover*, Hannover, 2023.

Ocean Batteries and Energy Farms: A Digital Scenario

Argyris NIPYRAKIS, Chara BITSAKI, Lucy AVRAAMIDOU

University of Groningen, Broerstraat 5, 9712CP, Groningen, Netherlands

Abstract. The need to focus on renewable energy harvesting and storage has guided the development of a digital scenario on Ocean Batteries and Energy Farms. The goal was to develop digital education readiness in pre-service teacher education. The scenario was tested during an international summer school and local implementations in blended learning mode. Data were collected from teachers' reflections about engineering and technological aspects of the scenario, and were qualitatively analysed. Findings revealed that teachers reflected positively on authentic simulations on engineering design and the societal and real-world relevance of the topic. Suggestions for emphasising collaboration and reflection were provided.

Introduction

Efforts to limit gas emissions and to support sustainable ways of energy harvesting have been set as priorities globally [1]. This has impacted an increasing need to develop efficient and sustainable renewable energy sources. However, one of their main problems is that fluctuations appear in the energy supply due to their dependence on weather conditions. Therefore, there appears to be a need to develop storage technologies that can complement and support renewable energy sources [2]. Specifically, combining off-shore energy production farms with on-site energy storage technologies can provide added value in terms of increased efficiency and reliability.

The Ocean Grazer project (www.oceangrazer.com) is a research and development project in this direction. Specifically, the project develops 'ocean batteries', devices that make use of the pressure difference between a rigid reservoir (held in atmospheric pressure) and the pressure at the external space i.e. the seabed. The abundant energy which is harvested through renewable energy sources – in this case, wind turbines and wave energy converters [3], is used to drive a pump that pumps a fluid from the rigid reservoir to the flexible bladder; hence energy is stored in the form of potential energy. Contrastingly, the back-flow of the fluid can take place at a desired moment, so energy is provided as the flow of water passes a turbine, hence electrical energy is produced [4].

In the context of the [name] project, the University of [name] developed a digital scenario on Ocean Batteries & Energy Farms for pre-service teacher education. The goal of the scenario, aligned with the goal of the [name] project is to develop digital education readiness for pre-service teachers to teach STEM topics that are relevant to real-world problems, such as sustainability and green energy in the case of the Ocean Batteries and Energy Farms scenario.

Particularly, the scenario made use of a) a Matlab-based simulation of the operation of the ocean batteries, where participants could carry out variable testing and check its efficiency, b) a gamification platform (gather.town) to navigate across stages in an escape-room way, collaborate with peers and perform inquiry-based tasks, and c) AR agents with whom the participants could interact to check the knowledge gained and access the passwords for the next stage of the platform.

Context & Methods

The scenario was tested during a 5-days summer school developed for the needs of the [name] project, where 13 pre-service teachers from the 5 participating EU institutions participated in the [univ. name] scenario. The scenario was also tested locally during a 5-day workshop with 55 pre-service teachers in blended learning mode, 15 of them in in-person sessions and 40 of them online.

Data were collected from a) post-reflection questionnaires about teachers' views on engineering practices and digital technologies used, b) participants' responses in the online notepads while experiencing the scenario, c) researcher's field notes during whole-group reflections, d) post-reflection interviews of 3 participants after the end of the local implementation. Data were analysed through qualitative content analysis in order to identify patterns in teachers' views and reflections on engineering practices, and their views on technology i.e. potentialities, challenges, and tendencies to implement them in the future.

Findings & Discussion

According to participants' reflections in the summer school, pre-service teachers high valued engagement with simulations and software that are used in authentic research and development projects. They also evaluated positively the real-world relevance of the topic (n=10 participants) and its future-oriented relevance (n=3). Most participants also reflected positively on engaging with the engineering design cycle (n=8), and the engineering thinking and practices (n=6). However, some participants (n=3) stated that engineering took place at a surface level or not at all, while they didn't like the fact that the parameters to change were pre-defined (n=2). One participant also mentioned that it was possible to just try out the assessment quizzes and skip the simulation activities. Regarding collaboration, even though the scenario provided opportunities for collaboration (n=9), some participants (n=2) mentioned that it was possible to perform the activities solely by a person; therefore collaboration was not imperative. The socioscientific relevance of the topic was also deemed important, even though it was solely discussed explicitly in the last teaching unit, which was considered a limitation.

The analysis of data from the local implementation of the digital scenario revealed that teachers high valued the interactive and problem-based features of the scenario, while they found the topic inspiring. The interviewees regarded the visualisation and simulation of experimental settings that are hard to experience (e.g. the seabed) as a critical advantage of the scenario. However, they regarded that the scenario could be challenging depending on the background and age of the participants. Finally, regarding the blended learning modality, most participants considered it useful, as long as it entails a degree of interaction from the users.

Overall, participants' reflections on specific features of the digital scenario provide insights for developing technology-integrated teacher education programmes. The main findings reveal that teaching engineering processes through authentic simulations and interactive scenarios as well as engagement with society-relevant and real-world topics appear promising for teachers.

References

[1] United Nations Educational Scientific and Cultural Organization (UNESCO) (2022). *UNESCO Environmental Sustainability Report 2022.* https://unesdoc.unesco.org/ark:/48223/pf0000383996

[2] A. Di Modugno, *A Techno-Financial Model of Ocean Grazer's Hybrid Integration Proposing the Ocean Battery as Deployable On-site Storage Profitability Optimizer for Offshore Renewable Production Plants* [Doctoral dissertation, University of Groningen], 2021.

