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METHODOLOGICAL GUIDELINES FOR CREATING THE FRAMEWORK OF THE *ImTech4Ed* PROJECT

Intellectual Output 1

ImTech4Ed: Immersive Technologies for Education

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

Intellectual Output	**O1: ImTech4Ed Methodological Guidelines for creating the framework of the *ImTech4Ed* project**
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Executive Summary:	*ImTech4Ed* is based on the concept of interdisciplinary thinking as a means towards the envisioning, design, and creation of immersive educational technologies, aiming at improving the way these technologies are created and brought into educational practice in a sustainable way. *ImTech4Ed* delivers methodological guidelines together with a set of immersive educational prototypes evaluated in educational practice. These are accompanied by supporting authoring tools, a teacher training program and concrete STEAM-oriented educational scenarios. The direct impact of *ImTech4Ed* is on participating students, pupils, teachers, educators, and researchers in broadening their view and understanding of interdisciplinary approaches and collaborative international work towards the creation of immersive educational technologies. The current report first describes the theoretical framework underpinning *ImTech4Ed and* outlines the pedagogical and didactical approach that should underlie the project's activities and outputs, in order to promote game-based, ICT enhanced STEAM Education. It identifies the current situation, best practices, and challenges regarding STEAM education and game design and their application at the University as well as at the Secondary School levels The Methodological Guidelines primarily address university students and secondary school in-service teachers across Europe. The report offers the methodological framework and recommendations for understanding how to (i) increase European youth's (pupils 12-18 years old) skills in STEAM related courses and attractiveness to STEAM studies and careers through game-enhanced learning, and (ii) make an appropriate use of Augmented and Virtual Reality (AR/VR) and other immersive technologies for this purpose. Finally, the Methodological Guidelines take into consideration the 21st century skills in order to ensure that future EU citizens develop a broad set of competences from early on in life, which will ultimately boost employability, competitiveness and growth in Europe.

European Commission

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2. International Hellenic University (Diethnes Panepistimio Ellados) (EL)
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List of abbreviations / acronyms

Abbreviation / Acronym	Description
CY	Cyprus
DE	Deutschland (Germany)
EL	Hellas (Greece)
ImTech4Ed	ImTech4Ed: Immersive Technologies for Education
EU	European Union
STEM	Science, Technology, Engineering, Mathematics
STEAM	Science, Technology, Engineering, Arts, Mathematics
TPACK	Technological Pedagogical Content Knowledge
4Cs	Communication, Collaboration, Critical Thinking, Creativity

ImTech4Ed Project description

Immersive technologies such as augmented and virtual reality or digital games expand the way humans can interact with computers significantly. These technologies also offer a wide range of possibilities for educational use. However, their uptake in education is so far very limited. Among the reasons for this is in the mono-disciplinary education in fields that would need to collaborate to deliver widely usable immersive educational solutions. Relevant fields comprise: game design, where immersive and interactive solutions are designed and developed; Computer Science, where the technological foundations for immersive technologies and for scalable architectures for these are created; and teacher education, where future teachers are educated.

Currently, these fields have only little connection to each other. The students in each field are educated separately and do not experience interdisciplinary collaboration. However, truly useful and widely usable immersive educational solutions can only be created by combining educational, technological, and design-oriented perspectives in order to conceptualise and develop good solutions.

The objectives of the ImTech4Ed project are:

- Creating interdisciplinary and international collaboration among students, educators, and researchers from the participating disciplines;
- Delivering creative and valuable prototypes for immersive educational solutions;
- Strengthening interdisciplinary thinking and approaches across students from various disciplines;
- Strengthening interdisciplinary and international cooperation;
- Evaluating prototypes in real teaching situations at connected schools;
- Establishing a network of connected/interested partners.

The project's main target groups are:

a) university students who participate in the development of game prototypes, fostering thus their motivation and learning of STEAM disciplines, while strengthening the development of a cluster of other key and transversal competencies (21st century skills).
b) secondary school in-service STEAM teachers who apply the methodological framework and guidelines, enhancing thus, their knowledge, skills, and dispositions for the integration of game prototypes, applying game design and STEAM teaching and learning in their classrooms.

The Intellectual Outputs of the project include:

- IO1: ImTech4Ed Methodological Guidelines
- IO2: Authorware Tools
- IO3: ImTech4Ed University student and in-service STEAM Teacher training program
- IO4: ImTech4Ed Immersive Game Prototypes
- IO5: ImTech4Ed STEAM Educational Scenarios

The Main Results of ImTech4Ed will include:
a complete set of didactical and technical instruments to help teachers utilise immersive educational technologies in their education, aiming to:

- learn about how to integrate immersive technologies as part of everyday education (IO1) and have prototypes at hand to explore (IO4)
- learn how to create immersive application cases related to didactic methodologies (IO2) and have authoring frameworks and tools at hand to do so (IO3)
- have immersive technologies embedded as core part of teacher education programmes to lower barriers for accessing and utilising tools and approaches (IO5).

After the project completion and through the ImTech4Ed outputs, the results will be multiplied achieving the following impact:

- 500 relevant stakeholders will become aware of the project outputs yearly during the 5 years after its completion, through the dissemination actions to take place according to the sustainability strategy
- 60 University students and STEAM teachers will be trained each year via the learning/training guides during the 5 years after the completion of the project
- 500 secondary school pupils will participate in teaching interventions based on the game-based STEAM education methodology of the project (for 5 years)

Seven partners from three EU countries (Cyprus, Germany, Greece) participate in the consortium, organized in such a way so as to cover the required competences for the successful implementation of the project. These include: Technische Hochschule Koln, Cologne Game Lab (DE), International Hellenic University (Diethnes Panepistimio Ellados) (EL), Open University of Cyprus (OUC), European University Cyprus (CY), Ellinogermaniki Agogi Scholi Panagea Savva AE (EL), The English School, Nicosia (CY) and Humance AG (HUM), (DE)

1 Introduction

Immersive technologies such as augmented and virtual reality and digital games offer a wide range of possibilities for educational use. Among the reasons for their limited uptake in education this far, is the mono-disciplinary education in fields that would need to collaborate to deliver widely usable immersive educational solution: game design, computer Science, teacher education. Currently, these fields have only little connection to each other. However, truly useful and widely usable immersive educational solutions can only be created by combining educational, technological, and design-oriented perspectives combining educational, technological, and design-oriented perspectives in order to conceptualise and develop good solutions.

The EU-funded, three-year project *ImTech4Ed*: aims at creating interdisciplinary and international collaboration among students, educators, and researchers from the respective disciplines in order to: (i) deliver creative and valuable prototypes for immersive educational solutions; (ii) strengthen interdisciplinary thinking and approaches across students from various disciplines; (iii) strengthen interdisciplinary and international cooperation; (iv) evaluate prototypes in real teaching situations at connected schools; (v) establish a network of connected/interested partners. The project targets to develop methodological guidelines together with a set of immersive educational prototypes evaluated in educational practice. These will be accompanied by supporting authoring tools, a teacher professional development course, and concrete STEAM-oriented educational scenarios.

This document is the first intellectual output of the project and aims to offer the methodological guidelines, and thus the framework, for the rest of the project's activities. It does so by identifying the current situation at country level regarding STEAM approaches, game design and interdisciplinary thinking in secondary and higher education. More specifically, the report consists of three parts.

In the first part, an overview of the literature identifies several crucial issues relating to STEAM education and the urgent need to equip the young generation with a new skillset to cope with the demands of modern society. Considering an observed decline in students' interest in key STEM topics and careers as well as students' low achievement in related fields (mathematics and science), it is important that more active learning environments are adopted for motivating and encouraging learners to establish the relevance and meaning of scientific concepts. In particular, research indicates that there is need for:

a) The modernization of STEM teaching and learning, and a bigger focus on ICT technologies as an instructional tool;
b) The widening of accessibility to STEAM fields for all members of society, including females, students from low socioeconomic backgrounds, and students with disabilities and other groups of learners;
c) Appropriate and strategic integration of technological tools which can have a positive impact on both student attitude and learning of concepts and processes;
d) High-quality professional development for the many teachers who have difficulties in developing comfort with immersive technologies and/or are negative with their uses as instructional tools;

e) Better designed and implemented educational solutions that require cross-disciplinary understanding and collaboration and are more closely align with the affordances of new technologies and the key STEAM concepts of innovation and creativity.

The second part of the report examines the existing situation at the three partner countries (Cyprus, Germany, Greece), within the wider European framework, and it attempts to link this information with the current literature. It particularly, discusses issues relevant to national policies and governmental support, educational reform, school expectations, gender and students' socio-economic status – all significant in shaping students' engagement with STEAM related fields, studies and future careers.

In the third part of the report, the results from surveys contacted in Secondary and Higher Education with both students and teachers are presented. The surveys were administered in the three partner countries aiming to collect data relevant to students' perceptions about STEM/STEAM studies and careers, their experiences with STEM/STEAM either through courses or afternoon activities, and their uses of digital games either at home as part of their leisure activities or as part of their instruction and formal education. The surveys also aimed at collecting data relevant to instructors' insights to STEM/STEAM education, self-efficacy and perceptions about STEAM and game based pedagogical approaches, current teaching practices and the degree to which they teach STEM/STEAM courses in an integrated manner with the use of digital games. Additionally, the data collected provided insights to teachers' needs and recommendations for the adoption and use of immersive technologies in education.

The conclusions drawn from the analysis of surveys along with the insights provided by the literature review as well as the country specific information offered by the national reports, define a complete and comprehensive framework for the development of the methodological framework (IO1). This, in turn, shapes the pedagogical and didactic approach that will inform the development of the rest of the project's intellectual outputs (training program, game prototypes and educational scenarios).

2 Theoretical framework

Global society has in recent years experienced a social, political, and economic shift from the digital age of the 1990s and early 2000s to the age of Industry 4.0 (Davis, 2016). This shift, which has come to be known as the Fourth Industrial Revolution, has moved us into an era characterized by the omni-presence and omni-use of technology, and by the blurring of boundaries between the physical, digital, and biological worlds. In this era, advances in artificial intelligence (AI), big data, robotics, the Internet of Things (IoT) and other newly emerged technologies are set to impact society like never before, forever changing the way humans live and work (Xu, David, & Kim, 2018).

Whether realizing it or not, most people are already surrounded by disruptive technologies (e.g. smart sensors, digital assistants in smartphones, personalization of users' online experience offered by search engines, etc.). In most scientific fields, technologies like AI are being applied to help solve complex societal problems (e.g. observation and protection of endangered species, medical diagnosis and enhancement of the healthcare system, minimization of traffic jams and improvement of pedestrians' safety, improvement of elderly care services, etc.). The influence of these technologies on all aspects of life will be even bigger in the very near future. The impact on the workforce is expected to be huge (Xu, David, & Kim, 2018). Due to technology-powered tools, transformation of the nature of almost all industries and automation of many processes will occur. This will make many of the current occupations redundant. However, the eliminated jobs will be replaced by new or altered professions, which will offer lucrative career prospects to those equipped with the proper knowledge and skills. This will include good knowledge of emerging technologies (e.g. AI, robotics, AR/VR), data literacy skills to manage the flow of big data, and transversal skills such as creativity, social and emotional intelligence, communication and collaboration, and critical thinking (Wahyuningsih et al., 2020; Asbari et al., 2020).

While an exciting era for innovations and technology advancements, the 21st century is also a challenging time for educational practitioners and policymakers (Fomunyam, 2019). The advent of new and emerging technologies and the creation of new professions have underlined a threatening deficit in the future skills required for successful integration into the labour market. According to a recent EU report, 42% of European Citizens are lacking critical digital competencies while 90% of the professions in near future will require digital competencies (International Digital Economy and Society Index 2019). Thus, an **urgent need exists to equip the young generation with a new skillset to cope with the demands of modern societ**y, so as to become "tomorrow's progressive leaders, productive workers, and responsible citizens" (Ge, Ifenthaler, & Spector, 2015, p. 384).

The need for the development in youth of key competences related to Science-Technology-Engineering-Mathematics (STEM) and the **so-called 21st century skills**, plays a direct role in driving economic growth and is set high on the priority list of the European Commission. One the one hand, the demand for a strong STEM workforce is growing and is recognized by academic, non-profit, and government institutions alike. On the other hand, there are challenges that threaten our ability to recruit, train, and retain such a workforce in ways that are effective and sustainable and foster innovation (Segarra et al., 2018). Students' motivation for learning and subsequent achievement in STEM topics is currently at a low point, since present-day STEM education at national, European, and international level often fails to engage students' interest.

Cross-national studies of student achievement (e.g., Trends in International Mathematics and Science Study (TIMSS), Programme for International Student Assessment (PISA)) indicate lack of mathematical and scientific competence for a considerable proportion of the student population in Europe and internationally. In addition to **students' low achievement**, there is also well-documented evidence of **declining interest in key STEM topics and careers** (e.g. Cedefop, 2012; OECD, 2014; OECD, 2015a; Kudenko & Gras-Velázquez, 2016). This unfortunate situation of low student performance and decline in interest in STEM is of concern, since skills in STEM are among the key competencies all individuals need in a knowledge-based society for employment, inclusion, subsequent learning, and personal fulfilment and development (Eurostat, 2018).

The **methods of instruction** have been identified as contributing to students' falling interest and performance in STEM education (e.g. Clark-Wilson, Oldknow, & Sutherland, 2011; Meletiou-Mavrotheris, 2013). This connection between attitudes towards STEM subjects and the common teaching methods sets a critical agenda for the revision of pedagogical practices in STEM education. Educational leaders and professional organizations in mathematics, science, and technology education (e.g. American Association for the Advancement of Science, 1993; National Council of Teachers of Mathematics, 2000; European Commission, 2007; Common Core Standards in Mathematics, 2010) have for decades been advocating the adoption **of more active learning environments that motivate learners, and encourage them through authentic inquiry to establish the relevance and meaning of scientific concepts**. In Europe, the Rocard Report (2007) called for shift in science education practices across the continent through the adoption of new forms of pedagogy focused on inquiry, problem-solving based approaches to science teaching and learning. Various reports (e.g. World Bank, 2014) have also identified mathematics and science curricula and pedagogy as key areas for action, calling for a **modernization of STEM teaching and learning, and a bigger focus on ICT technologies as an instructional tool**. This shift was reflected in most countries' revised educational policies and official curricula, which currently advocate pedagogical approaches that support inquiry-based, technology-supported STEM education. Despite, however, the extensive calls for the uptake of learner-centred, inquiry-based pedagogical models, the international research literature indicates a disconnection between curricula initiatives and calls for reform and actual classroom practice and the persistence of traditional, teacher-centred approaches (e.g. Klette, 2009). There is strong evidence that, in practice inquiry-based STEM education is not widely implemented in partner countries (European Commission, 2007; Euler, 2011).

