MULTILINGUAL BLENDED TEACHERS' TRAINING CURRICULUM

Enlivened Laboratories within STEM Education (EL-STEM)

Motivating EU students to choosing STEM studies & careers and improving their performance in courses related to STEM education

Co-funded by the Erasmus+ Programme of the European Union

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Executive Summary:	A main output of the EL-STEM Project is an innovative professional development course targeting EU secondary school STEM teachers (ages 12-18). The course aims at strengthening teachers' profile and competences in adopting the Enlivened Laboratories approach for enhancing instructional practices and students' motivation and learning processes in secondary STEM education. Teachers are acquainted with ways in which they could employ AR/MR/VR to promote students' engagement in STEM education and to strengthen their 21st century skills. The current report first describes the theoretical framework underpinning the EL-STEM in-service teacher training, providing an overview of the five interrelated bodies of research upon which it is based: (a) Problem-Based Learning, (b) Inquiry-Based Learning, (c) Scaffolding in STEM education, (d) Principles of Adult Education and (e) Re-contextualized TPACK framework. It then describes the course design: pedagogical and didactical approach, aims and objectives, content and structure. The online Teacher Training Curriculum, offered as OER via the EL STEM online learning environment (elstem.ouc.ac.cy), combines all the key Intellectual Outputs of the EL STEM Project. Its pedagogical foundation is based on the IOs of Accounting for Diversity and Accessibility in STEM Classrooms and the Enlivened Laboratories Methodology Guidelines (ELMG). Further, it offers rich resources for implementing STEM approach at schools, which include sample STEM Learning Objects (LOs) and Lesson Plans (LPs) as well as a list of reviewed tools for implementing STEM Content.

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List of Abbreviations/ Acronyms

Abbreviation / Acronym	Description
AR	Augmented Reality
CY	Cyprus
EE	Estonia
EL	Hellas (Greece)
ELMG	Enlivened Laboratory Methodological Guidelines
EL-STEM	Enlivened Laboratories within Science, Technology, Education and Mathematics
EU	European Union
FI	Finland
ICT	Information Communication Technologies
IO	Intellectual Output
IoT	Internet of Things
LO(s)	Learning Objects
LP(s)	Lesson Plans
M#	Month of the project time plan (M1-M30)
MR	Mixed Reality
OER	Open Educational Resources
PT	Portugal
STEM	Science, Technology, Education and Mathematics
VR	Virtual Reality
WP	Work Package

Relevant Publications

- Lasica, I.E., Meletiou-Mavrotheris, M., & Katzis, K. (2020) A Teacher Professional Development Program on Teaching STEM-Related Topics Using Augmented Reality in Secondary Education. In: Yu S., Ally M., Tsinakos A. (eds) *Emerging Technologies and Pedagogies in the Curriculum. Bridging Human and Machine: Future Education with Intelligence* (pp. 113-126). Springer, Singapore.
- Lasica, I.E., Meletiou-Mavrotheris, M., Mavrotheris, E., Pitsikalis, S., Katzis, K., Dimopoulos, C., & Tiniakos C. (2019). Enlivened Laboratories within STEM Education (EL-STEM): A Case Study of Augmented Reality in Secondary Education. In Th. Prodromou (Ed.), *Augmented Reality in Educational Settings* (pp. 267-294). Brill, Sense Education.
- Mavrotheris, E., Meletiou-Mavrotheris, M. & Lasica, I.E. (2018). Implementing Enlivened Laboratories within European Secondary STEM Classrooms. In *Proceedings of the 10th International Conference on Education and New Learning Technologies*, EDULEARN18 (pp. 10962-10966), Palma, Spain.
- Mavrotheris, E., Lasica, I.E., Pitsikalis, S. & Meletiou-Mavrotheris, M. (2018, March). Project EL-STEM: Enlivened Laboratories Within STEM Education. In *Proceedings of the 12th International Technology, Education and Development Conference* (pp. 9099-9107). IATED Digital Library.
- Lasica, I.E., Meletiou-Mavrotheris, M., Katzis, K., Dimopoulos, C. & Mavrotheris E. (2018). Designing a Teacher Training Program on The Integration of Augmented and Mixed Reality Technologies Within the Educational Process. *In Proceedings of the 12th International Technology, Education and Development Conference* (pp. 8943-8953). IATED Digital Library.

EL-STEM Project Description

The Project objective is to develop a new approach, which combines Augmented Reality (AR)/Mixed Reality (MR) technologies with Remote and/or Local Laboratories, for encouraging 12-18 year-old students' STEM engagement. In particular, we are targeting students of lower and upper secondary schools and irrespective of the expected varying individual inclination to STEM subjects, we are aiming to:

(a) attract students who currently might not be interested in STEM related studies/careers and enhance the interest of those who have already chosen this field of studies/careers,
(b) improve students' performance in courses related to STEM education.

Inspired by the emerging technologies of IoT (Internet of Things) and AR (Augmented Reality), we wish to connect the physical laboratory and/or the remote laboratory to the digital world and turn it into an "Enlivened Laboratory". We aim to explore various digital solutions to "immerse" students within STEM laboratories while implementing experiments. Moreover, we aim to attract more students to STEM related studies/careers through intense hands-on experiences, where they can participate, transform and augment what they are implementing, thus applying digital competences, developing haptic skills, collaborating with peers and ultimately, becoming more engaged in STEM education. This approach will be supported at school as well as at home through the involvement of appropriate platforms offering remote access to laboratories.

Acknowledging the crucial role of teachers in any effort to bring about change and innovation, our project will make available the necessary knowledge, indicative tools, and will introduce underlying dynamics in teaching cultures that will enable STEM education to obtain the full benefits of AR/MR. This will be achieved by providing teachers with high quality professional development opportunities to acquire knowledge and skills to effectively embed AR/MR in teaching and learning. More specifically, we will create a comprehensive framework for providing teachers with innovative digital tools to enrich their laboratory-based courses, in order to not only attract students' attention towards STEM education but also to achieve better performance in STEM related subjects. Project outputs will include AR/MR educational scenarios implemented through Remote and/or Local Laboratories. The technologies used for the implementation of these scenarios explore where applicable, the utilization of (a) AR/MR Remote Laboratories, (b) AR/MR Local Laboratories, (c) Mobile Technologies (e.g. smartphones and/or tablets), and (d) AR hardware technologies (e.g. AR glasses) in the teaching and learning of STEM courses.