[3] A. Asiikkis, D. Grigoriadis, A. Vakis, Maximizing the Surge Amplitude of a Floater Through an Adaptable Mooring Tightening Technique. *Proceedings of the European Wave and Tidal Energy Conference* **15** (2023). https://doi.org/10.36688/ewtec-2023-274

[4] J. Jonker, Flexible bladder behaviour in shallow water conditions. [Doctoral dissertation, University of Groningen], 2021.

Influence of STEM Digital scenarios on pre-service teacher professional learning

Eilish MCLOUGHLIN, Stephen GAMMELL

Centre for the Advancement of STEM Teachign and Learning & School of Physical Sciences, Dublin City University, Dublin 9, Ireland

Abstract. A literature review on the design principles for pre-service teacher professional learning in primary and secondary level STEM education highlights the importance of using a range of in-person and technology-mediated instruction alongside using appropriate methods for teaching and learning in these contexts. The present study was carried out as part of the Erasmus+ project "STEM DIGITALIS" and examines the influence of STEM Digital scenarios implementation on pre-service teacher professional learning. The finding provide insights into the guidelines for pre-service teachers training programs development regarding the use of digital technologies in STEM teaching.

Introduction

A review of literature on the design principles for pre-service teacher professional learning in primary and secondary level STEM education highlights the importance of using a range of in-person and technology-mediated instruction alongside using appropriate methods for teaching and learning in these contexts. Pre-service teachers (PSTs) may need to overcome their own preconceptions and experiences of teaching through their own schooling in order to have confidence to implement a wider range of pedagogical techniques [1]. Pre-service teacher education needs to go beyond the acquisition of new skills and knowledge and into allowing teachers the time to reflect critically on their practice and to fashion new knowledge and beliefs about content, pedagogy, and learners [2]. Situation-specific and authentic professional learning for teachers has been highlighted as important to allow PSTs to construct their own knowledge, based on experience within their working environments [3,4].

Recent trends have emphasised the importance of the integration of STEM subjects (science, technology, engineering and mathematics) in education and therefore as a professional development priority for pre- and in-service teachers [5]. While there are diverse perspectives about STEM and STEM education, STEM education is seen as an approach which interconnects STEM disciplines, often emphasising the teaching of science and mathematics through inquiry, use of (digital) technology, engineering design, and 21st century skills [1,6]. However, if teachers are to design authentic learning experiences which integrate core STEM competences within real-world contexts, it is essential that they have firsthand experience in these contexts themselves [5].

Methodology

This study examines the influence of STEM Digital scenarios on pre-service teacher professional learning. This research has been carried out as part of the Erasmus+ STEM Digitalis project (https://stemdigitalis-project.eu/) which aimed to develop effective approaches for teaching STEM in a blended learning environment. Five STEM scenarios were designed to engage pre-service teachers with advanced STEM topics, facilitate the development of PSTs conceptualisation of STEM learning and provide authentic learning experiences which support PSTs to develop their pedagogical content knowledge around STEM. Each scenario (Water, Interferometry, Energy at Home, Climate Change, Ocean Batteries and Energy Farms) was presented over several units, with

each unit comprising of several learning activities. These activities were designed around a five-dimensional instructional framework (shown in Fig 1) which was developed in the STEM Digitalis project, informed by literature on integrated STEM learning [1] and blended learning [7]. The content of each scenario was trialled in local educational contexts (Estonia, Germany, Greece, Ireland, and the Netherlands) by each of the project partners.

Fig 1 Five-dimensional instructional framework for STEM Digitalis scenarios.

Findings

The design and implementation of the scenarios provided exemplar approaches to how digital tools and technology can be used as an indispensable part of STEM education. We observed that technology can be used as a complementary asset of the teacher to support individualised and self-regulated learning. The use of digital tools in STEM teaching supported PSTs active learning and their collaboration while they also provide opportunities for their problem-solving skills development especially when their use is accompanied with the use of real data. PSTs recognised the value of using digital tools to allow everyone to contribute their own thinking before agreeing how to progress or to agree on how to share responsibility within a group for completing a task. This presentation will also discuss the role of both the teacher and the technology in facilitating the successful implementation of a digital scenario in primary and secondary classrooms.

References

[1] J. Radloff and S. Guzey, Investigating pre-service STEM teacher conceptions of STEM education, *Journal of Science Education and Technology* **25** (2016) 759-774.

[2] D. Butler, M. Leahy, M. (2021). Developing preservice teachers' understanding of computational thinking: A constructionist approach, *British Journal of Educational Technology* **52**(3) (2021).

[3] L. Darling-Hammond, Changing Conceptions of Teaching and Teacher Development, *Teacher Education Quarterly* **22**(4) (1995) 9-26, https://www.jstor.org/stable/23475817

[4] A. Kokolaki and D. Stavrou, Pre-service primary teachers develop teaching artifacts on contemporary socioscientific issues, *Journal of Science Teacher Education* **34**(3) (2023) 287-306.

[5] M. Hurley, D. Butler, E. McLoughlin, *Immersive STEM Learning Experiences to Shape Shared Futures.* Dublin: Dublin City University, 2021. https://doi.org/10.5281/zenodo.5589759

[6] Y. Li, K. Wang, Y. Xiao, J. E. Froyd, Research and trends in STEM education: A systematic review of journal publications, *International Journal of STEM Education* **7**(1) (2020) 1-16.

[7] L. E. Margulieux, W. M. McCracken, R. Catrambone, A taxonomy to define courses that mix face-to-face and online learning, *Educational Research Review* **19** (2016) 104-118.