During the past decade, considerable attention has been given on the integration of Arts in the STEM disciplines, as Arts commonly share with STEM a focus on problem solving and experiential and immersive learning, while at the same time also promoting innovative and creative thinking. The integration of Arts with science and technology topics, which has come to be known as STEAM, can make STEM disciplines more accessible, facilitate inquiry learning, promote conceptual understanding, and make the learning experience fun, engaging and more meaningful (Segarra, et al., 2018). However, the STEAM education model has remained a theoretical conception at large, with limited examples and resources on how this can be achieved in practice. Despite dedicated efforts and research, the STEAM-focused field is still limited by little evidence-based knowledge of the impacts of educational programs on the STEAM mindset and competences of students (Shahin, et al., 2021).

STEAM and Industry 4.0 are closely linked, as the competencies required in STEAM (i.e., creativity, problem-solving, foresight, and adaptability) are aligned with core skills required in the modern era. Recently, emphasis has been placed by researchers and policymakers, in **widening the accessibility to STEAM fields for all members of society, including females, students from low socioeconomic backgrounds, and students with disabilities and other groups of learners** who tend to be underrepresented in STEM/STEAM related fields of study and career (OECD, 2014). Considering the above, the need to invest in STEAM education, and in the development of necessary resources is evident. As part of this need, teachers need to find a mechanism for presenting and delivering the major stories that STEAM education must tell in a readily understood and motivating form for their students, but also for promoting the cultivation of interdisciplinary key competences related to STEM/STEAM.

Rapid advances in information and communication technologies have provided the opportunity to create entirely new learning environments by significantly increasing the range and sophistication of possible instructional activities in both conventional and e-learning settings (Meletiou-Mavrotheris et al., 2017). A wide diversity of powerful and readily available technological tools including serious games, simulations, high-quality streaming video, cloud-based computing, digital textbooks, virtual/augmented/mixed reality, and learning analytics, offer myriad opportunities for transforming pedagogy through the adoption of innovative, learner-centred instructional approaches.

A continuously growing body of research literature indicates that **appropriate and strategic integration of technological tools** can have a positive impact on both student attitude and learning of concepts and processes (Cheung & Slavin, 2011; Crawford Li & Ma, 2010; Higgins, Huscroft-D'Angelo, 2019; Suh & Prophet, 2018; Wouters et al., 2013; Yousef, Chatti, & Schroeder, 2014). At the same time, the review of the literature makes it clear that mere use of technological tools cannot, in and of itself, directly change teaching or learning, but rather that the success of technology-enhanced instruction **depends on how well it is designed and implemented** (Guy & Marquis, 2016; Seidel, Blomberg & Renkl, 2013). Successful design and implementation of the technology-enhanced STEAM approach requires reconstruction of school curricula and methods of teaching, learning, and assessment to more **closely align with the affordances of new technologies and the key STEAM concepts of innovation and creativity**. STEAM education should exploit the capabilities of modern technologies that are intrinsically motivating to learners, in order to create high quality learning experiences that foster students' innovation, creativity, communication and collaboration, critical thinking, and problem-solving skills.

The role of teachers, in particular, is paramount to the successful integration of ICT in STEAM educational settings. Their required skills set includes good knowledge about the pedagogical possibilities offered by the new technological solutions, recognizing their potential, benefits, advantages and issues surrounding their use, and creating conditions for their successful implementation. However, a number of research studies have asserted that it is much more demanding for teachers to exploit the growing prominence of mobile and other ICT technologies and their transformative potential in instructional settings than was originally anticipated, and that many teachers remain unprepared to effectively employ ICT tools in their teaching practices (e.g. Blackwell, 2014; Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012; Attard, 2015).

Research suggests that **many teachers have difficulties in developing comfort with immersive technologies** (Blankenship & Kim, 2012) **while others are negative with their uses as instructional tools** (McNair & Marybeth, 2016). Even future teachers (e.g. preservice teachers), while recognizing that immersive technologies are highly motivating, engaging and support students, still have concerns about their use and implementation and many of them feel inexperienced in using such technologies (Cooper et al., 2019) or find the available tools difficult, especially at the beginning (Delello, 2014). In addition, teachers may also need to design, model and program immersive activities, however, there is **little support in creating mixed-reality education spaces** (Elliot et al., 2012). Thus, to facilitate the proliferation of emerging technologies in instructional settings and its use in more creative ways that can have a true impact on teaching and learning, teachers should be provided with **high quality professional development** that brings innovative technologies to the forefront of their consciousness.

Undoubtedly, educators need to expand their technology toolbox to meet the needs of today's technologically savvy student. They need to bring inside the classroom the technology students use in their daily lives to learn, communicate, and entertain themselves. Technology should be used in ways that add value to the educational process and extend the possibilities of traditional learning tools. Educating the 21st century learners means using state-of-the-art technological tools to facilitate and inspire student innovation and creativity, to design and develop both personalized and collaborative learning experiences and assessments, to model digital-age interdisciplinary work and learning, and to promote equity, digital citizenship and responsibility.

A huge obstacle in the uptake of advanced technological solutions (such as serious games, augmented and virtual reality) in schools on primary and secondary level, is that pre-service and in-service teacher education does not contain the concepts of conceptualising, designing, and applying such solutions to the extent required. At the same time, the increasingly available study programmes for game designers and game developers (such as the bachelor and master programmes at CGL) only begin to take educational games and advanced educational technologies into account. Currently, those programmes lack the theoretical underpinning of pedagogic and didactic theories to contribute to the development of educational technologies more substantially. Likewise, computer science education focuses on the technical aspects of solutions with too little attention to design aspects and pedagogical underpinnings. As a result, contributions to increased use of digital technologies in education often come from mono-disciplinary backgrounds and thus do not reflect the state of the art in various disciplines. Consequently, solutions often fall short to reach their educational potentials (Kelle et al., 2011).

Acknowledging the fact that the increasing complexity of concepts such as augmented reality games for educational purposes require **cross-disciplinary understanding and collaboration** to deliver valuable results from educational, game design, and technological perspectives, the *imTech4Ed* project was proposed in an attempt to move away from the mono-disciplinary approach in fields that would need to collaborate to design and deliver widely usable game-based educational solutions. Relevant fields comprise: game design, where immersive and interactive solutions are designed and developed; Computer Science, where the technological foundations for immersive technologies and for scalable architectures for these are created; and teacher education, where pre- and in-service teachers are educated. Currently, these fields have only little connection to each other. However, recent approaches in the relatively new interdisciplinary game design educational programs for bachelor and master students demonstrate the value of interdisciplinary education and problem-based learning (Klemke & Hettlich, 2019) for cross disciplinary collaboration **of programmers, designers, and artists**. Recognizing the potential of such approaches, *ImTech4Ed* aims to reverse the current situation and to deepen research in the emerging area of serious games and other immersive technologies for STEAM, attempting to bring together teacher education, game design education, and computer science education to engage in participatory game co-design.

Recent developments in the literature **emphasize the transformative power of collaboration and interactivity** when working on STEAM education projects. Through collaborative projects, students engage in co-design and authoring, where they contribute their ideas, insights, and creativity to shape the content and structure of immersive experiences. This active involvement fosters a sense of ownership and agency, empowering students to take control of their learning and become co-creators of knowledge. Collaboration in STEAM projects also promotes peer-to-peer learning, as students exchange ideas, provide feedback, and collaborate in real-time within virtual environments. By working together, students develop essential skills such as communication, problem-solving, and critical thinking, while also building teamwork and empathy. Moreover, when teachers actively participate in the collaborative process, they serve as facilitators, guiding and supporting students' learning journeys. This collaborative approach in STEAM projects not only enhances engagement and motivation but also nurtures deeper understanding and meaningful learning outcomes. The added value of collaboration is evident throughout all stages of an educational activity, irrespective of the learning context (e.g., conventional or e-learning) or the scientific subject involved and adds value to every step of the research process, such as hypothesis generation, data interpretation, and result dissemination (Mystakidis et al., 2022).

In addition, immersive technologies can further foster collaboration in STEAM projects. They enable students to discover and explore an environment interactively and collaboratively (Syawaludin and Rintayati, 2019). This way they provide a unique platform for students to become active participants in their learning process. Immersive technologies, when properly implemented, can improve the performance of students, motivate them, help them collaborate more, increase spatial awareness, and boost their motivation (Ajit, 2021; Kalemkuş and Kalemkuş, 2022). Alkhabra et al. (2023) conclude that the integration of immersive technologies and STEM activates complex problem-solving and fosters collaboration. Pellas et al. (2017) stress the important role of collaboration based on theoretical foundation of Socio-Constructivism for STEM education. According to Miller et al. (2020) the key point of social constructivism emphases that knowledge is not confined solely within individuals. Instead, learning and comprehension are fundamentally social processes, and meaningful collaboration is essential for both individual and group development. Creating the conditions for students to discuss and exchange their opinions provide them with the appropriate learning environment to explore and encourage an investigative attitude which are fundamental features of an instructional design aimed at supporting knowledge acquisition through interaction.

The discussion that follows links the existing situation in all partner countries of the *ImTech4Ed project* (Cyprus, Greece and Germany) with the current literature in relation to identified questions concerning students' interest in STEAM studies and careers and how this is influenced by factors such as gender, socioeconomic status, performance and expectations. It also illustrates how these are linked to secondary students' participation in tertiary education for the pursue of degrees in STEAM related fields. Finally, the sections that follow attempt to present the status of national policies at country level, and the degree of adoption of interdisciplinary STEAM approaches and game-based pedagogy in education. The information presented, not only highlights the need for widening the accessibility to STEAM fields for an inclusive range of learners, but also supports the necessity of offering further solutions for the adoption of cross-disciplinarity both in secondary and in higher education. Finally, the following sections exemplify the significance of enhancing teachers' professional development as priority at policy level, as much as of facilitating teachers' familiarization with emerging technologies at microlevel, for the promotion of STEAM fields, careers and related skills; the latter identified as essential in cultivating collaboration, creativity and collective consciousness among today's learners/citizens.

3 Existing situation concerning STEAM studies and careers

The following section discusses the existing situation concerning STEAM studies and careers in the three partner countries (Germany, Greece and Cyprus), within the wider European framework, and it identifies elements such as national policies and governmental support, educational reform, school attitudes, and students' access to counseling, that might be significant in shaping studies and careers in STEAM. More so, the section discusses secondary education students' performance in math, science and the arts, adolescents' expectations and choices relating to their future careers, students' representation in STE(A)M studies and careers later in life and how their choices might relate to factors such as gender and socio-economic status. Finally, the section provides insight to the demographics of researchers by sector and academic field, and their representation in higher education institutions (e.g. academic staff, university heads, part-time employment, salaries).

3.1 Performance in Math, Science And The Arts (@ Secondary & HE)

Based on the most recent PISA results (OECD, 2019), which included data from 79 countries about **15-year-old student performance in reading, math, and science**, adolescent students from Greece and Cyprus perform below the OECD mean in both science and mathematics, whereas in Germany students perform higher than the average OECD mean in both math and science. While this has been the case for German students' performance in math since 2003, the average performance in sciences has declined since 2012 as the Natural Sciences are no longer one of the major domains in the country. However, as stated in Trends in International Mathematics and Science Study (TIMSS) the overall performance for both math and science has seen a decline over the past few years in Germany, **posing questions relevant to how this relates to and impacts on students' motivation, confidence and positive attitude towards math and science.** Similar indications were reported in Cyprus where a decline from 4th to 8th grade can be observed in students' enjoyment, confidence and value beliefs about science, as 8th grade students' score tended to drop below the center point[1]. Respectively, students seemed to maintain positive views about the enjoyment and value of math and about their ability to succeed in mathematics at the secondary level (Mullis et al., 2020) and this is possibly linked to their ability to achieve higher scores in math (as reported in TIMSS 2019).

Studies have similarly supported that there is a close relationship between students' performance and their attitudes; the latter refers to a student's learned tendency to respond positively or negatively to an object or concept. Negative attitudes seem to impact effective learning, and consequently learning outcomes and performance (Mazara et al., 2019). In another relevant study, it is suggested that students can have positive and negative attitudes at the same time, and that it is unclear whether positive attitude towards Math is the cause of high achievement (Syyeda, 2016). Instead, the study found that high ability and gender are factors that impact on performance, since,

[1] Centerpoint refers to the mean of the combined achievement distribution of all participating countries, which in this case was 500.

for instance, girls – even high achieving girls – “seem to be under the impact of imposter syndrome […] and are unsure of performing well” (Syyeda, 2016, p.55).

Another factor that seems to impact on students’ high achievement in math and science is not only the students’, but the **school’s attitudes towards academic achievement**. Schools that emphasize academic success are often well prepared with highly skilled teachers, while parents are equally supportive, since they have their own high expectations for students’ success. In such environments, students seem to also desire to do well and are well supported to meet the school’s academic goals across different disciplines (Mullis et al., 2020).

3.2 Adolescent Student's Career Expectations in Stem or Steam

According to the European Commissions’ *Education and Training Monitor (ET 2020)*, “European countries have made great progress towards expanding participation in education since the establishment of EU benchmarks in 2009 as part of this process”. However, approximately 20% of 15-year-olds across Europe **remain at risk of educational poverty with main factors being the lack of basic competences in literacy and mathematics or sufficient knowledge of science subjects**.

In Cyprus, more than 30% of 15-year old students failed to reach basic proficiency levels in mathematics, in 2015, whereas the percentage of students with low achievement in mathematics in the EU was 22.2%. PISA defines “low achievers” as those students who in basic skills score below the baseline level of proficiency that is required to participate fully in modern society. This can result in increased risk of unemployment and exclusion from society. **Such low achievement in mathematics at national level is possibly linked to career expectations and fewer possibilities for adolescents to pursue a career in STEAM**.