1. Introduction

The "STEM pipeline" problem (Cannady, Greenwald & Harris, 2014; Sanders, 2009) as well as the need for human resources equipped with 21st century skills (critical thinking, creativity, problem-solving, collaboration etc.) during the past years (Xue & Larson, 2015), have been highlighted in the research community. Moreover, cross-national studies concerning students' achievements (e.g. TIMSS, PISA) indicate a significant number of underachievers in STEM-related courses (e.g. Mathematics, Physics, Computer Science, Chemistry) in all educational levels, especially secondary education, while attractiveness, motivation and engagement in STEM, also appear in low rates (Gasiewski, Eagan, Garcia, Hurtado & Chang, 2012). Statistics are also discouraging concerning students' tendency towards STEM studies and careers (Aeschlimann, Herzog & Makarova, 2016; Wang & Degol, 2013). This situation calls for urgent action, since STEM skills (Bybee, 2010) are among key competencies needed in a knowledge-based society for employment, personal fulfilment and development (Panorama, 2016; OECD, 2016). While in past years, some EU countries have made significant progress towards improving their students' performance in science skills, other countries are still behind. The need to reduce the number of underachievers in member states has been expressed by EU policy makers, in a series of EU summits and reports from the Education Committee (OECD, 2016; Panorama, 2016) culminating in the strategic targeting of resources to improve science education and ensure full participation among people from all backgrounds.

Recent technological advances have provided the opportunity to create entirely new learning environments in STEM education by significantly increasing the range and sophistication of possible classroom activities (Meletiou-Mavrotheris & Prodromou, 2016). One promising approach lately explored, is the potential of integrating Augmented Reality (AR) and/or Mixed Reality (MR) within secondary STEM education, as a means of making the subjects more accessible and attractive for students, and particularly those at special risk of exclusion from scientific studies and/or careers. AR and MR are emerging technologies in the Immersive Learning Landscape and have gained a growing interest among researchers during the last two decades (Bacca, Baldiris, Fabregat, Graf & Kinshuk, 2014; Ibáñez & Delgado-Kloos, 2018; Lee, 2012; Lytridis, Tsinakos & Kazanidis, 2018; Meletiou-Mavrotheris, 2019). Laboratories within STEM related courses is a field in which schools and other educational authorities invest, in an effort to make their curricula more innovative, attractive and competitive. These two dimensions have recently been combined under multiple perspectives to promote the advantages of their intersection. Despite the increased interest on this field, the amount of available research on their integration into teaching and learning is still relatively small due to the novelty of the technologies (Bacca et al., 2014; Ibáñez & Delgado-Kloos, 2018). Nonetheless, the majority of existing studies point towards numerous positive attributes that have the potential to enhance both learning and teaching (Bacca et al., 2014; Akçayir & Akçayir, 2017).

As researchers argue, it is more productive to view AR/MR as a concept rather than a technology (Wu, Lee, Chang & Liang, 2013). AR/MR offers new learning opportunities but also creates new challenges in the educational process (Wu et al., 2013; Akçayir & Akçayir, 2017). For its successful integration within STEM education, it should be accompanied with innovative pedagogical approaches and re-contextualized learning environments that are

focused on inquiry and problem-solving. However, changing teaching practices is proving difficult. A number of studies have asserted that it is much more demanding for teachers to exploit the growing prominence of AR/MR and other digital technologies and their transformative potential in instructional settings than was originally anticipated, and that many teachers remain unprepared to effectively employ Information Communication Technology (ICT) tools in their teaching practices (McNair & Green, 2016; Meletiou-Mavrotheris et al., 2017). Thus, the provision of high quality preservice and in-service teacher training that will equip teachers with the required knowledge and skills to effectively infuse AR/MR and other emerging technologies into teaching and learning is of utmost importance (Delello, 2014; Meletiou-Mavrotheris, Paparistodemou, & Christou, 2019). Teachers should be encouraged to recognize the true potential and the groundbreaking impact that AR/MR laboratories could have on teaching, learning, and assessment, and should be informed about best practices in their exploitation as instructional tools (Meletiou-Mavrotheris, 2019).

The important role of teachers' preparation in the instructional use of AR/MR is highlighted in numerous studies (Delello, 2014; Dunleavy & Dede, 2014; McNair & Green, 2016) which indicate that many teachers reject new technologies for reasons such as fear and lack of confidence in their use, lack of time or motivation for acquiring new technological skills, lack of existing resources, and failure of materials to align with standards (Delello, 2014; McNair & Green, 2016). Another important barrier is the fact that teachers do not feel comfortable with the new style of learning provided by AR/MR technologies which moves away from teacher-centered approaches (Delello, 2014). Dunleavy and Dede (2014) underlined the need of teachers' preparation in using AR and the different pedagogical strategies that this task entails. Changes in teaching cultures that will help improve student performance and attitudes, and to reduce disparities in STEM outcomes between different EU countries are required. Departing from this point, it could be suggested that teachers are key persons in beginning to understand the how, what and why of AR/MR supported laboratories within STEM education, as they are the persons who can provide the necessary instructional support to students, maximizing the impact of this technology. For this purpose, training that involves applying AR/MR and other innovative technological tools through standards-based pedagogical approaches seems to be a priority. A renovated effort in providing continuing professional development in this area is needed, as well as providing teachers with new stimulus to tackle groups at risk.

As a solution to the above-mentioned situation, the Enlivened Laboratories for STEM Education (EL-STEM) project developed, pilot tested, and implemented an innovative professional development program targeting EU secondary school STEM teachers, offering high quality in-service training on the effective integration of AR/MR technologies within existing school curricula. A multifaceted Teacher Professional Development (TPD) program has been designed within EL-STEM to familiarize teachers with the potential of AR technology for enhancing the teaching and learning processes in secondary STEM education. Teachers can therefore employ this technology, to further encourage student's engagement and strengthen their 21st century skills.

The online Teacher Training Curriculum, offered as OER via the EL STEM online learning environment (elstem.ouc.ac.cy), combines all the key Intellectual Outputs of the EL STEM Project. Its pedagogical foundation is based on the IOs of Accounting for Diversity and

Accessibility in STEM Classrooms and the Enlivened Laboratories Methodology Guidelines (ELMG). Further, it offers rich resources for implementing STEM approach at schools, which include sample STEM Learning Objects (LOs) and Lesson Plans (LPs) as well as a list of reviewed tools for implementing STEM Content.

2. Theoretical Framework of the Blended Teachers' Training Curriculum

The important role of teachers' preparation in the instructional use of AR/MR is highlighted in numerous studies (Delello, 2014; Dunleavy & Dede, 2014; McNair & Green, 2016), where it is indicated that many teachers reject innovative technologies for reasons such as (Delello, 2014; McNair & Green, 2016):

i. lack of time or motivation for acquiring new technological skills,
ii. fear and lack of confidence in their use,
iii. lack of existing resources, and
iv. failure of materials to align with standards.

Teachers usually do not feel comfortable with the new style of learning provided by innovative technologies, including AR/MR, which differentiates from teacher-centered approaches (Delello, 2014). Radical changes in teaching cultures are required to support students' performance improvement and to reduce disparities in STEM outcomes between different EU countries. Dunleavy and Dede (2014) underlined the need of teachers' preparation in using AR and the different pedagogical strategies that this task entails. Thus, training that involves applying AR/MR and other innovative technological tools through standards-based pedagogical approaches seems to be a priority.

The theoretical framework underpinning the EL-STEM in-service teacher training program is grounded on and structured under the interrelated bodies of research of: (a) Problem-Based Learning, (b) Inquiry-Based Learning, (c) Scaffolding in STEM education, (d) Principles of Adult Education and (e) Re-contextualized TPACK framework.

2.1. Problem-Based Learning (PBL)

PBL is widely used in STEM education with multiple benefits for both students and teachers. During PBL students need to define conceptual solutions to ill-structured problems and support them with appropriate arguments (Belland, 2017). Success in addressing authentic ill-structured problems within the educational process is possible when students are provided with (Belland, 2017):

a) appropriate information concerning the problem, and
b) instructional scaffolding to extend and enhance their capabilities during their engagement in the learning process.

Figure 1: Problem-Based Learning approach at a glance (infographic by Mia MacMeekin available at: https://anethicalisland.wordpress.com/)

Recently, AR appears to play a vital role in PBL, promoting the development of critical thinking and problem-solving skills through authentic activities (Dunleavy & Dede, 2014).

2.2. Inquiry-Based Learning (IBL)[1]

IBL is a student-centered approach, based on the premise that education begins with the curiosity of the learner (Dewey, 1997), promoting active learning and focusing on questioning, seeking information, critical thinking and problem solving (Savery, 2015). Similarly, to PBL, IBL is frequently used within STEM education where students practice the scientific method while tackling authentic problems. Learning activities within this approach begin with a core question followed by investigating solutions, while new knowledge is constructed during the process of gathering information and discussing discoveries and experiences (Pedaste et al., 2015). Inquiry is not actually seeking for the right answer (there is usually no unique answer),

[1] More details in IO1 (Accounting for Diversity and Accessibility in European STEM Classrooms) report.

but rather seeking appropriate resolutions to questions and issues (Pedaste et al., 2015; Pedaste et al., 2016).

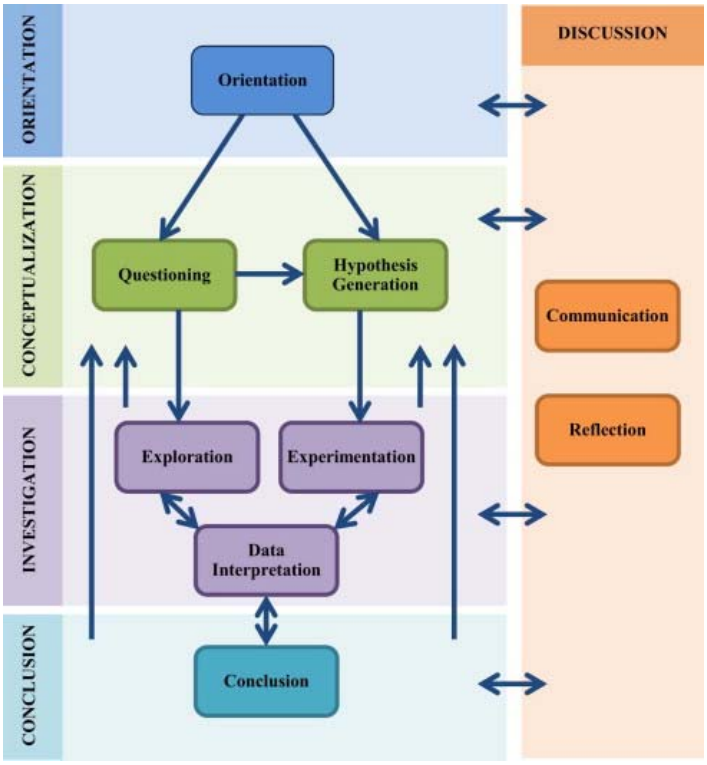
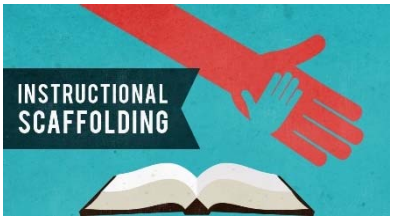


Figure 2: Inquiry-Based Learning approach at a glance (Pedaste et al., 2015)

The role of the teacher in both PBL and IBL is that of facilitator of the whole process (encouraging students, rewarding teamwork etc.), and of provider of information for the problem under investigation (Pedaste et al., 2016). There are some studies (Chiang, Yang & Hwang, 2014) highlighting that AR environments can guide students to share knowledge in IBL activities.

2.3. Scaffolding in STEM education



Scaffolding could be defined as the support provided by teachers, parents, peers or digital tools (Belland, 2017) to fill the gap between what learners could achieve on their own and what when being guided by others (Van de Pol, Volman & Beishuizen, 2010). The main steps for the implementation of this approach could be (Van de Pol et al., 2010):

a) contingency, (teacher's adaptation to the student's specific needs and recognition of the cognitive situation),
b) fading scaffolding (progressive reduction of scaffolding provided to prepare students for independency), and
c) transfer of responsibility (from the teacher to the students to achieve the learning objectives).