There is also an observed **gender gap** in students’ performance both in mathematics and in the natural sciences. It is estimated that girls will pursue a career related to natural sciences to a greater extent than boys (OECD countries, d = 0.15). It is worth noting that in Greece the differences between the two genders in favor of girls are significantly higher than the OECD average. In Germany, however, not only are there fewer girls than boys performing at or above Level 5 in Natural Sciences, but girls – even top-performing girls – are also less likely than boys to expect to work in a science-related occupation. Amongst high-performing students in mathematics or science, about one in four boys in Germany expects to work as an engineer or science professional at the age of 30, while only one in eight girls expects to do so. About one in four high-performing girls expects to work in health-related professions, while fewer than one in ten high-performing boys expects to do so. Only 7% of boys and 1% of girls in Germany expect to work in ICT-related professions. Of the total number of students, 63.1% of students in Greece expect to work in jobs unrelated to the natural sciences (Sofianopoulou et al., 2017). On average, Greek students expect to do some work related to sciences in higher rate than the OECD average. More specifically, Greece ranked second in the world, behind only Italy, regarding the number of women who chose natural sciences and engineering for their post-secondary education. 44% of individuals studying in these fields were women, compared to an average of 34% throughout the areas of the OECD.

Certainly, gender is not the only factor that impacts on adolescent students' career expectations in STE(A)M. Several studies have identified **socio-economic status** to be of significance in terms of the choices that students make, but most importantly in terms of students' expectations about their future careers. In a recent study, findings showed that the exploration of career options increased based on career aspirations, regardless of students' socioeconomic status. Yet, "findings from this study underline the vital role of socio-economic status in the way individuals actualize their career aspirations in career exploration activities" (Sawitri & Suryadi, 2020, p.262). In another study, authors point out the significance of understanding the diversity and complexity of career aspirations and how these intersect with socioeconomic status and other markers of social difference across the years of schooling (Gore et.al. 2015). The same study indicated that students from higher socioeconomic status tend to speak of future careers based on passion and interest, appearing to have a feeling that of greater scope in terms of the range of careers that are able to pursue, whereas students from lower socioeconomic status tend to cite money as the main motivator (Gore et.al. 2015). These are particularly important in better understanding students' motivations and choices of their future careers and essential in considering ways through education and instruction, to offer a broader range of possibilities available to all students.

This also relates to another more general concern relevant to **students' access to counseling and appropriate support services that help them make informed decisions about their future careers**. According to the European Commission's *Joint Employment Report 2019* (2019, p54) "Cyprus has launched an outreach project supported by the Ministry of Education in cooperation with the Ministry of Labour and the Cyprus Youth Board, aiming to reach out to 4,000 inactive NEETs (Not in Education, Employment or Training) and to provide them with activation support through counselling and tailor-made training". This is particularly important for all EU countries, considering the shifting demands of the labour market, the complexity of career options, and the shrinking sense of stability and job security. More so, the focus has moved from preparing students for a single career path towards preparing students for career changes over their lifetime as well as for lifelong learning.

3.3 Students' Representation in STEM/STEAM (UG And PG Programs)

3.3.1 Participation in tertiary education

Based on data produced for the years between 2010-2017, across the EHEA (European Higher Education Area), most tertiary students (56.4 %) were enrolled in first-cycle programs (bachelor programs), while 21.2% was enrolled in second-cycle programs (master degree or equivalent level) and 19.7% in short-cycle tertiary education. Just 2.7 % of tertiary students were enrolled in third-cycle programs (doctoral or equivalent) (European Commission, 2020). According to *The Bologna Process Implementation Report* (European Commission, 2020) the largest percentage increase in the number of enrolled students in tertiary education, between 2000 and 2017 took place in Turkey, with an increase of over 600 %, followed by Cyprus (increase of over 300 %). Comparing 2000 to 2017, a rise in the enrolment rates was recorded in the majority of countries. Greece, experienced an increase of about 11 percentage points. Based on the same report, these changes for this particular period of time, need to be considered in relation to other factors, such as demographic changes, the structure of the (higher) education systems (type and amount of programs available, facilitation of part-time study etc.), country-specific characteristics, national policies and changes in economic conditions (i.e. employability rates) that all impact on students' expectations and desire to enroll to tertiary education and to continue their studies at a doctoral level .

According to the report of the German Ministry for Education and Research (BMBF)[2], in no other OECD country is the STEM degree as popular as in Germany. More than a third (36%) of all graduates obtained a tertiary degree in 2017, i.e. a university degree or a job-oriented tertiary educational degree in a STEM subject[3]. The percentage of STEM graduates in Germany in 2018 is 46,7% higher than in the EU (35,2%).

Greece has the fourth highest tertiary enrolment rate among OECD countries and has experienced an increase in tertiary education attainment over the last decade (OECD, 2019c). According to the OECD and data gathered during the year 2012 (OECD, 2015b), Greece has the sixth-highest number of "STEM" graduates in the world, with 26% of its degrees being awarded in the fields of STEM. According to the Publications Office of the EU (2016) for the 6-year period between 2006 and 2012, the share of graduates in STEM-related disciplines in Greece increased from about 19.5% to 23.5%. Both of these were upper than the EU28 average which were stable at 19% for 2007 and 2012. Further, the percentage of graduates in STEM-related disciplines in Greece at 2012 is the third higher over the European countries. According to the IOBE (2017) report, it appears that university graduates pursuing postgraduate studies in Greece, are mostly in the scientific fields of Natural Sciences, Mathematics and Statistics (from 16.8% in the 2002-2003 academic year, the number decreased to

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[2] https://www.datenportal.bmbf.de/portal/de/bildung_und_forschung_in_zahlen_2020.pdf

[3] While the percentage of graduates is above average in Germany, the gender gap in tertiary education in STEM is bigger than the EU in general. In Germany the women in STEAM education tend to choose natural sciences, mathematics and statistics significantly more than engineering or ICT. In 2012 the number of women graduating from ICT decreased slightly and increased in natural sciences, mathematics and statistics in comparison to 2006. Within EU-28, Germany had the largest increase of females in STEM in tertiary education from 2004-2012, however, a slight decrease in vocational training.[3] In 2019 the participation of females in Math and Science was nearly 50%. In Greece, for 2018 only 42% of graduates were women.

According to the European Institute for Gender Equality (EIGE, 2018) large variations in terms of gender segregation exist inside STEM. ICT, engineering, manufacturing and construction are the most men-dominated fields of education. Overall, in the EU, women constitute 19% of STEM graduates in engineering, manufacturing and construction, and 17% in ICT. Overall, at the EU level, the share of women graduates in ICT decreased from 22% in 2004-2006 to 17% in 2010-2012. At the EU level, the share of women graduates in engineering, manufacturing and construction reduced from 19% in 2004-2006 to 18% in 2010-2012. Natural sciences, mathematics and statistics have sustained a gender-balanced distribution of graduates or remained a women-dominated study field during the last decade. The proportion of women among STEM graduates for the years 2013-2015 in Greece is close to the EU average for Natural sciences, mathematics and statistics, and Engineering, manufacturing and construction, however it is significantly higher in the field of ICT where Greek women have a proportion more than 30% when the EU average is at 17%

13.2% in the academic year 2015-2016) and Engineering, manufacturing and Construction (from 13.2% to 9.6%).

In Cyprus, despite the improved performance of students in Math and Science at 8th grade, the percentage of students in STEAM fields at the university level is still much lower than in other fields: the total percentage of graduates in the fields of the Arts and Humanities (7%), the Natural sciences, mathematics and statistics (2%), ICT (2%) and Engineering (10%) together do NOT amount for the percentage of graduates in Business Administration and Law (39%) (*Education and Training Monitor 2020*, 2020). According to Education and Training Monitor 2020 for Cyprus[4], the share of STEM graduates back in 2018 was at 15%, which is much lower than the EU average at 25%. Only 2% of graduates obtained a degree in ICT (EU average: 3.6%).

Given the above, it is imperative for all EU countries to encourage, promote and fund STEAM related activities in order to improve these numbers. Industry 4.0 suggests that future graduates should be able to cope with the needs of future jobs. Such jobs are the green jobs that are expected to be created in manufacturing, construction, services, waste management and sustainable finance (EC, 2020). Also, due to the Covid 19 pandemic outbreak, some jobs had to switch to new modern technologies[5] in order to cope with the situation and move part of their services online. This indicates that future citizens / professionals should have an all-round education with strong science background to tackle future societal challenges.

3.3.2 Entrance to doctoral programs and doctoral degrees earned

As presented in the previous section, only 2.7 % of tertiary students were enrolled in third-cycle programs (doctoral or equivalent) based on data produced for the years between 2010-2017, across the EHEA (European Commission, 2020). Across the EHEA both women and men show high preference for doctoral studies in the field of natural sciences and mathematics (European Commission, 2019a).

For Cyprus, the proportion of women among doctoral graduates increased in the decade between 2007-2016 (European Commission, 2019a). Based on the same source, for Cyprus: women graduates in natural sciences mathematics and statistics was around 30% compared to the 20% of men in the same field; there were no ICT women graduates while men graduates in ICT were around 10%; and around 10% of women and 30% of men were in engineering manufacturing and construction. In Germany, the participation of females in Math and Science was nearly 50%. Of the women in Math and Science, 35,4% are graduating with a Bachelor, 29.6% obtain a Master's degree, and 15% graduate with a PhD. In Engineering however 56.1% are graduating with a Bachelor, 36.3% earn a Master's degree, and just 3.6% graduate with a PhD. In general, the career percentage of women is constantly dropping across fields. The percentage of female academics who pursue careers in Math,

[4] https://op.europa.eu/en/publication-detail/-/publication/f2b8bedb-2496-11eb-9d7e-01aa75ed71a1

[5] According to the 2020 report "The Future of Jobs" by the World Economy Forum: "... by 2025, 85 million jobs may be displaced by a shift in the division of labour between humans and machines, while 97 million new roles may emerge that are more adapted to the new division of labour between humans, machines and algorithm" (p. 5)

Science, or Engineering is lower than their participation in the study programs. The gap is highest on the level of professors.

According to OECD (2019c) for 2018 in Greece, women account for 45% of doctoral graduates, which is close to the average share across OECD countries. This share is slightly smaller for the broad field of engineering, manufacturing and construction, and slightly larger in the field of natural sciences, mathematics and statistics. According to SHE Figures 2018 report (European Commission, 2019a), the fields where women have the highest proportion of doctoral graduates are in education (72%) and Services (63%) followed by the field of Natural sciences, Mathematics and Statistics (58%) with much lower proportion in the fields of Engineering manufacturing and construction (36%) and at the field of Information and Communication Technologies (14%).

3.4 Employment in Stem/Steam Research and Professions

3.4.1 Demographics

According to the Bologna Process Implementation Report (2018) (*The European Higher Education Area in 2018: Bologna Process Implementation Report | Eurydice*, n.d.) Cyprus had a notable increase of 204% of academic staff between 2000-2016, with a corresponding increase in student enrollment in tertiary education around the same period (2005-2016). The age group of 35-49 accounts for the largest proportion (almost 40%) of the academic staff, with the percentage of academic staff over 50 to be less than 30%. More so, according to the SHE Figure (2018) most grade A staff of either sex, across the EU as a whole, were in the oldest age group. The least numerous age group was the youngest one, which represented 0.4 % of women and 0.2 % of men in grade A positions. This is to be expected if one takes into account that advancement to **grade A positions usually requires a number of years of academic experience.** The 35-44 age group made up 9.9 %, and the 45-54 age group made up 34.7 % of grade A women in the EU.

At the same time, achieving an equitable gender distribution has been a system level aim. In Cyprus the percentage of female representation in academic positions has increased from 37% (in 2000) to 42.3% (2017) compared to the EHEA median of 45.2%. According to the Bologna Process Implementation Report (European Commission, 2018) Greece had the lowest proportion of academic staff at the ages bellow 35 (3.3%), for the year 2015. The age group of 50-64 accounted for the largest proportion (46.2%) of the academic staff, with the percentage of academic staff of 35-46 to be close by 44.7%. In addition, for the year 2016, Greece had the fourth lowest proportion of female academic staff (32.7%).

According to the European Commission (2019a), women face greater difficulties than men in advancing to the highest academic positions in all the countries examined. Further research shows that the **gender gap in scientific output** is attributable to women's different patterns in a number of factors that are essential of the advancement of their scientific career. For example, women are less internationally mobile than men in more senior positions and therefore have fewer opportunities for international collaboration, which is essential for successful grant competitions. Women are often caught in a vicious circle: less funding success leads to fewer opportunities to improve their scientific performance and vice versa.

Nevertheless, the situation for women has improved, albeit slightly, since 2013 in most countries (SHE Figures, 2018). The proportion (%) of women among heads of institutions in the Higher Education Sector (HES) in 2017 was 21.7% for EU-28 (Cyprus: 10.4%, Greece: 11.1% and Germany: data unavailable).

According to (European Commission, 2019a) in 2015 the average for EU-28 proportion of women working as researchers was 33.4% while in Cyprus this percentage was a little higher (37.9%); of that the business sector occupied 12%, the governmental sector 12%, the higher education sector 72% and the private sector the remaining 4%. At the same time, the male researcher percentages were 15% for the business sector, 6% for the governmental sector, 72% for higher education, and 7% for the private sector.

Based on the same source, it seems that women in Cyprus are more likely to engage in research in the social sciences (34%) rather than in natural sciences (18%) or engineering and technology (21%). At the same time, male researchers engage in the various disciplines as follows: 30% in social sciences; 29% in engineering & technology; 21% in natural sciences and 13% in humanities. According to SHE Figures 2018 report (European Commission, 2019a) in Greece both men and women researchers were more likely to work in engineering and technology. However, it is indicative that for the year 2016 in Greece the number of senior academic staff by field of Research and Development was 103 women in contrast to 539 men for natural sciences and even worst 107 women in contrast to 763 men for Engineering and technologies.

As reported in SHE Figures (European Commission, 2019a) part-time employment of researchers in the higher education sector out of the total population of researchers was women 13% and men 8% for EU-28, while for Cyprus the equivalent numbers were women 6.7% and men 8.5%. For Greece the equivalent numbers were: women 2.1%, men 1.0%. Based on the same resource, in the vast majority of countries, women working in scientific R&D earn less on average than men, with the gender pay gap being slightly wider than in the total economy. Overall, the gender pay gap in scientific R&D widens with age. At the EU-level, women's average gross hourly earnings were 16.6 % lower than those of men in the total economy, and 17.0 % lower in scientific R&D activities.

Employment rate of tertiary-educated 25-64 year-olds at 2018 for Engineering, manufacturing and construction was 77% in Greece which is lower from OECD and EU23 average which was 89% for both of them (OECD, 2019c). According to Publications Office of the EU (2016), STEM unemployment rate in Greece at 2003 was about 6% when the average unemployment was about 26%. Therefore, the potential of STEM fields in labor market for Greek people is positive and for this reason many students will choose to study one of those fields.