In the context of AR technology, when referring to scaffolded IBL approach, the literature indicates better results in learning and achieving high complexity task elements (Crippen &

Archambault, 2012). Dunleavy and Dede (2014, p.1) argue that AR "*positions the learner within a real-world physical and social context while guiding, scaffolding and facilitating participatory and metacognitive learning processes such as authentic inquiry, active observation, peer coaching, reciprocal teaching and legitimate peripheral participation with multiple modes of representation*".

2.4. Principles of Adult Education

During the design of a teachers' training program, it is vital to take into consideration the main principles of adult education. There is general acknowledgement of the fact that in adult education (Knowles, 1973; Mezirow, 1981):

i. the adults' own competencies and potential for growth and development should be emphasized while any dependency of adults on teachers should be prevented;
ii. teachers should act as facilitators of learning and help adults learn to teach themselves;
iii. adults should take responsibility for their own learning in instructional settings as they do so in everyday life situations;
iv. the actual real-life situations are the source and the focus of learning;
v. learning starts in the actual lived-in situation of adults - in workplace settings or in social communities - and aims to develop knowledge and skills that are usable and applicable in these situations; and
vi. learning in informal ways in a meaningful setting is much more effective than learning in traditional classroom settings.

Thus, to make training more relevant and attractive for teachers and to increase their motivation, they should experience it as usable and applicable to their actual classrooms. Dunleavy and Dede (2014) underlined the need of teachers' preparation in using AR and the different pedagogical strategies that this task entails.

2.5. Re-contextualized TPACK framework

Building on Shulman's idea of Pedagogical Content Knowledge (1986), the TPACK framework proposed by Mishra and Koehler (2006), is based upon the premise that effective technology integration for pedagogy around specific subject matter requires developing understanding of the dynamic relationship between all three knowledge components (technological, pedagogical and content). Thus, teacher ICT training cannot be treated as context-free, but should be accompanied with emphasis on how technology relates to pedagogy and content. TPACK is a powerful and influential conceptual framework, in response to the absence of theory guiding the integration of technology into education, which has, in recent years, become central to research into technology education and teacher professional development in many different disciplines including STEM education.

Within the EL-STEM project, the aim is to move teachers beyond technocentric strategies that focus on technology, and to promote their critical reflection on the use of AR/MR technologies in STEM education. TPACK is a research framework for facilitating and assessing teachers' professional growth in the use of ICT in STEM education (Phillips, 2013), including the

utilization of AR/MR technologies as tools for the development of students' scientific reasoning (Ke & Hsu, 2015).

Despite the usefulness of the original TPACK model, some limitations and challenges do exist. In particular, the basic TPACK model's individual-oriented focus is a drawback of the framework, since it fails to take into account the socially mediated contexts in which teachers develop their TPACK (Meletiou-Mavrotheris, Paparistodemou & Christou, 2019). As a result, TPACK was recently re-contextualized by Phillips (2016), who focused on the contexts in which the TPACK framework is implemented, based on previous literature and the importance of communities of practice (Phillips, 2013; Wenger, 2010). As shown in Figure 3, Phillips' re-contextualized model attends to the sociocultural influences on (a) pedagogical technology practices and (b) identity transformations, adding the key role of the place (school, educational institution, etc.) where the TPACK framework is implemented.

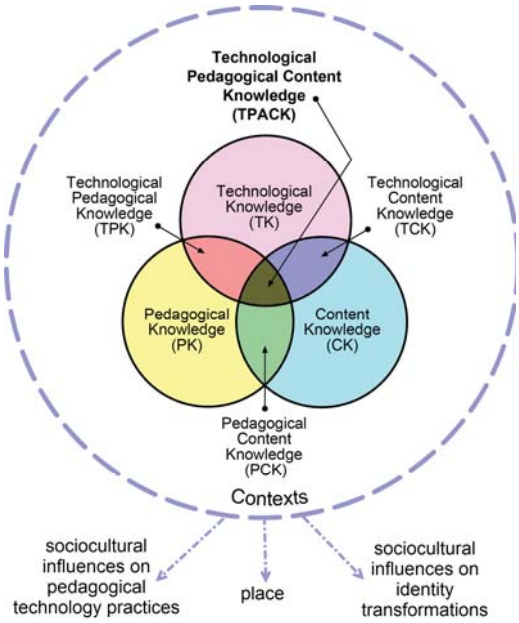


Figure 3: TPACK re-contextualized framework (Source of the initial TPACK image: http://tpack.org/)

3. Designing the Blended Teachers' Training Curriculum

Teachers' training programs targeting the instruction of 21st century skills (Ertmer, Ottenbreit-Leftwich & Tondeur; 2014) supported by learner-centred forms of pedagogy, focusing on inquiry and problem-solving based learning (Sanders, 2009), are of critical importance. There is a gap within STEM education between the required skills and knowledge to teach a STEM topic and the way STEM topics are actually taught within classrooms (Corlu, Capraro & Capraro, 2014). Usually teachers, when teaching a STEM-related topic, tend to focus instruction on the subject of their expertise. STEM education, however, requires teachers to "*excel in utilizing natural and active exchanges of knowledge, skills, and beliefs among STEM disciplines*" (Corlu et al., 2014, p. 76).

Recognizing the promising prospect of AR/MR technologies for upgrading STEM education, and on the basis of the special characteristics and needs of the stakeholders and Phillips' (2016) revised TPACK model, an in-service teacher training program for lower and upper secondary STEM teachers has been designed and implemented, on how to effectively implement inquiry-based instruction within the school curricula, through the functional integration of AR/MR technology with existing core curricular ideas.

The design and the main objectives of the training program meet the theoretical framework described in the previous section and the EU provision to provide high quality training to in-service teachers (OECD, 2016), by implementing the necessary changes in teaching cultures that will enable education to reap the full benefits of innovative technologies. The aim of the training program is to familiarize teachers with the potential of AR technology for enhancing the teaching and learning processes in secondary STEM education. Teachers can therefore employ this technology, to further encourage student's engagement and strengthen their 21st century skills.

A blended approach has been adapted, to offer teachers time flexibility, provide easy access to additional content (articles, videos etc.), encourage communication, and develop a personal contact with the participants. In the context of this approach face-to-face training seminars (see APPENDIX I: SUGGESTED FRAMEWORK FOR F2F MEETINGS) as well as the EL-STEM project online course (https://elstem.ouc.ac.cy/) are being provided:

- **Face-to-face teacher training:** Combination of workshops per participating country, including technology-based and hands-on activities and practice in small groups, presentations by experts, videos and tutorials, as well as discussions to exchange ideas and experiences.
- **ICT-mediated instruction:** Using the EL-STEM course platform and accompanying tools and resources to offer teachers time flexibility and ease of access to additional content (articles and other reading material, videos, etc.).

The final part of the TPD program includes guided field practice. Teachers expand upon the digital tools and the instructional material provided to them, and apply them in their own classrooms, through design and implementation of Lesson Plans/Educational Scenarios, and AR/MR Learning Objects (LOs). The EL-STEM consortium members act as mentors, providing their support to teachers.

3.1. Matching the Blended Teachers' Training Curriculum with the TPACK framework

Concurring with Phillips (2016), the EL-STEM project considers TPACK not as an individually acquired attribute but as an embodied phenomenon shaped by social, organizational, and cultural factors extending beyond individuals. The project adopts a systematic approach to examining and extending teachers' TPACK, by putting emphasis on the socially mediated contexts in which pre-service or in-service teachers develop their TPACK. Within the EL-STEM teacher training program, the context dimensions for the TPACK framework implementation are defined as follows:

- **Place**: The training program is offered through combined use of e-learning and physical meetings and is open to secondary education STEM teachers of EL-STEM partner countries (Cyprus, Greece, Estonia, Finland). After completing the pilots and implementing the necessary changes within the initial training program, it will be widely open to all secondary education STEM teachers within the EU and beyond. To ensure the effectiveness and safe use of AR/MR technology both within school and home, a range of other key stakeholders (out-of-school environment) will also be involved in the adoption process: parents, IT professionals, educational authorities etc.

- **Sociocultural influences** on (a) **pedagogical technology practices** and (b) **identity transformations**: At the project start, pre-surveys have been developed and administered to teachers and students[2], in order to:

a. collect baseline information about prior experiences and attitudes towards STEM education in general, and AR/MR in particular, and
b. identify trends in the use of AR/MR and other technologies in school and/or at home.

As far as the effective integration of ICT within the educational process is concerned (in particular AR technology), a deep understanding (by the teachers) of the relations between the three components (Technology, Pedagogy and Content) of the TPACK framework is required. The contexts' definition could contribute positively to this direction and to the effective implementation of the TPACK framework (Philips, 2016) within the teachers' training program suggested. The following table describes the necessary knowledge axes of the teachers' training program (Jimoyiannis, 2010) to the related knowledge that lies at the TPACK framework intersections (PCK, TCK, TPK).

Table 1: Matching of TPACK Knowledge intersection with knowledge axe within secondary education in the suggested teachers' training program

TPACK Knowledge	**Knowledge Axes within secondary education**
PCK	Awareness of curricula concerning STEM-related courses (Mathematics, Physics, Chemistry, Computer Science etc.)

[2] More details in IO1 (Accounting for Diversity and Accessibility in European STEM Classrooms) report.

	Scientific Knowledge of STEM-related topics/concepts
	Awareness of difficulties and misconceptions in STEM-related topics
	Pedagogical Models - Teaching Approaches concerning STEM courses – Willingness for collaboration between teachers of different courses – promotion of student-centered approaches
TPK	Pedagogical Models - Teaching Approaches based on ICT, especially AR technology
	Promotion of Inquiry-Based learning and interdisciplinarity within STEM courses, supported by AR
	Self-esteem and real experience acquirement concerning the usage of AR during the educational process
TCK	Familiarization with AR (tools, applications, existing libraries etc.)
	Knowledge and skills on the effective integration of AR within the educational process in the context of STEM-related courses
	Technical Issues prediction and/or resolution

To ensure the successful implementation of TPACK, the suggested teachers' training program involves teachers in both the *design of the educational activities* (through the Lesson Plans) and *the creation of AR Learning Objects* (supporting the Lesson Plans designed) that have been and/or will be applied in classrooms and/or school laboratories.

In addition, the familiarization with AR (tools, applications etc.), has initially been achieved through the teachers' involvement in solving hypothetical educational STEM-related problems during the face-to-face meetings. The EL-STEM consortium members, have been coordinating the whole effort, supporting the teachers in tackling any difficulties, concerns and obstacles they might have encountered.

3.2. Teacher Training Program Objectives

The main aim of the teacher training program designed is to develop a supportive culture, motivating teachers of STEM-related courses on effectively integrating AR with core STEM curricular ideas to transform their classrooms and/or laboratories into a smart-learning environment both by (a) using existing AR Learning Objects (LOs) and (b) creating their own AR LOs and Lesson Plans (LPs) with appropriate tools.

Teachers are trained on how to implement inquiry-based learning LPs in the fields of STEM, supported by AR, in order to engage their students in authentic problem-solving activities. They also get familiarized with different tools for developing AR LOs within STEM-related courses and existing repositories of AR LOs, such as HP Reveal, ARTutor, ZapWorks, EON Experience, Scratch and Unity.

These LPs and LOs are pilot tested with their students during follow-up classroom experimentations. The AR LOs are not expected to be designed to enhance extra-curricular activities, but instead, to become an important part of the main curricula and consist of reusable educational material for teachers in EU.

3.3. Teacher Training Program Target Groups

Secondary Education in-service teachers of STEM-related courses, not extensively using laboratories and innovative technologies within their courses, consist of the core target group selected for participating in the in-service teacher training, in order to motivate them change their teaching cultures.

In addition, teachers of STEM-related courses already using laboratories, applying innovative approaches within their courses and/or willing to include AR technologies are also included in the training to obtain full benefits of AR, and to act as pioneers in their countries. Priority has been given to teachers serving in classes with a particularly high proportion of students from low socio-economic backgrounds. However, since the teacher training program sparked interest among other teachers as well (primary education teachers, teachers in fields that are not related to STEM), they have also been encouraged to join the program.