3.4.2 Employability of STEM/STEAM professionals

Based on the Council recommendations in the *2019 National Reform Programme of Cyprus* (European Commission, 2019b), the proportion of young people not in education, employment or training in 2018 was among the highest in the EU. As reported in the 2019 *National Reform Programme of Greece* (European Commission, 2019c), the share of long-term unemployed, who represented 70% of the unemployed in Greece in 2018, is very high, while high youth unemployment and low labor market participation of women are also a matter of concern.

This is mainly due **to inadequate public employment services and their limited activation in helping people find work.** Part of the recommendations for reinforcing support for access to employment, in particular for young people and the long-term unemployed, is the **promotion of self-employment** and helping people gain skills that are better suited for the needs of the labour market. This, along with an identified lack of basic digital skills among Cypriots between 16 and 74 years (only 50%) and with ICT specialists still representing a lower proportion of the workforce compared to the EU (2.3% vs 3.7%), a direction towards STEAM careers seems essential. STEM related job openings are anticipated to increase in Cyprus (and all member states) during 2013-2025 (*Encouraging STEM Studies - Publications Office of the EU*, n.d.) .

According to the report *Does the EU Need More STEM Graduates?* (Publications Office of the EU, 2016) in 2016 the stock of STEM professionals and associate professionals in Cyprus included 37% in the age group of 25-34; a 26% in the age group of 35-44 and the remaining 37% in the age group of 45-64 years old. According to the Publications Office of the EU (2016), Greece has an increased stock of young professionals in STEM among other EU countries. In particular, for 2013 the stock of STEM professionals and associate professionals in Greece included 33% in the age group of 25-34 which ranks Greece 11th between the 28 reported countries; a 26% in the age group of 35-44 and the remaining 41% in the age group of 45-64 years old.

In the majority of EU-28 countries, **fewer women than men are employed as scientists and engineers** (S&E), according to the SHE Figures 2018[6]. Despite a number of strategies aimed at encouraging more women to opt for technical and engineering jobs, these categories do not feature in the list of the 20 most popular professions among women. Instead, women (as stated by the national report of Germany) tend to prefer jobs such as office administrator, doctor's receptionist and sales assistant, while the shortage of skilled STEM workers emphasizes the lack of female interest in the domains of engineering and IT, which are often more popular among men (Gillmann, 2018).

[6] https://ec.europa.eu/info/publications/she-figures-2018_en

3.5 National Education Policies that Promote Steam Studies and Careers

Beyond individual characteristics, gender gaps, the family and school environments, it has been proven that policy interventions at a national level strongly influence young people's career plans as much as their willingness and ability to pursue a career in STEM/STEAM. At a European level and based on supporting literature, the importance of cross-disciplinary educational approaches, of digital skills, creativity and criticality have been acknowledged as essential competences and skills for the labour market. STEAM education has also been widely recognized as a possible way towards achieving such goals and as "means of fostering scientifically oriented careers initiated from a very early age" (STEAMonEDU report, 2020)[7].

The new Digital Education Action Plan (2021-2027) for resetting education and training for the digital age, published by the European Commission[8], sets out two main priority areas for improvement: a) fostering the development of a high-performing digital education ecosystem emphasizing connectivity, infrastructure, training and ethical standards, and b) enhancing digital skills through digital literacy, computing and AI education, as well as ensuring that girls and young women are equally represented in digital studies and careers.

In Cyprus, according to the Joint Research Centre (European Commission, 2018), the existing situation concerning initiatives to improve STEM education is as follows: there exists a national strategy, 2 central mathematic activities are declared, no national centers and no careers guidance are denoted. According to the Ministry of Education (2019), at a national level, the Cyprus Youth Board submitted *The National Youth Strategy* that was adopted in 2019 and included the following policy proposals:

- Creation of a Youth Policy Institute
- Creation of a National Centre of Youth
- S.T.E.A.M. development and enhancement

In Germany there is a well-established STEM policy which was initiated more than 14 years ago that supports STEM education in early childhood through the implementation of individual competences in the school curriculum. However, STEAM is not formally included in the primary, secondary and high school educational system. Engagement with STEAM is based mostly on non-formal educational initiatives and opportunities (STEAMonEDU report, 2020). The same report mentions that the Federal Ministry of Education and Research in Germany published the STEM Action Plan in 2019 and defined four fields of action: STEM education for children and young people, STEM professionals, opportunities for girls and women in STEM, and STEM in society (STEAMonEDU report, 2020).

In Greece, on the other hand, there are no official state policies to promote the implementation of STE(A)M Education in Greek public schools (STEAMonEDU report, 2020). The STEAMonEDU report

[7] https://all-digital.org/wp-content/uploads/2021/01/WP3_D6_Guide-on-STEAM-education-policies-and-educators-needs_FINAL.pdf

[8] https://ec.europa.eu/education/education-in-the-eu/digital-education-action-plan_en

(2020) mentions “[t]he policies are exhausted in the urge for implementation of STE(A)M Education in texts of the Institute of Educational Policy (IEP). IEP is a scientific agency that provides support to the Minister of Education, Research and Religious Affairs on issues, among others, regarding primary and secondary education. IEP deals with scientific research and study and provides ongoing scientific and technical support on relevant educational policy planning and implementation”.

Moreover, a series of consultations between major EU policy makers led to the publication of official recommendations (COUNCIL RECOMMENDATION of 22 May 2018 on key competences for lifelong learning) and communications (Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions) that encourage progress on adoption and implementation of STEAM education, by calling for better research, knowledge sharing and awareness raising. Among the notable initiatives to advocate towards a STEAM Education framework, a series of funding schemes have been set by the European Commission in order to provide support for STEAM Education in Europe.

4 Existing situation concerning STEAM in education

There has been a worldwide interest in promoting STEM and STEAM education. In Africa, Europe, Middle East, US and indeed in many parts of the world, countries have been implementing various strategies / initiatives to promote STEM/STEAM education. For example, in Europe, Denmark has implemented a policy that aims at increasing the number of students who are interested in STEM programmes in school, while in Italy, a national plan is in place to support educational activities directed at encouraging careers in academic studies in the STEM areas (Belbase et. al 2021). Furthermore, five European countries (UK, Italy, Portugal, Belgium, and Spain) have launched the EuroSTEAM project (Haesen & Van de Put, 2018). This is a collaborative school programme that implements a framework for STEAM education in the partner countries. In the UK, the National Endowment for Science Technology, and the Arts (NESTA), Creative Learning Industries Federation and the Cultural Learning Alliance (CLA) collaborated to promote STEAM education aiming to create an amicable learning environment, where young students can have their full potential to grow (Siepel et. al., 2016).

At European Union level, the ‘strengthening STE(A)M education in the EU’ policy was adopted on the 26th of June 2019. The aim of this policy is to promote STEAM skills with a multi-fund approach to developing physical infrastructure, curriculum, training, and implementation in schools to achieve regional and gender equity in STEAM related careers (European Committee of the Regions, 2019). In addition, EU digital education action plan 2021-2027 (European Educational Area, 2021) was implemented, under the priority of enhancing digital skills and competences for the digital transformation, encouraging women’s participation in STEM studies. For this reason, a European Union project called Girls Go Circular (https://eit-girlsgocircular.eu) established. This project is contributing to reducing the digital gender gap by empowering girls aged 14-19 in Europe to develop their digital and entrepreneurial competencies. Therefore, a dedicated online learning platform was implemented offered courses for secondary education level, E-STEAM festivals were organized, and new educational programs were offered based on the interdisciplinary STEAM approach. In Africa, there have been a number of initiatives from various countries in the continent. More specifically, in South Africa, the STEAM Foundation NPC has been promoting STEAM education through educator training, manufacturing, and distributing instructional materials, and researching on STEAM issues (STEAM Foundation NPC, 2020). Other STEAM education initiatives reported, aimed at the empowerment and equity for women and girls; an example was the program called Women Entrepreneurs for Africa (WEforAFRICA, 2020). Another example is the Inspire Africa STEAM program, which was launched in schools in South Africa and used drone technology with science, engineering, mathematics, and arts (Kruger, 2019). In the Middle East, countries such as Egypt (Aziz, 2015) and the United Arab Emirates (Shaer et al., 2019), have actively supported the reform of the school’s curriculum to integrate STEM/STEAM education. In Egypt, schools are employing certification and STEM/STEAM accreditation to encourage and promote STEM/STEAM education. In the United Arab Emirates, STEM/STEAM education has been promoted through various programmes, such as the Advanced Science Agenda, Think Science, and National Agenda and the UAE Vision. In the US, a number of STEAM pedagogy initiatives have been implemented as means for inclusion and justice in pedagogy for marginalized and underrepresented communities (Kant, Burckhard & Meyers, 2018). In Hong Kong, there is a growing emphasis on the promotion of STEM education, which can be traced back to the '2015 Policy Address' that marshalled the Curriculum Development Council to promote STEM education for cementing the country's global competitiveness in innovations across the fields of STEM (Ali, 2021). Prior to this launch, most Hong Kong teachers taught only a couple of subjects, and they were not required to consider interdisciplinary STEM education with added engineering elements (Geng et al., 2019). The Turkish Science Curriculum of 2018 emphasized the significance of students' hands-on experiences in STEM, along with entrepreneurial applications. This new curriculum aims to foster students' understanding of the interdisciplinary nature of STEM fields and their ability to establish connections between engineering and science (Ibrahim & Seker, 2022). The new Australia Curriculum (version 9.0) which was approved in 2022 is taking several actions towards promoting STEM learning (Masters, 2022). In South Korea, Kang (2019) reported a decrease in STEM career interest among young people. This has compelled the government to initiate various educational reforms enabling the addition of STEAM lessons in all schools. As reported by Kim and Bolger (2016), the participants received positive influence on their attitudes towards integrated STEAM lessons, developing higher perceived ability and more profound value and commitment to STEAM teaching and learning.

For ImTech4Ed, the participating countries have reported some of their prominent examples in the subject as follows:

Cyprus has noted numerous STE(A)M-related activities at all educational levels, and a significant increase in STE(A)M educational approaches aimed mainly at primary and secondary level. The country reports at least five (5) local institutions offering related courses together with ten (10) research projects since 2016. This indicates that the country has been particularly keen in introducing and adopting the STE(A)M approach in their education system.

Germany has listed two examples, namely:

- The International School of Bremen[9] was awarded the MINT-EC status with a highly committed team who give extra-curricular activities such as support clubs for Mathematics, ECDL, Coding and Science, that help promote STEM profile to the students. The school is reported to organise several STEM-related activities mostly focusing on environmental sciences and space technologies.

- The Fraunhofer-Gesellschaft[10] which has created its own Talent School for students aged 16-19 interested in STEM subjects. The program comprises STEM-related workshops where talented young people work in teams for three days to develop solutions for various

[9] International School of Bremen. MINT/STEM. https://www.isbremen.de/education/mintstem - Last accessed on March 17th, 2021

[10] Fraunhofer-Gesellschaft. (2017). STEM Programs - Routes to Success in Science and Technology. https://www.fraunhofer.de/content/dam/zv/en/jobs-career/training/STEM-Programs_Routes-to-success-in-science-and-technology.pdf

challenges in modern research. Currently, there are eleven such schools in Germany that on average take 400 participants each year.

Greece has reported various example throughout the education system spanning from kindergarten to universities aiming to promote STEAM and STEM education. Most notable are:

- GMERA (Greek Ministry of Education and Religious Affairs) initiatives such as: "edulabs" in 2016, "skill labs" in 2020 (as a pilot approach to add STEM/STEAM material in the curriculum of public school). The ministry is planning to incorporate STE(A)M education lessons in the upcoming (2021-2022) academic year.

- GFOSS (Greek Organisation for Open Technologies) a non-profit organisation comprised of 37 Greek-speaking universities, which has supported the "STEM Discovery 2020 campaign" and designed the aforementioned "edulabs" for GMERA.

- E3STEM a non-profit professional body which provides best teaching and learning practices for the delivery of STEM education.

- Ellinogermaniki Agogi a private education organisation participating in numerous STEAM related research programs like: iMuSciCa and Open School for Open Societies for Stories of Tomorrow.

Overall, the three participating countries reported the existence of several STE(A)M activities and initiatives. These aim to promote STE(A)M education through training, workshops, competitions (hackathons) and by formally incorporating related courses in the curriculum of the countries' education systems. The main actors in this are public and private educational institutions, ministries, non-profit / non-governmental organisations; funding secured from EU research projects and local funding schemes and the people involved in carrying out these activities: the students and educators. It should be noted that in the last 5 years there has been a trend in introducing new projects/activities/initiatives in mostly STEM education but with an increasing interest in STEAM education.

5 The extent of adoption of STEAM and/or game-based pedagogical models

Based on the reports of the consortium partners, there is a growing interest in both STEAM and game-based pedagogy among the researchers and the practitioners in all the participating countries (Greece, Cyprus, Germany). However, the adoption of both STEAM and game-based pedagogy seems to be in an embryonic stage. The educational systems have not officially introduced either of them in their national curricula or everyday teachers' practice. However, it is reported that there are several EU funded research/educational programs or private initiatives regarding those areas implemented by local Universities and/or Schools or even by the National Pedagogical institutes. Yet, the fields mentioned above seem to be new for these countries; STEM pedagogy has already been introduced to a wider audience (Greece) or even in the national curriculum (Cyprus). The adoption of those approaches / pedagogical models in higher education is not reported in any of the participating countries. It seems that the research focus of both researchers and higher education institutions is concentrating on the implementation of those approaches/models in secondary education for research purposes.

As STEAM is a newly introduced concept, there are several perspectives and approaches regarding the purpose, the definition and the integration of A(rts) in the STEAM. Because of all these differences in the conceptualization and implementation of the approach, the non-adoption of STEAM approach by educational systems seems reasonable. The different purposes, types of integration, and perspectives of what A or Arts stands for will be presented in what follows.

There are two different approaches concerning the purpose of STEAM education which researchers in empirical studies adopt. The first emphasizes the significance of promoting learning in STEM disciplines. In contrast, the second one emphasizes the importance of enhancing students' general skills, such as perspective-taking, creative and problem-solving skills, knowledge transfer across disciplines, and promoting, exploring and experiencing new ways of knowing to students (Perignat & Katz-Buonincontro, 2019). Although empirical studies are divided between these two approaches, the pedagogical frameworks proposed highlight learning across disciplines related to a common and shared goal as the purpose of STEAM.

As Peppler and Wohlwend (2018) argue, "The promise of STEAM approaches is that, by coupling STEM and the arts, new understandings and artifacts emerge that transcend either discipline" (p. 88).