The school management team has a critical role in the implementation of the teacher training program, being responsible for promoting it and encouraging the school teachers to attend it, as well as encouraging of the guided field practice in their schools.

Finally, students attending STEM-related courses are a directly related target group, after the in-service teacher training program completion. It is also necessary to involve the students' parents through additional informational activities, so that the school has their approval and support (Hornby & Lafaele, 2011).

3.4. Face-to-face meetings

The face-to-face meetings consist of a combination of mini-workshops including presentations by experts, AR-based and hands-on activities in small groups, familiarization with AR tools/applications, role-play and discussions. Following the design of the EL-STEM framework (see APPENDIX I: SUGGESTED FRAMEWORK FOR F2F MEETINGS), the face-to-face training seminars take place in each partner country of the EL-STEM project with around sixty (60) participating teachers from Cyprus, Greece, Estonia and Finland. The face-to-face trainings started during Fall 2018, with a series of hands-on professional development seminars and the project's staff training and will be completed during Fall 2019.

During the face-to-face trainings, teachers are provided with ample opportunities for interactive and collaborative learning through the use of contemporary technologies and related equipment and are engaged in authentic collaborative educational activities. The personal contact developed between the researchers and the teachers is critical for their future applications in their real classrooms.

The instructional strategies of the suggested face-to-face meetings include open-ended investigations, AR visualizations, collaboration and reflection on one's own and on others' ideas and experiences, providing a learning environment that helps participating teachers gain

better understanding of AR supported education, inquiry and interdisciplinarity. Moreover, the learning environiment is expected to serve as a model to the teachers they should also employ in their own schools with their colleagues, and then, in their own classrooms and school laboratories, to promote student motivation towards STEM-related studies and careers (Meletiou-Mavrotheris & Mavrotheris, 2007). The face-to-face trainings have been culturally differentiated for each country of the EL-STEM consortium, to accommodate local conditions in each participating country.

4. Teacher Training via the EL STEM Online Learning Environment

As already mentioned, the course has been designed to promote teaching STEM-related topics supported by Augmented Reality as a transversal skill for all secondary education teachers of STEM-related courses. Teachers taking the course develop their knowledge and skills in teaching and learning using the EL-STEM approach through exposure to innovative learning methodologies and resources, and cross-cultural exchange of experiences and ideas. Central to the course design is the functional integration of technology with existing core curricular ideas, and specifically, the integration of Augmented Reality and other technology-enhanced tools and resources provided by the EL-STEM platform. Online moderated discussions allow participating teachers across partner countries to share content, ideas, and instructional strategies. Moreover, educational content in various formats is shared (online text, videos, manuals, additional readings, tutorials, etc.) allowing teachers to deepen their knowledge.

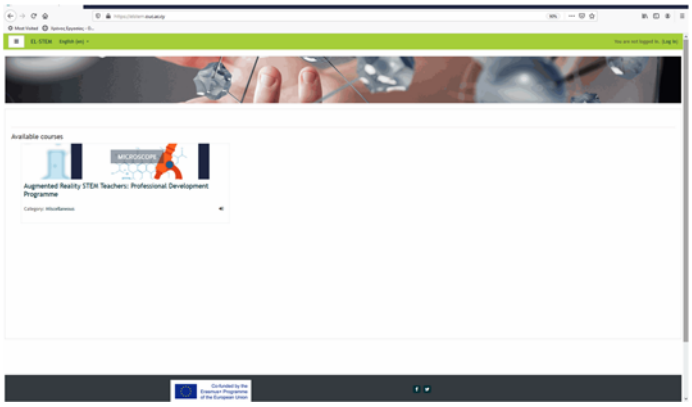
The Enlivened Laboratory Methodological Guidelines (ELMG) is the "heart" of the EL-STEM approach and the core content of the online course. They provide guidelines to the teachers on how to apply the methodology of the Enlivened Laboratories (EL-STEM), in order to create their own Lesson Plans (LPs) and AR Learning Objects (LOs) within their STEM-related courses. More specifically, they provide answers to core questions, including:

(a) **whom** they are addressed to and to whom they can be applied,
(b) **where** they could be implemented,
(c) **why** they should be applied within the context of STEM-related disciplines,
(d) **what** approaches, and which tools could be used and finally,
(e) **how** they could be applied to teach STEM-related disciplines in secondary education using AR technologies.

These guidelines are explained in-depth through the online course's content, made of seven modules, covering the following topics:

4.1. Overview of the EL STEM Online Learning Environment

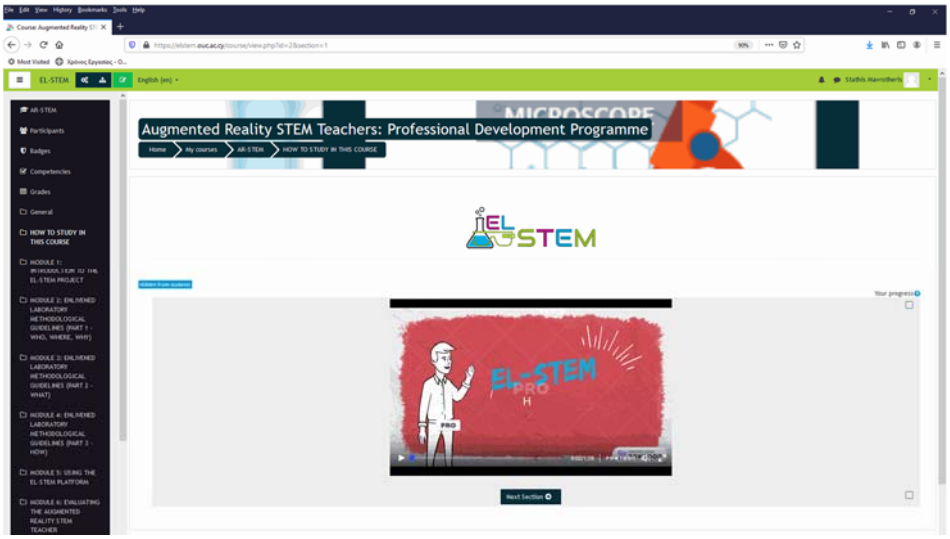
The Teacher Training is offered via the Project EL STEM Learning Environment which was implemented and is hosted by the Open University of Cyprus utilizing the open source LMS Moodle. The Training Course is freely available as OER at, https://elstem.ouc.ac.cy/



The Teacher Training is offered for Teacher Professional Development course is structured in seven Modules as follows.

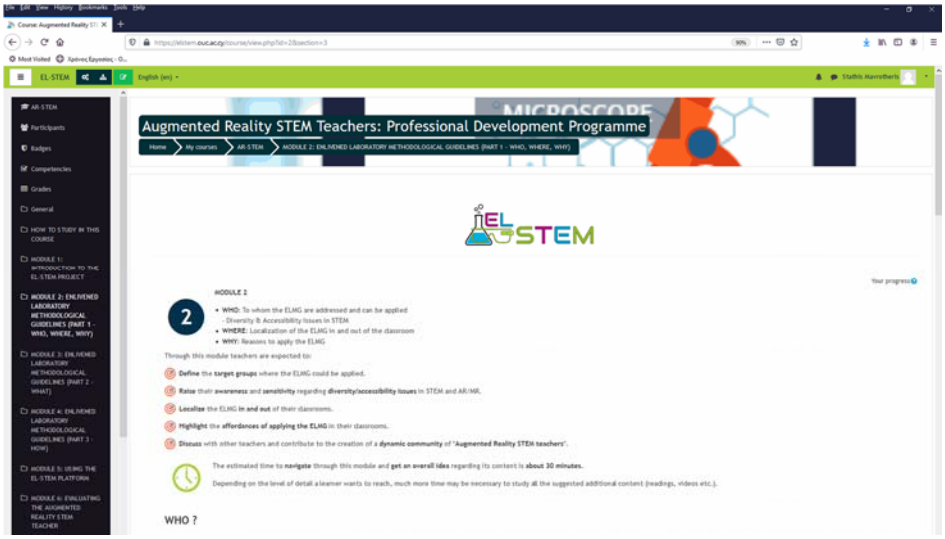
Module 1

Module 1 provides an overview of Project EL STEM and of the Teacher Training Program.



Module 2

The Enlivened Laboratory Methodological Guidelines (ELMG Part 1 - Who, Where, Why), includes a module for motivating teachers to use student-centred approaches in their STEM courses and apply innovative technologies, such as AR in their classes and school labs.



Module 3

Enlivened Laboratory Methodological Guidelines (Part 2 - What), which consists of the main theory of the online course, including STEM-related concepts/Instructional & Learning. Approaches related to STEM education and AR environments/understanding the differences of Virtual, Augmented and Mixed Reality, as well as the value of laboratories within STEM education/features and affordances of AR in education/case studies of AR/MR in STEM.

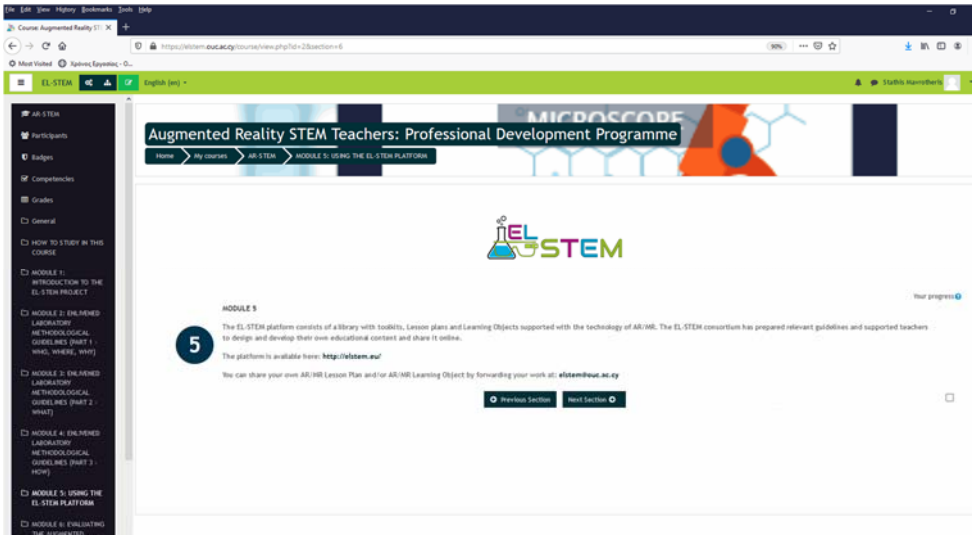
Module 4

Enlivened Laboratory Methodological Guidelines (Part 3 - How), which includes all the necessary guidelines and tools/application on:

- how to create a Lesson Plan applying the ELMG (teachers are also provided with Lesson Plans examples and ideas on how to integrate the EL-STEM approach into the school classrooms and laboratories),
- how to create an AR/MR Learning Object applying the ELMG (teachers are also provided with reusable educational content to be used in different STEM-related courses) and tips for applying and promoting the ELMG.

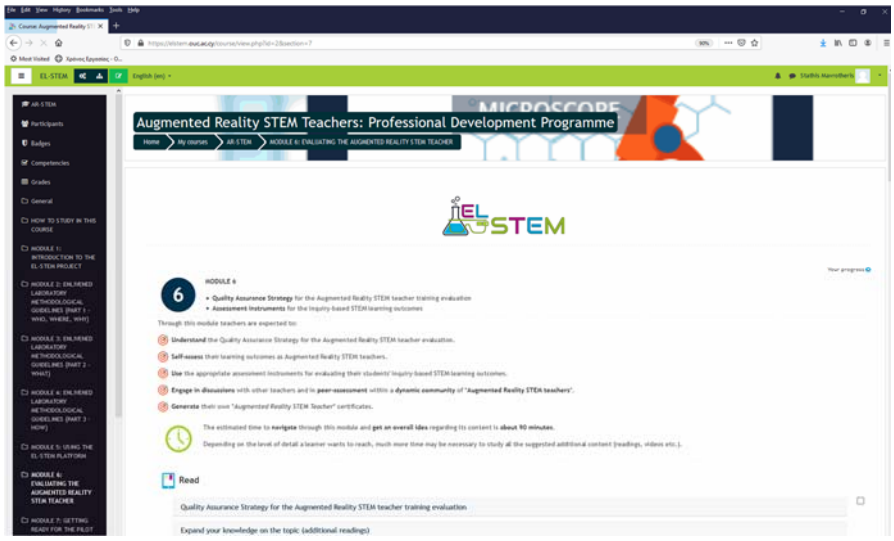
Module 5

Hostthe Project EL STEM Library and Toolkits, i.e. indicative Learning Objects (LOs) and Lesson Plans (LPs) developed as well as list of reviewed AR/MR/VR tools, that were reviewed and tried during the Project by the Partners and participating teachers.