Transdisciplinarity, interdisciplinarity, multi-disciplinarity, and cross-disciplinarity are the four main types of integrations reported (Perignat & Katz-Buonincontro, 2019). It is clear that the STEAM approach brings these fields together, but there are different approaches on how that integration will take place within the STEAM. Table 1 explains the differences between the types of integration. Besides that, researchers also disagree whether STEAM should integrate all five areas or two or three of the disciplines (Perignat & Katz-Buonincontro, 2019).

Table 1 Types of integration in STEAM education based on Perignat & Katz-Buonincontro (2019)

Type of integration	Description	Examples
Transdisciplinary STEAM	Fully merged disciplines without boundaries and lessons rooted in authentic problems or inquiry	Liao, 2016; Glass & Wilson, 2016; Quigley et al., 2017
Interdisciplinary STEAM	Several disciplines together under a common theme, but each discipline remains discrete	Smith & Paré, 2016; Thuneberg, Salmi, & Fenyvesi, 2017
Multidisciplinary STEAM	Collaboration among two or more disciplines but are not merged	Gershon & Ben-Horin, 2014; Payton, White, & Mullins, 2017
Cross-disciplinary STEAM	Observing one discipline through the perspective of another	Gates, 2017 Smith & Paré, 2016

Although it is clear among educators and scholars that S is for Science, T is for Technology, E is for Engineering, and M is for Mathematics, there are different perspectives on what A stands for. Of course, A in the acronym is stands for "Arts", but the definition of that varies between researchers and educators from Arts Education to Arts and all the disciplines that are not included in STEM (i.e., Arts, Humanities and Social Sciences) and Arts as a "synonym of project-based learning, problem-based learning, technology-based learning, or making" (see Perignat & Katz-Buonincontro, 2019).

Researchers seem to struggle with several challenges concerning the design, the learning approaches, and other characteristics of innovative methods relating to game based learning. During the last two decades, mobile phones, for instance, play a significant role in everyday life, and it seems that this has strongly influenced researchers to focus on their educational use within the game-based learning context. Digital and mobile game-based learning seem not to be a simple transformation of the existing game-based learning approach due to new difficulties that come up in that context (Giannakas et al., 2018). Giannakas et al. (2018, p. 379-380) also point out that scholars and developers need to focus on:

1) *finding the juste milieu between delightful play and learning outcomes with reference to learning theories,*
2) *embedding adaptivity and flexibility capabilities for improving and varying the educational content and extending the game's life span,*
3) *embedding personalized functionalities for enhancing the learning characteristics of the environment and enriching the learning outcomes,*
4) *considering end-users' security and privacy doubts to an acceptable level,*
5) *taking advantage of emerging technologies and software frameworks (including cloud computing, game engines, advanced wireless infrastructures and services) to add flexibility, adaptivity and easy access to the educational content,*
6) *examining the potentials of creating new context-based learning activity strategies to assist developers to enrich context awareness, and*
7) *developing standards and common interoperability frameworks for facilitating and instrumenting code porting processes to a newer or different mobile platform.*

Moreover, Chang and Hwang (2019) highlight that considering learners' achievement, learning style, or other personal factors could lead to a better mobile digital game-based learning environment.

In conclusion, the four types of integration in STEAM education presented in Table 1, go beyond the boundaries of individual disciplines, emphasizing the integration of knowledge, skills, and perspectives from diverse fields. Within the STEAM framework, in particular, while trans-disciplinarity promotes the exploration of connections between STEM subjects and the Arts, there are several limitations, as trans-disciplinarity requires careful planning, coordination, and support from educators to effectively integrate diverse disciplines. Additionally, assessing transdisciplinary learning outcomes can be complex due to the multidimensional nature of knowledge integration. Moreover, it can be challenging to provide transdisciplinary instruction, learning, and inquiry, because of the inherent challenges of integrating multiple disciplines, as well as multiple ways of thinking, doing, and being (MacDonland et al. 2019)

STEAM and digital game-based learning are part of the state-of-the-art of education research and practice. Still, based on the above mentioned challenges along with the need of preparing educators for new approaches / models, their adoption from educational system is quite slow.

6 Survey results

As part of the Erasmus+ Programme "ImTech4Ed: Immersive Technologies for Education" surveys were carried out, involving secondary and higher education students as well as in-service teachers in secondary and higher education, in all the three partner countries: Cyprus, Germany, and Greece. The purpose of the surveys was to better understand the backgrounds, experiences, and views of our target populations in relation to STEM/STEAM studies and careers, game design, and integration of courses. Based on the results of the analysis information was gathered to support the development of the methodological guidelines of the ImTech4Ed project. In the next sections the methodology and the main findings of the teacher and student surveys are presented.

6.1 Secondary Education Student Surveys

6.1.1 Methodology

The survey was conducted in secondary education school children aged between 12-16 and the gist was to understand their in-school and out-of-school experiences as well as their background and beliefs regarding STEM/STEAM studies and careers. The survey aimed to also extract information about attitudes towards games not only as entertainment but also try to realize the extent to which games are used as part of a STEAM education approach. The survey was distributed to Cyprus, Germany and Greece. The instruments used were two versions of the same Google form (one in English and one in Greek). The survey included questions on: demographics; current knowledge regarding STEM/STEAM careers; attitudes and perceptions towards STEAM studies and careers; use of games in daily life; after school activities; current school practices on STEAM; use of games in school. Invitations were electronically distributed to partners (including the two main schools, one in Greece and one in Cyprus). Participation was completely voluntary and anonymous. No identifying information was collected from participants.

A total of 518 answers were collected from the two partner institutions: 320 (61.58%) from the English School, Nicosia Cyprus and 198 (38.42%) from Ellinogermaniki Agogi, Athens Greece. The participants included 64 12-year-old students, 104 13-year-olds, 147 14-year-olds, 147 15-year-olds and 56 16-year-olds. Gender wise, there were 248 boys (47.88%) who participated in the surveys, 249 girls (48.07%), 10 participants who identified as ‘other’ (1.93%) and 11 who selected ‘I prefer not to respond’ (2.12%).

In the following sections we put forward the main findings of this survey mostly focusing on identifying the current situation and best practices regarding STEAM education and the use of games in schools.

6.1.2 Knowledge regarding STEM/STEAM studies and careers

In the survey students were asked whether they had adequate knowledge of the types of activities that are involved in STEAM careers, whether they had family members or family friends who had worked in a STEAM related field, and whether they received support to attend higher-level math and science courses. Finally, students were questioned about the sources they have access to for getting/receiving career advice.

Based on students' responses it is evident that students are quite aware of the activities involved in STEAM careers, of the subjects they need to take for a career in STEAM as well as about sources for obtaining relevant information. As the table below demonstrates (Table 2) more than 40% of the students state that they have adequate to a lot of knowledge relevant to all three categories (activities, subjects, information finding). If one accounts for the students who have stated that they 'know something about it' then the percentage rises above 75%. This indicates that most students are aware of STEAM.

Table 2 Student knowledge regarding activities, subjects and information finding relating to careers in STEAM

Category	Activities	Subjects	Information finding
1 – I know very little about it	7.34	3.47	6.56
2	10.23	9.85	10.62
3	32.63	23.55	23.94
4	33.98	36.87	33.40
5 – I know a lot about it	15.83	26.25	25.48

On the question "Whom to you go to for advice concerning field of study or career choices" 85.5% of students selected 'Parents/guardians and family members', 30.6% selected 'Friends' while 29.3% selected 'Teachers' and 21.4% ticked 'Career Counselors'. The high percentage of students who turn to their family environment for advice and support is expected, but what is also of interest is the low percentage of students who turn to 'Career counselors' for advice. Counselors are supposedly there for this specific purpose. This identifies either a possible shortcoming of the system (i.e. not adequate professional development of counselors to adjust to the growing needs of adolescents today) or inadequate structures to support the cultivation of a relevant school culture that promotes the importance of career counseling for students.

The family's impact on students' choices is also reflected in the question relating to 'encouragement to take more or higher-level math or science classes'. In this question, 41.9% of students strongly agree and 30.3% agree that the immediate family plays a very important role in their decision to take higher level courses. Equally important seems to be their teachers' encouragement, as 31.1% of students strongly agree and 27.4% of them agree that teachers' role is significant in their decisions. Friends' encouragement seems to be of less importance, with 14.5% of students strongly agreeing and 28.2% of them agreeing that friends encourage them to take such courses.

6.1.3 Students' experiences in STEM/STEAM in higher education

During the survey students were asked if they currently take or have ever taken any STEM/STEAM classes. An almost even three-way split was reported with 39.1% answering 'No', 32.7% saying 'I am not sure' and 28.1% replying 'Yes'. One aspect worth mentioning is the high percentage of negative responses which indicates that STEAM courses or the STEAM pedagogy might not have penetrated the classroom as much as expected. However, this should be considered in conjunction to the equally high number of students not being sure if they have had a STEAM class or not. It seems that although students seem to be aware of the subjects needed for a STEM/STEAM related career (i.e. science, technology, engineering, math or arts), they remain unclear of STEM/STEAM as an integrated course.

The latter explanation is enforced by the fact that when students were asked about the classes they currently take, 74.5% responded that they take traditional classes e.g. math, physics, history; 15.0% takes classes integrating two or more subjects, while only 12.9% and 8.3% take STEM and STEAM classes respectively. The inter-disciplinary courses number a notable positive trend, but the relative STE(A)M percentages come to confirm the low penetration of the paradigm into the classroom.

Students were also queried if teachers perform certain tasks in their science, technology, engineering, arts or mathematics classes. These tasks relate to inquiry-based learning along with games and interdisciplinarity. The table below shows the most relevant questions and the percentages of the received answers (Table 3). What is noteworthy is the similar pattern of distribution across the different questions. It seems that teachers sometimes do often ask questions about a topic and encourage students to adopt research-based methods to collect and analyze information, promote collaborative learning (working in groups to find solutions to problems), use new ways of doing things and/or technology for inquiry. However, there is still a long way to go, since students indicated that there are still many cases in which instructors do not (rarely to never) find new ways of doing things or use technology for inquiry-based learning (38.7% and 41.1% respectively).

Table 3 Student replies related to inquiry-based learning

Frequency	.. Ask questions about a topic and search for information about it	.. Collect and analyze information	.. Work in small groups to find answers to problems	.. Find new ways of doing things and come up with new and different solutions	.. Use technology for inquiry (e.g. analyze data, use simulations, virtual worlds, write code)
1 – Never	7.1	8.11	7.9	12.7	16.2
2 – Rarely	18.1	12.9	16.9	26.0	24.9
3 – Sometimes	37.2	38.6	36.4	30.0	25.4
4 – Very often	25.6	29.1	31.2	19.9	21.8
5 – Always	11.7	11.2	7.34	11.2	11.5

An even bleaker picture is being painted by the questions relating to games and interdisciplinarity. More specifically when asked if games are used in order to learn something the replies included: 25.6% 'Never', 24.9% 'Rarely', 27.4% 'Sometimes', and only 15.4% 'very often' and 6.5% 'always'. The interdisciplinarity question prompted students if they are asked to 'work on interdisciplinary projects (e.g. combining engineering with arts)'. The answers were as follows: 33.2% said 'never', 29.3% replied 'rarely', 21.2% responded 'sometimes', 10.6% said 'very often' and only 5.6% selected 'always'.

These results might reflect instructors' limited familiarization with such integrated approaches, limitations relevant to school resources, lack of adequate time in the everyday curriculum, and a possible need for further training for the successful integration of such approaches in the classroom.

6.1.4 Digital Games and/or immersive technologies at home and at school

Some of the questions in the survey sought to gather data relating to students' engagement with games at home (as part of their leisure activities) and at school (as part for their formal education and learning). Based on questions relating to digital gaming habits and usage (i.e. 'Do you enjoy playing digital games?') 35.9% of students replied 'I enjoy it a lot', 25.8% replied 'I enjoy it', 17.7% answered 'It is ok', 13.3% replied 'I don't enjoy it that much' and 7.14% replied 'I do not enjoy it at all'.

The frequency of playing digital games at home was also queried and students were asked about the frequency in which they play digital games. To this, 33.7% of students replied '2-3 times a week', 23.1% selected 'every day' while 15.2% answered 'rarely', 11.9% said 'once a week', 10.4% noted 'once every few weeks' and finally 5.4% reported 'never'. The percentage of systematically playing students (33.7% + 23.1% = 56.8%) is a positive finding as more students will have the game-like mentality and would be willing to try games for learning. However, this also poses a certain challenge for the teachers since students' engagement with digital games in their everyday lives subsequently increases demands for teachers who are more technologically savvy and familiar with possible ways of integrating games in their teaching methodologies in fun and engaging ways.

On the question about the duration of playing ('How many hours do you play digital games per week?') 47.7% replied '1-5 hours'; 17.3% noted '6-10 hours'; 13.4% answered '0 hours' and 8.5% replied 'more than 20 hours'; 8.1% noted '11-15 hours' and 4.6% said '16-20 hours'. The high percentage of students playing 1-5 hours should not be a concern as this translates to less than one hour per day. What might be an issue for consideration is that about 20% of students play more than 11 hours per week and almost half of those play more than 20 hours per week (that is 1 day of the week is lost in playing games).

The survey results have also indicated important information relevant to the use of digital games in school; more specifically, about the frequency of use of digital games in the classroom, the courses which integrate games and the type of games used.

For the question about the frequency of digital games' use in the classroom the answers were disappointing as 47.3% of students answered 'rarely', 27.2% said 'sometimes'; 18.1% replied 'never' and 5.0% answered 'very often' while only 2.3% answered 'always'. Related to this question are two more aspects about the use of games in the classroom. The table below shows the responses to the questions about the subjects in which games are used and the categories of games used (Table 4).

Based on the table below, it would seem that 'trivia' and 'riddles' are the most used categories of games used in the classroom. This is somewhat expected as trivia can test existing knowledge, as well as produce new one – making it an easy-to-apply tool for many instructors, even those who are not very familiar with technology – while riddles can improve awareness, enhance analytical skills and improve concentration. In terms of school subjects that often use digital games, 'history' comes first which can be explained by the fact that the subject easily lends itself to trivia-based games; it is followed by 'Greek', and then 'science' where analytical skills in mathematics could be put to the test with riddles; it is followed by 'computing' where solving a riddle could be used to learn about 'sequencing', 'procedures' or 'conditionals'; Spanish and PSHCE are also subjects that seem to use similar digital games.