Module 6

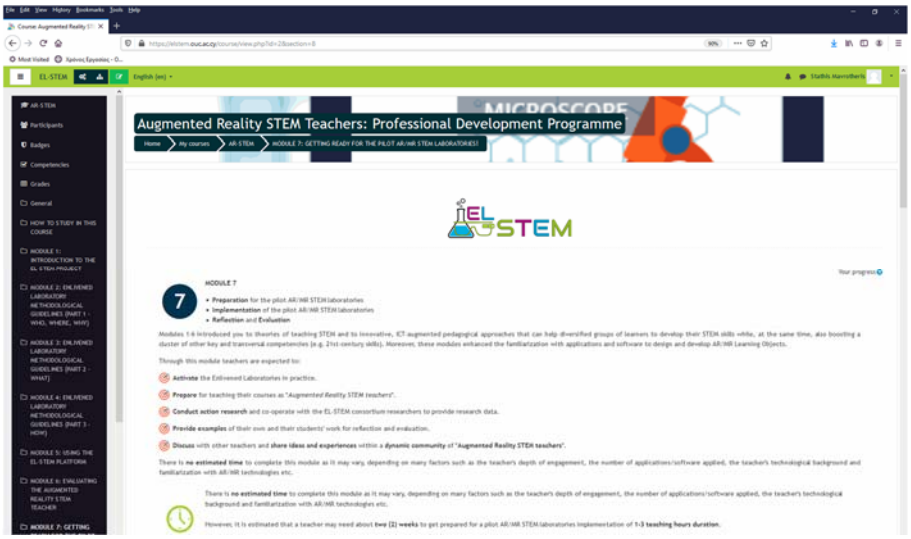
Evaluating the Augmented Reality STEM Teacher, which describes the quality assurance strategy for the Augmented Reality STEM teacher training evaluation, while assessment instruments for the inquiry-based STEM learning outcomes are provided.



Module 7

Getting Ready for the Pilot AR/MR STEM Laboratories! (guided-field practice), where teachers are guided for teaching their courses as "Augmented Reality STEM teachers".

A special emphasis of the EL-STEM teachers' training program is on building an online community through collaboration tools promoting dialogue (such as forums, chats, social media etc.) for the exchange of ideas, educational content, tools/applications, and instructional approaches among the European secondary education teachers, participating in the training.



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APPENDIX I: SUGGESTED FRAMEWORK FOR F2F MEETINGS

INITIAL SUGGESTED TEACHERS' TRAINING PROGRAM

TITLE	**Motivating students to choosing STEM studies & careers and improving their performance in courses related to STEM education by using AR/MR technologies**
TARGET GROUP	Lower & Upper Secondary Education Teachers (teaching students between 12 and 18 years old) in the field of STEM-related courses
MAX NUMBER OF TEACHERS	*20* *Note: The workshop could be implemented more than one time with more participants, if possible in each country*
TOTAL F2F MEETINGS	5
SUGGESTED DURATION	3 hours
SUGGESTED DATES/ HOURS	First 4 F2F meetings during November & December 2018 5th meeting in January 2019 (so that the teachers have some time to implement their scenarios) 16.30 – 19.30 *Note: All partners are encouraged to decide on the dates and hours of their F2F meetings.* *However, the meetings **SHOULD NOT**:* *- start before November 2018 (the training will not be completed by then)* *- end after March 2019 (pilots in real classrooms should be implemented during Spring 2019/ March-June 2019)*
TEACHER TRAINERS' NAMES	#### #### (at least one instructor for the theory, one for the practice on the AR tool and, if possible, 1-2 teachers of the consortium presenting their scenarios as examples)
NECESSARY EQUIPMENT	Desktops/ Laptops, Mobile Devices (Smartphones/ Tablets), stable Wi-Fi Internet connection
MAIN OBJECTIVES	- Familiarization with STEM approaches and AR educational environments - Introduction to Augmented/ Mixed Reality Technologies – Practice on AR tools - Development of Lesson Plans and Learning Objects in the field of STEM-related courses by using AR tools

WORKSHOP DESCRIPTION	**1st meeting** - Introduction to STEM (what is STEM, inter-/ multi- disciplinarity, what are the trends in STEM studies & careers, diversity/ accessibility/ gender issues - Real STEM examples (preferably presented by teachers instead of researchers or staff, so that they can discuss the difficulties and how they faced them - Introduction to STEM instructional and learning approaches/ emphasis on inquiry-based learning **2nd meeting** - Introduction to Virtual, Augmented and Mixed Reality - Real examples of using Augmented Reality in Education - Presentation of different tools for creating Augmented Reality content and related outcomes - Introduction to HP Reveal/ Metaverse – Practice Workshop *Note: Partners can choose which tool(s) to practice on (e.g. HP Reveal, Metaverse, Unity, Scratch 3) and prepare separate workshops for each tool.* **3rd meeting** - Continue practice on HP Reveal/ Metaverse tools - Action Research: Link the workshop with the EL-STEM project and encourage the teachers to participate in the data collection process - Teachers design their own STEM scenarios on a topic of their choice (individually or in groups) applying inquiry-based learning and using Augmented Reality Technologies **4th meeting** - Development of AR Learning Objects using the HP Reveal and/or Metaverse tool - Integration of the Learning Objects developed within the STEM scenarios designed in the previous meeting - Time schedule for applying the Lesson Plans and Learning Objects designed and developed in the teachers'' real classrooms **5th meeting** - Discussion and Reflections on the applications applied in the teachers' classrooms - Sharing Lesson Plans and Learning Objects on the EL-STEM Library/ encouragement to attend the "AR STEM teachers' community"