Table 4 Students' responses relating to current practices of games in school

Question: In what subjects do your teachers ask you to play digital games? (check all that apply)	n	%	Question: What categories of digital games do your teachers use in their classrooms? (check all that apply)	n	%
Art	18	3.5	Action	23	4.4
Computing	141	27.2	Adventure	14	2.7
French	46	8.9	Augmented reality	17	3.3
Geography	84	16.2	Kahoot	41	7.9
German	104	20.1	Riddles	129	24.9
Greek	177	34.2	Role-play	18	3.5
History	228	44.0	Simulation	49	9.5
Maths	73	14.3	Sports	16	3.1
Music	45	8.7	Strategic	59	11.4
PSHCE	120	23.2	Trivia	281	54.2
Religious studies	20	3.9			
Science	157	30.3			
Spanish	123	23.7			
Games are not used in any of my subjects	74	14.1	My teachers don't use any games in their lessons	112	21.6

More so, the survey included questions that aimed to collect data relevant to students' opinion about the learning process and their performance. The perceptions of students relating to the use of games in class is worth mentioning. More specifically, to the question 'I enjoy the learning process when we play games in class', 38.8% and 36.6% of students respectively answered 'strongly agree' and 'agree'. 16.9% replied 'neither agree nor disagree' while the 'disagree' and 'strongly disagree' answers were at 2.9% and 4.6% respectively. This would indicate that the interest level of students is increased and students appear more motivated to enjoy learning when games become an integral part of instruction. This would be further supported by students' responses to the statement 'playing games can help me develop my problem-solving skills'. In this, 33.5% of students replied 'agree', 28.1% said 'strongly agree', 25.4% noted 'neither agree nor disagree' and only each of 6.3% replied 'disagree' and 'strongly disagree'. These answers are almost mirrored to the ones relating to students' agreement with the statement: 'playing games can help me develop my critical thinking'. In this, 33.7% of students replied 'agree', 29.5% said 'strongly agree', 23.3% noted 'neither agree nor disagree' and only each of 6.7% replied 'strongly disagree' with 6.5 answering 'disagree'.

6.2 Higher Education Student Surveys (HE)

6.2.1 Methodology

Surveys with students were also conducted in higher education. The aim of these surveys was to investigate the background and perceptions of Higher Education (HE) students on STEAM studies and careers and their experiences with STEAM, STEM, multi-disciplinarity, immersive technologies and digital games in their university course settings. The survey was carried out in Greece, Cyprus and Germany. Almost all the questions were Likert-scale or multiple choice to allow students to complete the questionnaire in max. 20 minutes. The instrument was developed and posted electronically via Google forms. Invitation messages explaining the purpose of the study, and providing a link to the survey, were sent via email to instructors in higher education institutions in the three partner countries. Instructors were asked to carry out the survey in their classes, explaining that participation was entirely voluntary and anonymous. No identifying information was collected from participants.

A total of 150 HE students from Greece (36.7%), Cyprus (28%), Germany (28%) participated in the survey (56.7% male, 38% female, 4% other). The age range of the participants was as follows: 32.7% of students were between 17-20 years old, 26.7% of them were between 21-24 years old and 40.7% were 25 years old or older. Participants' field of study varied as follows: Computer Science (36%), Digital Games (15.3%), Social and Behavioral Sciences (14%), Arts (12.7%), Education (8.7%), Natural and Health Studies (6.7%), Humanities (3.3%), Engineering (2.7%) and Mathematics (0.7%).

6.2.2 Students' Knowledge regarding STEM/STEAM studies and careers

Based on students' responses in relating questions, students seem to have moderate knowledge (*mean:3.4, St. Dev.: 1.08*) about the types of activities involved in careers in science, technology, engineering, arts, or mathematics. The results are similar in the case of students' knowledge concerning the kind of courses someone needs to take in order to pursue a career in the fields of STEAM (*mean:3.6, St. Dev.: 1.05*) and how to find information about careers in the areas of STEAM (*mean:3.6, St. Dev.: 1.05*).

Based on students' responses (Table 5), someone from their family or a family friend is working or has worked in a math or science-related field (68%), as an engineer or in the information technology sector, or a related field (66%) and in an arts-related field (51.3%). It seems that among the participants, a large percentage (40.7%) has the least access to someone who is working in the field of the arts, whereas one out of four students, doesn't know anyone working in a math or science-related field or someone who works as an engineer or in the information technology sector or a related area.

Table 5 Students' familiarity with STEAM related jobs

Do you know anyone who is working or has …			
	… in a math or science-related field (e.g. chemist, statistician, meteorologist, biologist)?	… as an engineer or in the information technology sector, or a related field (e.g. electrical or civil engineer, software or games developer)?	… in an arts-related field (e.g. actor/actress, writer, ballet or modern dancer, musician, visual artist, cinematographer)?
Members of my family and family friends	**68.0**	**66.0**	**51.3**
Friends and colleagues	**5.3**	**7.3**	**8.0**
No, I don't know anyone	**26.7**	**26.7**	**40.7**

More so, based on students' responses (Table 6), it was most likely that their family encouraged them or thought it would be cool if they chose a job/career in math, science, engineering or technology (61.3% agree/strongly agree) compared to a job/career in the arts (34.6%), and to take more or higher-level math or science classes when they were in high school (60% agree/strongly agree) compared to art-related courses (36.7%).

Table 6 Students encouragement towards STEAM related careers and higher-level courses in math or science

	My friends encouraged me to take more or higher-level math or science classes during high school.	**During high-school, my friends would have approved or thought it would be cool if I chose a job/career in math, science, engineering or technology.**	**During high school my family encouraged me to take more or higher-level math or science course.**	**During high school, my family encouraged me or thought it would be cool if I chose a job/career in math, science, engineering or technology.**	**During high school my teachers encouraged me to take more or higher-level math or science classes.**
Strongly disagree	20.7%	12.7%	6.7%	8.0%	10.0%
Disagree	18.7%	14.0%	10.7%	7.3%	12.0%
Neither Agree nor Disagree	36.7%	26.0%	22.7%	23.3%	24.0%
Agree	**16.7%**	**25.3%**	**31.3%**	**24.0%**	**30.7%**
Strongly agree	**7.3%**	**22.0%**	**28.7%**	**37.3%**	**23.3%**

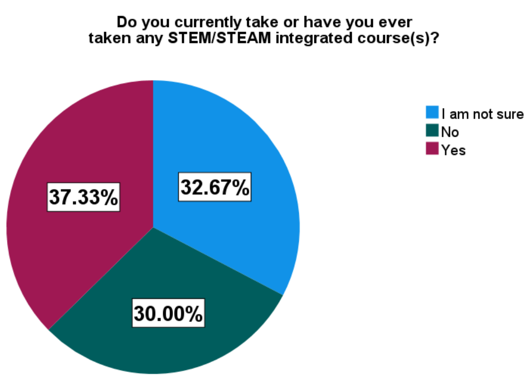
The same seems to be the case for their teachers in high school who had encouraged them to pursue a career in math, science, engineering or technology (54%) rather than a career in the arts (29.4%). It seems that there is not an important difference between the stances of their friends to either one of the two issues (pursuing a career in STEAM related jobs or undertaking higher level courses in any STEAM related area) (Table 7).

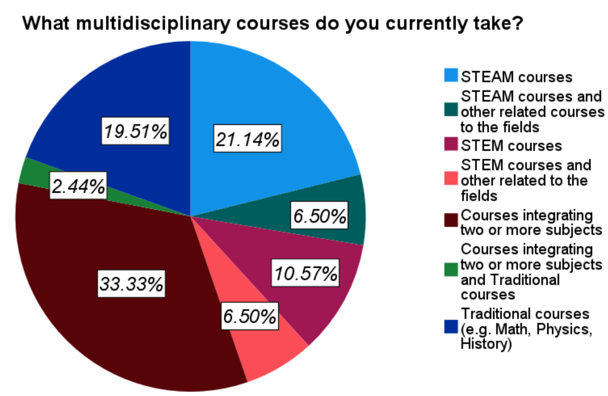
Table 7 Students' encouragement by friends towards STEAM related careers and higher-level courses in math or science

	During high school my friends encouraged me to take more or higher-level art-related classes.	During high school, my friends would have approved or thought it would be cool if I chose a job/career in the arts.	During high school, my family encouraged me to take more or higher-level art-related courses.	During high school, my family encouraged me or thought it would be cool if I chose a job/career in the arts.	During high school my teachers encouraged me to take more or higher-level art-related classes
Strongly disagree	21.3%	10.7%	16.7%	17.3%	18.7%
Disagree	20.0%	12.0%	20.0%	14.7%	18.0%
Neither Agree nor Disagree	32.0%	32.0%	26.7%	33.3%	34.0%
Agree	**17.3%**	**26.0%**	**24.0%**	**21.3%**	**18.7%**
Strongly agree	**9.3%**	**19.3%**	**12.7%**	**13.3%**	**10.7%**

6.2.3 Students' experiences in STEAM/STEM at the University

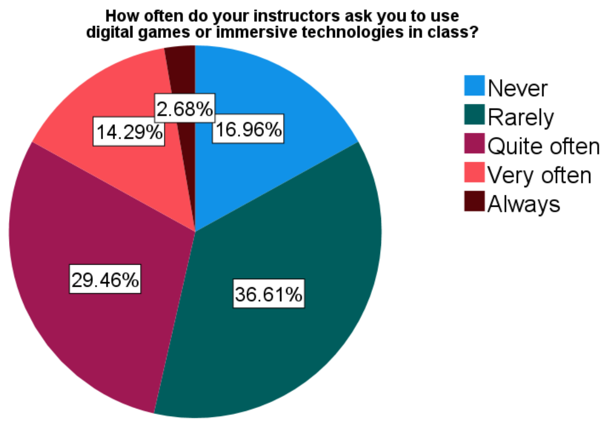
Based on the survey results, students are divided into three almost equal groups. Students of the first group (37.3%) stated that they have participated in STEAM/STEM integrated courses in the past, students in the second group (32.7%) stated that they have had no such prior experience, while a large percentage of students (30%) seem to remain inconclusive on that question, possibly reflecting a lack of a precise understanding and awareness of the nature of an integrated STEM/STEAM course.





Of course, the same students gave a more precise answer when asked about the type of multidisciplinary courses they currently take at the university. About one out of four students (27.6%) take STEAM and/or other multidisciplinary courses, 17% per cent of the students take STEM and/or other multidisciplinary courses, one out of three students (35.7%) participating in courses integrating two or more subjects and the rest seems to participate only in traditional courses (e.g., Math, Physics, History).

6.2.4 Digital games or immersive technologies at the University



The use of digital games or immersive technologies in class seems not frequent among the students who participated in the survey. About half of the students were rarely or never asked by the instructor to use digital games or immersive technologies in their courses. As shown in the pie chart, only about 16% use digital games or immersive technologies in class.

Table 8 Use of digital game and/or immersive technologies by subject

Course	Digital games or immersive technologies in class
Computer Science	37.3%
Art	22%
Education	15.3%
Humanities	8.7%
Engineering courses/laboratories	8%
Mathematics	8%
Social or Behavioral Sciences	5.3%
Natural or Health Sciences	3.3 %

Based on students' responses, instructors tend to integrate digital games or immersive technologies in their courses mostly in the field of Computer Science (37.3%), followed by Art (22%) and Education (15.3%). Digital games or immersive technologies are scarcely used in courses in the fields of Humanities

(8.7%), Engineering courses/laboratories (8%), Mathematics (8%), Social or Behavioral Sciences (5.3%) and Natural or Health Sciences (3.3%).

6.3 Secondary Education Teachers Surveys

6.3.1 Methodology

An instrument was developed and posted electronically via Google forms to collect information on teachers' current perspectives and experiences regarding STEM/STEAM education, current teaching practices and game-based learning in secondary education. The instrument was developed in English and contained one section on demographics and 4 other sections that focused mainly on various topics such as the Insights on STEM/STEAM in secondary education, self-efficacy and perceptions on immersive technologies learning, current teaching practices, current STEM/STEAM related teaching practices, the use of games and why games are not used, current game-related teaching practices, needs and recommendations relating to STEM/STEAM education. Nearly all questions were Likert-type or multiple-choice, to make it easy for teachers to complete the survey and respond to all questions. The questionnaire was distributed to all partners of the consortium in March 2021.

The questionnaire was administered to teachers in the partner High-Schools in Cyprus, Germany, and Greece. Teachers were informed that their participation was completely voluntary and anonymous. A total of *22* teachers (13 female, 8 male, 1 preferred not to respond) completed the survey: *11* teachers were from Cyprus (*50%)*; *10* teachers from Greece (*45.5%)*; and *1 teacher from Germany* (4.5*%)*. The majority were aged between 30-49 (*n=18, 81.8%*) and had been teaching for more than 5 years (*n=17, 77.2%*). Also, the large majority (*n=14, 63.6%*) had a Master's degree. Some of them (*n=8, 36.4%*) had worked in the industry. Also, the majority (*n=20, 90.9%*) work for a private institution.

During their undergraduate and postgraduate studies, teachers had a major, minor or special emphasis on various subjects such as Physics (*n= 7, 31.8%*), Science Education (*n= 7, 31.8%*), Elementary or secondary Education (*n= 7, 31.8%*), Computer Science (*n= 6, 27.3%*), STEM Education (*n= 6, 27.3%*), Biology or other life science (*n= 5, 22.7%*), Mathematics and/or Statistics (*n= 5, 22.7%*), Language (*n= 3, 13.6%*), Engineering (*n= 2, 9.1%*), STEAM Education(*n= 2, 9.1%*), Social Studies (*n= 2, 9.1%*), Arts – Visual Arts (*n= 1, 4.5%*), Physical Education (*n= 1, 4.5%*), etc.

The majority of teachers that participated in this study are currently teaching in High School (*n= 13, 59.1%*) whereas the rest in Middle School (*n=9, 40.9%*). Teachers had taught disciplines ranging from STEM Education (*n=11, 50%*), Physics / Chemistry (*n=7, 31.8%*), Science Education (*n= 7, 31.8%*), PSHCE (*n= 7, 31.8%*), Elementary or secondary Education (*n= 7, 31.8%*), Mathematics (*n= 6, 27.3%*), Computer Science (*n= 5, 22.7%*), Biology or other life science (*n= 4, 18.2%*), STEAM Education(*n= 4, 18.2%*), Language (*n= 2, 9.1%*), Social Studies (*n= 2, 9.1%*), Engineering (*n= 1, 4.5%*), Arts – Visual Arts (*n= 1, 4.5%*), Physical Education (*n= 1, 4.5%*), etc.

In the next sections the main findings of this survey are presented. Results are based on data on teacher responses to questions addressing their practices and views about STEM/STEAM education, current teaching practices and game-based learning. Due to the small number of participants no comparisons between institutions/countries were carried out.

6.3.2 Insights to STEM/STEAM education

In the question "Has STEM education (e.g. programs, courses) been introduced in the school where you work?", a significant portion of the participants (*n=14, 63.6%*) answered positively; some (*n=5, 22.7%*) answered negatively and the remaining (*n=3, 13.6%*) responded with 'I don't know'. Furthermore, for the question "Has STEAM education (e.g. programs, courses) been introduced in the school where you work?", a significant portion of participants (*n=12,* 54.5%) answered positively; some (*n=5, 22.7%*) answered negatively and the remaining (*n=5, 22.7%*) responded with 'I don't know'. Responses to the question about how many years instructors have been involved in STEM/STEAM education varied between 0 – 10.

This shows that STEM education appears to be slightly more widely used than STEAM in secondary schools. Furthermore, the majority of teachers (*n=12, 54.5%*) showed that they have had an involvement or a professional role in STEM/STEAM education. Some instructors stated that they had experience of more than 5 years in the field. Their role varied from participating in STEM/STEAM competitions (e.g. F1 in Schools, TEKE), as mentors, or teaching after school STEM activities, or being responsible for the design of educational scenarios in STEM (particularly in Physics Education with a focus on Modern Physics and Astronomy, earthquake sonification, educational visits, etc).

Regarding having any opportunity to participate in any STEM/STEAM related professional development activities, the majority of teachers stated that (*n=11, 50%*) they participated in training sessions/workshops while more than half of the teachers (*n=12, 54.5%*) had the chance for independent reading of professional literature. About (*n=4, 18.2%*) of the teachers stated that they have attended conferences, seminars, or professional association meetings. They also participated in a network of teachers and participated in international projects (*n=4, 18.2%*). Teachers also had the opportunity to participate in some professional development activities related to game-based learning such as (*n=8, 36.4%*) "Independent reading of professional literature", (*n=8, 36.4%*) of participants replied "Course/workshop/training sessions" and (*n=8, 36.3%*) of participants replied that they didn't participate in such activities.

6.3.3 Self-efficacy and perceptions on STEM/STEAM and game-based learning

In terms of Self-efficacy and perceptions on STEM/STEAM and game-based learning, the majority of the teachers stated that they are familiar with STEM education (*n=13, 59%*) and the teaching pedagogical methods (*n=14, 63.6%*) employed in STEM education. The majority of teachers (*n=15, 68.18%*) stated that they feel confident in their ability to motivate their students to study STEM subjects. Nevertheless, some participants (*n=7, 31.8%*) wonder if they have the necessary skills to teach STEM effectively while (*n=11, 50%*) believe they do. Nevertheless, the majority of teachers (*n=14, 63.6%*) stated that they feel comfortable incorporating STEM activities into their classroom and that they feel competent to facilitate the interdisciplinary, inquiry-based learning process in STEM education (*n=12, 54.5%*).

Regarding STEAM education, the majority of teachers (*n=14, 63.6%*) stated that they are familiar with this education approach and that they understand (*n=15, 68.1%*) the similarities and differences between STEM and STEAM education. They also stated that they know (*n=12, 54.5%*) what pedagogical methods are employed in STEAM education, while some of them (*n=11, 50%*) feel confident in their ability to motivate their students to study STEAM subjects. Regarding having the necessary skills to teach STEAM effectively, some teachers (*n=8, 36.3%*) believe that they do so, but some other are not sure (*n=7, 31.8%*) or feel that they don't have the necessary skills. Furthermore, more than half of the teachers stated (*n=12, 54.5%*) that they are comfortable incorporating STEAM activities into their teaching. Similarly, (*n=11, 50%*) teachers stated that they feel competent to facilitate the transdisciplinary, inquiry-based learning process in STEAM education and that they have (*n=6, 27.2%*) good awareness of potential STEAM career pathways for their students. Some teachers stated that they do not know where to find recourses (*n=9, 40.9%*).

When asked to state whether they agree with the statement "I do not understand why STEAM is beneficial", the majority (*n=15, 68.18%*) answered that they 'strongly disagree' and 'disagree' indicating that they do understand the benefits of STEAM. Similar negative responses were received (*n=17, 77.2%*) for the statement "I don't like the STEAM approach because I think it diminishes the individual importance of each content area" indicating that the teachers do appreciate the importance of STEAM. In addition to this, the majority of the instructors stated that they understand the importance of integrating content from different subject areas and disciplines (*n=21, 95.4%*). Most teachers (*n=15, 68.1%*) also recognize the importance of adding Arts to the interdisciplinary Science, Technology, Engineering and Mathematics (STEM) education framework. They also appreciate that with adopting the STEAM education approach, it is possible to improve teaching practices (*n=18, 81.8%*). The majority of participants believe (*n=17, 77.2%*) that there is a need for teachers of Arts/Humanities to plan and work closely with teachers in STEM disciplines to deliver STEAM courses. The majority of participants (*n=18, 81.8%*) also believes that the STEAM curriculum can bring an improvement in students' problem-solving and critical thinking skills while it can enhance students' learning as it connects different subjects within an authentic, real-world context.

For game-based activities, the majority of participants (*n=20, 90.9%*) agree that game-based activities should be used in educational practice. They also agree that game-based education promotes higher learning (*n=18, 81.8%*). Some teachers also believe that it is easy to monitor students' progress when incorporating game-based activities (*n=13, 59%*). It is also clear to the participants (*n=20, 90.9%*) that game-based activities promote 21st century skills. All teachers (*n=22, 100%*) also agree that students enjoy the learning process when they are engaged in a game-based activity. Nevertheless, some teachers (*n=6, 27.2%*) also consider that with game-based activities students' attention can be distracted away from learning while they also believe (*n=5, 22.7%*) that the use of electronic games for non-educational purposes affects student behaviour negatively.

6.3.4 Current teaching practices

During their classes, some teachers (*n=10, 45.4%)* stated that they often ask their students to solve complex problems or answer questions that have no single correct solution or answer. This was not so much the case when teachers were asked if their students were requested to create an original product (*n=12, 54.5%)*. Some participants (*n=16, 72.7%)* indicated that they ask their students to choose their own topics of learning or questions to pursue and they "very often" ask their students to take initiative when confronted with a difficult problem or question. Furthermore, the teachers "very often" ask (*n=10, 45.4%)* their students to draw their own conclusions as well as analyse (*n=8, 36.3%)* competing arguments, perspectives or solutions to a problem. Furthermore, the majority of the teachers stated that they encourage their students to collaborate with other students to set goals and create a plan for their team (*n=12, 54.5%)*. In addition, the majority of the participants (*n=12, 54.4%)* suggested that they 'very often' ask their students to use technology to support teamwork or collaboration and share information. The majority of the participants (*n=10, 45.4%)* also stated that they 'very often' ask their students to use technology to help solve real-world problems as well as work on projects that approach real world applications of technology.

When asked to indicate how often teachers use technologies/technological tools in their teaching, among the replies were the web browser (*n=20, 90.9%)*, email applications (*n=15, 75%)*, presentation software (*n=21, 95.4%)*, spreadsheets (*n=12, 54.5%)* photo/video recording or editing software (*n=19, 86.3%)* and word processors (*n=17, 77.2%)*. Some teachers (*n=10, 45.4%)* stated that they use education software designed for teaching such as Geogebra. Regarding using mobile devices in the class, results indicated that (*n=4, 18.1%)* of the teachers ask their students to use it in the class while some other teachers (*n=8, 36.3%) indicated that they use it very often*. About (*n=13, 59%)* of teachers also stated that they always or at least very often use game-based platforms or animations or simulations while another (*n=4, 18.1%) stated that they rarely or never use it*. Regarding the use of AR/VR tools during their class, the majority replied that they rarely or never do (*n=15, 68.1%)*. The same applies for real-time data collection devices and sensors (*n=12, 54.5%)* as well as educational robots (*n=15, 68.18%)*. The use of electronic voting is also another tool employed by teachers with (*n=8, 36.3%) stating that they always or very often use it.*

The majority of teachers also stated that assessment is mostly based on classroom participation (*n=20, 90.9%*) and exams (*n=12, 54.5%)*. Some teachers also stated that they do not assess or rarely assess their students based on physical models (*n=9, 40.9%*), dynamic digital products (*n=14, 63.6%*), prototypes (*n=15, 75%*) or portfolios (*n=10, 45.4%*). They do seem to prefer assessing them using authentic problem-based tasks and projects (*n=14, 63.6%*), worksheets (*n=15, 68.1%*) and quizzes (*n=13, 59%*).

When asked, "What courses do you currently teach?", more than half of the participants (*n=12, 54.5%)* replied 'individual disciplines' while another (*n=7,* 31.8%) replied 'both individual and STEM/STEAM integrated courses'. The remaining (*n=3, 13.6%)* taught in 'STEM integrated courses' and 'STEAM integrated courses' respectively. Also, the fields of knowledge the teachers cover in their STEAM/STEAM courses are (*n=6, 27.2%*) for 'natural science', 'technology' and 'engineering' and (*n=3, 13.6%)* 'art' and 'mathematics'. The approach methods teachers use for their STEM/STEAM courses were: the 'inter-disciplinary approach' (*n=7,* 31.8%), 'multi-disciplinary approach' (*n=2, 9*%) and the remaining (*n=1,* 4.5%) answered 'cross-disciplinary approach'. This was based on the feedback we received from 10 teachers.

Regarding the implementation of STEM/STEAM course(s), (*n=8, 36.3*%) teachers stated that they share knowledge, ideas and resources with teachers of other STEM/STEAM disciplines in their school. The same number of participants stated that they know where to find resources for teaching students using the STEM/STEAM approach. A low number of teachers (*n=3, 13.6*%) stated that they network and collaborate with teachers outside their school regarding STEAM/STEAM. Similarly, (*n=4, 18.1*%) teachers stated that they co-design, co-teach and participate in mentoring STEM/STEAM learning activities and materials with other colleagues.

6.3.5 Current game-related teaching practices

In the question, "Do you use game-based learning activities in your classroom?" answers were divided in the middle with (*n=11, 50*%) answering 'yes' and the remaining (*n=11, 50*%) 'no'. Teachers who do not use game-based learning activities, stated that they don't have the necessary skills to do it (*n=4, 18.1*%) while (*n=6, 27.2%)* stated that they neither agree or disagree with this. Some teachers stated that this requires a lot of time to prepare (*n=4, 18.1*%). Nevertheless, (*n=11, 50*%) are interested in professional development that will enable them to use game-based learning with their students.

In the statement "I would like to use game-based activities but they require a lot of time to implement in the classroom." (*n=6, 27.2*%) participants replied 'neither agree nor disagree', (*n=4, 18.1*%) replied 'agree' and (*n=1,* 4.5%) replied 'strongly agree'. Some of the reasons that participants stated for not using game-based learning activities are the lack of IT infrastructure and no wi-fi connection (in their classroom).

For game-related teaching practices, the categories of games used in classrooms reported where: (*n=6, 27.2%*) report 'trivia' and (*n=5, 22.7*%) mention 'role-play'. At (*n=4, 18.1*%) there are 'simulations' and 'strategic'. 'Action' and 'Sports' are used by (*n=2, 9*%) teachers while 'adventure', 'augmented reality', 'battle' and 'riddles' is implemented by (*n=1, 4.5*%). Some games reported by the participants were kahoot, hot potatoes, deck.toys were examples of creating interactive content; kodugamelab, scratch and scratch junior were examples of introducing programming; teachingeconomy.de contained online material; quizizz.com contained ready-made content as well as the ability to create interactive content. Other examples mentioned were roblox, Minecraft. When teachers were asked to point out the way they assess student performance with/around digital games, some of them (*n=6, 27.2*%) replied 'through learning analytics and feedback provided by certain games' and 'I create my own test/quizzes to assess student learning'; some other (*n=4, 18.1*%) replied 'through class discussions' and 'through their game performance'. Finally, (*n=2, 9*%) replied 'I do not assess student performance with or around digital games.

6.3.6 Needs and recommendations relating to immersive technologies

Teachers indicated the challenges that they currently experience or anticipate to experience when using immersive technologies in education. About (*n=13, 59%*) stated that their limited knowledge was an important or extremely important challenge. Similarly, teachers responded on the lack of confidence and knowledge regarding STEAM content, where (*n=7, 31.8%*) participants replied that this is a 'challenge', (*n=4, 18.1%*) replied that this is an 'important challenge' and (*n=3, 13.6%*) replied 'extremely important challenge'.

The majority of teachers (*n=13, 59%*) also stated that it is important to cover certain topics in their subject-matter so that students are prepared for future courses in their discipline. Another challenge is to familiarize students with lecture-based instruction and resistance to alternative ways of teaching. Some other teachers (*n=6, 27.2%*) replied that this was ‘challenge’ or ‘extremely important challenge’ and ‘important challenge’. Similarly, the same number of teachers (*n=6, 27.2%*) replied that the fact that classrooms are not being conducive to inquiry-based strategies (e.g. due to size, layout) is an “important challenge” or “challenge”. One of the most important challenges, is the lack of time to plan and prepare STEAM lessons with the majority of teachers stating that this is an ‘important challenge’ and ‘extremely important challenge’ (*n=14, 63.6%*). Another challenge brought up by (*n=6, 27.2%*) teachers was that some colleagues teaching other subjects in their school are resistant to the adoption of new methods.

Teachers also stated (*n=12, 54.4%*) that there is also lack of time to coordinate course content with other teachers. Another challenge reported was the “Insufficient technical or administrative support” by (*n=16,72.7%*) teachers while (*n=15, 72.7%)* teacher find that “Inadequate access to resources on STEAM concepts” is also a challenge. Teachers also think that there is “Lack of professional development opportunities when implementing STEAM education” with (*n=10, 45.4%*) participants stating that this is an ‘extremely important challenge’ or ‘important challenge’. Similarly, more than half of the teachers feel that there is lack of a STEAM culture at their school (*n=17, 77.2%*). Testing and evaluation (standardized assessments) preventing learning creativity with STEAM has also been indicated as a challenge with at least (*n=12, 54.4%*) teachers find it as an “extremely important” or just an “important” challenge.

For the question “Please indicate the degree to which each of the conditions below is an incentive for you to adopt the STEAM pedagogical approach in your classes”, the majority of the participants (*n=20, 90.9%*) replied that they would like to incorporate more student-centered teaching strategies into their courses. All participants (*n=22, 100%*) also replied that they find this an important incentive to incorporate innovative approaches in their teaching. Furthermore, (*n=21, 95.4%*) stated that it is important to cover a wide array of topics in their course, even if these topics are not all covered in-depth. Another incentive can be considered the STEAM curriculum which can bring an improvement in students’ critical thinking and problem-solving skills. The majority of participants (*n=18, 81.81%*) indicated they consider this as incentive. Similarly, the majority of teachers (*n=19, 86.3%*) find that this STEAM curriculum can bring an improvement to their students’ communication and collaboration skills and this can be considered an important incentive. Most teachers (*n=20, 90.9%*) consider that STEAM education better prepares students for their future studies and careers as this is also an important incentive. Finally, the majority of teachers replied to the statement “The STEAM approach will give me and other teachers in my school the opportunity to work as an innovative team” as (*n=21, 95.4%*).

Teachers were also asked to specify how “Do you, or your school, do any of the following to raise students’ interest and achievement in STEM/STEAM?” Half of the teachers (*n=11, 50%*) stated that they take students on STEM/STEAM related field trips and/or site visits, while (*n=10, 45.4%*) said that they hold school-wide STEM/STEAM fairs, workshops or competitions. Furthermore, (*n=9, 40.9%*) stated that their schools sponsor a STEM/STEAM after-school program. The same number of teachers (*n=9, 40.9%*) replied that they bring in guest speakers to talk to students about STEM/STEAM careers. Some other (*n=7, 31.8%*) replied that schools create opportunities for partnerships beyond school and (*n=6, 27.2%*) replied that schools partner up with a community college or university that offers STEM/STEAM summer programs or camps for high school students.

When teachers were asked “Do you, or your school, do any of the following to raise students’ interest and achievement in STEM/STEAM?”, several responses were received with the most popular one being the “take students on STEM/STEAM related field trips and/or site visits (*n=11, 50%*). The second most popular one was “Hold school-wide STEM/STEAM fairs, workshops or competitions with (*n=10, 45.4%*) responses. Another popular choice was “Sponsor a STEM/STEAM after-school program with (*n=9, 40.9%*). Other participants (*n=8, 40.9%*) selected “Bring in guest speakers to talk to students about STEM/STEAM careers. Another option that was selected by (*n=7, 31.8%*) was “Create opportunities for partnerships beyond school (involvement with business, sports, and arts communities). Similarly, (*n=6, 27.2%*) teachers selected the option to “partner with community colleges or universities that offer STEM/STEAM summer programs or camps for high school students.”

For the section on collaboration and problem-solving skills, a question was asked: “What do you think is the biggest barrier for students when it comes to STEM/STEAM studies and careers? There have been nine (*n=9, 40.9%*) responses pointing out areas/topics such as: “Lack of Knowledge and experiences in secondary school”, “The fact that they are trained to focus on exam”, “to trust something new”, “awareness”, “having the necessary school experience to feel confident to apply for these courses / careers”, “collaboration and problem-solving skills”. “Their own personal motivation first and foremost and then the lack of sound career prospects at least in my country”, “Parents not liking technology”.

Teachers also answered the question “How do you see the role of games in STEM/STEAM education?” There have been eight (*n=8, 40.9%*) responses for this and it is worth noting some of them which are: “the future”, “the way forward”, “challenging”, “could be useful”, “it is something very likely to motivate students”. When asked “would you be interested in receiving professional development on game-enhanced STEAM education? If yes, what type of professional development are you most interested in attending? There were (*n=11, 50%*) responses. The two most common ones are 1) the positive to any professional development program and 2) the hands-on training and workshops. A comment worth mentioning is “Yes, one without too many ‘frameworks’ but more hands-on work with presentation of good practices”

6.4 Higher Education Instructors Survey

6.4.1 Methodology

An instrument was developed and posted electronically via Google forms to collect information on instructors’ current perspectives and experiences regarding STEM/STEAM education, current teaching practices and game-based learning. The instrument was developed in English and contained one section on demographics and 8 other sections that focused on the following: Insights on STEM/STEAM education, self-efficacy and perceptions on immersive technologies learning, current teaching practices, current STEM/STEAM related teaching practices, use of games and rationale for such integration in their classes, current game-related teaching practices, needs and recommendations relating to immersive technologies. Nearly all questions were Likert-type or multiple-choice, to make it easy for instructors to complete the survey in a short time and respond to all questions.

The questionnaire was administered to instructors in the three partner Universities in Cyprus, Germany, and Greece. Instructors were informed that their participation was completely voluntary and anonymous. A total of *36* instructors (22 female and 14 males) completed the survey: *29* instructors from Cyprus (*80.6%)*; *4* instructors from Greece (*11.1%)*; and *3* instructors from Germany (8.3*%)*. The majority were aged between 30-49 (*n=14, 38.9%*) and had been teaching for more than 5 years (*n=25, 69.4%*). Also, the large majority (*n=26, 72.2%*) had a PhD degree while many of them (*n=15, 41.7%*) had worked in the industry. Also, the majority (*n=30, 83.3%*) worked for a private institution.

Instructors had taught disciplines ranging from STEM fields, Arts to Social studies. Most responses came from Computer Science (*n= 9, 25%*), Mathematics (*n= 8, 22.2%*) and Biology or other life science (*n= 7, 19.4%*).

The majority of participants (*n=20, 55.6%*) stated that STEM/STEAM Education has been introduced in the University where they work. However, more than two-thirds of the participants (*n=31; 86.1%)* stated that they did not currently have any involvement/professional role in STEM/STEAM education. The remaining (*n=5; 13.8%)* teachers had been involved in various types of STEM/STEAM education initiatives, such as conferences, training courses or workshops, and international projects.

In the next sections we present the main findings of this survey. Results are based on data on instructor responses to questions addressing their practices and views about STEM/STEAM education, current teaching practices and game-based learning. Due to the small number of participants no comparisons between institutions/countries were carried out.

6.4.2 Self-efficacy and perceptions on immersive technologies learning

When asked, whether immersive technologies activities should be used in education practice, the majority of participants (*n=29, 80.6%*) agreed on this. They also agreed that immersive technologies education promotes higher learning (*n=29, 75%*) and that it is easy to monitor student's progress when incorporating immersive technology activities (*n=26, 72.2%*). The majority of participants (*n=28, 77.7%)* agreed that immersive technologies promote 21st century skills. About (*n=15, 41.7%)* of the participants are not confident (neither agree nor disagree) on whether immersive technologies activities take too much of class time and that it's not always worth doing them, while (*n=14, 38.9%)* disagree with this statement.

6.4.3 Current teaching practices

During their classes, most instructors (*n=25, 69.4%)* stated that they ask their students to solve complex problems or answer questions that have no single correct solution or answer. This was not so much the case when instructors were asked if their students were requested to create an original product (*n=15, 41.6%)*. Some participants (*n=16, 44.4%)* indicated that they ask their students to choose their own topics of learning or questions to pursue and they very often ask their students to take initiative when confronted with a difficult problem or question. Furthermore, most instructors (*n=25, 69.4%)* very often ask their students to draw their own conclusions as well as (*n=26, 72.2%)* instructors ask them to analyse competing arguments, perspectives or solutions to a problem. Furthermore, the majority of the instructors stated that they encourage their students to collaborate with other students to set goals and create a plan for their team (*n=20, 55.5%)*. In addition, the majority of the participants (*n=23, 63.8%)* suggested that they ask their students to use technology to support teamwork or collaboration and share information. The majority of the instructors (*n=20, 55.5%)* also stated that they ask their students to use technology to help solve real-world problems as well as work on projects that approach real world applications of technology.

When asked why games are not used as part of their teaching practices, the majority of the instructors stated that they "neither agree or disagree" with the statement "I want to employ game-based activities but I don't have the necessary skills to do it" (*n=16, 44.4%*). This was also the case when asked "I would like to use game-based activities, but they require a lot of time to implement in the classroom" (*n=18, 50%*). However, many teachers (*n=9, 25%*) consider that "game-based activities are not appropriate for the course(s) that I teach" while (*n=9, 25%*) neither agreed or disagreed. This indicates that instructors didn't feel confident enough to use these tools and they also didn't know how much of their time it will require. Furthermore, they weren't sure whether these games were appropriate for their classes.

Among the replies received stating the most commonly used technological tools, these were the web browser (*n=27, 75%)*, email applications (*n=32, 88.9%)*, presentation software (*n=31, 86.1%)*, spreadsheets (*n=17, 47.2%)* photo/video recording or editing software (*n=19, 44.8%)* and word processors (*n=31, 86.1%)*. Some instructors (*n=14, 38.8%)* stated that they use education software designed for teaching such as Geogebra. Regarding using mobile devices in the class, results indicated that some (*n=10, 27.7%)* of the instructors *always* ask their students to use it in the class while some (*n=8, 22.2%)* of instructors do this *very often*. About half (*n=15, 41.6%)* of instructors also stated that they do not use game-based platforms or animations or simulations while another (*n=9, 25%) stated that they rarely use it*. This was more obvious when asked if they use AR/VR tools where the majority replied that they never do (*n=19, 52.7%)*. The same applies for real-time data collection devices and sensors (*n=20, 55.5%)* as well as educational robots (*n=21, 58.3%)*.

The majority of instructors also stated that assessment is mostly based on classroom participation (*n=24, 66.6%*) and exams (*n=20, 55.5%)*. The majority of instructors also stated that they do not assess their students based on physical models (*n=21, 58.3%*), dynamic digital products (*n=20, 55.5%*), prototypes (*n=21, 58.3%*) or portfolios (*n=16, 44.4%*).

Regarding our participants not using game-based learning activities in their classroom (*n=30, 83.3%*) and whether they would want to employ such activities, most of them believe that they want to employ such game-based learning activities with some of them agreeing that they don't necessarily have the skills to do it (*n=11, 30.5%*) while many of the instructors (*n=16, 44.4%*) do not agree nor disagree. Some participants (*n=11, 30.5%*) also stated that they would like to use game-based activities but that will require a lot of time to prepare. Also, (*n=16, 44.4%*) participants stated that they are interested in professional development that will enable them to use game-based learning with their students.

6.4.4 Current game-related teaching practices

During their classes, some instructors (*n=6, 16.6%)* stated that they use games in their classroom with their students. The games they have mentioned were, action, adventure, role-play, simulations, trivia and serious games/impact games. When asked in what ways do they assess student performance with digital games, all six of them (*n=6, 16.6%)* said that they do that through class discussions where some of the instructors (*n=2, 5.5%)* just do this through game performances, through learning analytics (*n=3, 8.3%)* or they device their own quizzes (*n=4, 1.1%)*.

6.4.5 Needs and recommendations relating to immersive technologies

Instructors also indicated the challenges that they currently experience or anticipate to experience when using immersive technologies in education. About (*n=13, 36.1%*) stated that their limited knowledge was an important challenge, while (*n=14, 38.8%*) thought that is was relatively an important challenge. Similarly, (*n=9, 25%*) said that the lack of confidence was an important challenge while (*n=14, 38.8%*) thought that this was relatively an important challenge. More than half instructors (*n=19, 52.7%*) thought that the lack of time was an important challenge while there is insufficient technical or administrative support (*n=12, 33.3%*). Many instructors (*n=16, 44.4%*) stated that the lack of content in national language is also another major challenge. Other challenges faced by instructors are facing resistance (*n=6, 16.6%)* in adopting new methods by their colleagues, lack of time to coordinate with other colleagues, insufficient infrastructure (*n=13, 36.1%*) and limited availability of resources related to immersive technology concepts (*n=13, 36.1%*).

When asked what do you, or your university, do to raise students' interest and achievement in immersive technologies, most instructors selected the choice to "Create opportunities for partnerships beyond university" (*n=17, 47.2%*) followed by "Bring in guest speakers to talk to students about immersive technologies careers" (*n=16, 44.4%*), "Hold university-wide immersive technologies fairs, workshops or competition (*n=11, 30.5%*), "Take student on immersive technologies related field trips and/or site visits" (*n=9, 25%*), "Sponsor immersive technologies extra-curriculum activities" (*n=6, 16.6%*), while some instructors selected (*n=12, 36.1%*) "none of the above".

Thirteen (13) participants also listed the biggest barriers they consider for students when it comes to immersive technologies studies and careers. Their responses included "time and money", "Perception and lack of culture", "For younger students there are no barriers apart from lack of knowledge / training of their teachers", "They are not as computer affine as one might think", "It's something they didn't get used to.", "lack of appropriate content", "speed of hardware ageing", "Unawareness", "Exposure to this kind of technologies".

Fourteen (14) participants also responded to the question "How do you see the role of immersive technologies in education?". Their input was "important", "Quite crucial and powerful", "Increasingly important", "a good way forward", "None", "highly content specific", "can be very interesting for some topics, while not so much for others", "very assistive", "Essential for the 21st century". Keeping the last comment along with "none", one can see how some instructors have completely contradictive views regarding immersive technologies and how these are employed in education. This might further support previous findings regarding instructors' limited knowledge about the nature and use of immersive technologies.

7 Conclusions

Based on the literature review and the results from the surveys, there seems to be an urgent need for equipping the young generation with a new skillset to cope with the demands of modern society, so as to become "tomorrow's progressive leaders, productive workers, and responsible citizens. STEAM educational approaches are acknowledged as paramount for the promotion, development and enhancement of such skills for the 21st century. However, research has indicated that students' motivation for learning and subsequent achievement in STEM topics, especially through the pursue of STE(A)M studies and careers is currently at a low point, since present-day STEM education at national, European, and international level often fails to engage students' interest. This is further supported by the results from surveys conducted with students in higher education.

College and university students seem to have moderate understanding of what STEM/STEAM courses are or what it entails to pursue a STE(A)M related career. Despite the fact that high school students seemed to have a very good understanding of the above, this does not seem to transfer to higher education, indicating either a conceptual gap in students' transition from secondary to higher education, or a time gap reflecting that STE(A)M approaches are only now gradually penetrating the educational system. Thus, students who are now in higher education might have never had the opportunity to engage in STE(A)M related activities when they were in secondary education a few years ago, contrary to students who are currently in secondary school. Indeed, based on the national reports, there has been a trend in introducing new projects/activities/initiatives in mostly STEM education, but with an increasing interest in STEAM education, and this was done only very recently (in the last five years).

The above identified gaps between secondary and higher education are further perpetuated by the fact that instructors in secondary education seem to be more familiar and to have previously engaged in STE(A)M related programs, workshops or professional development activities, contrary to higher education instructors who don't seem as well versed. Indeed, this seems in alignment with data from the three participating countries which reported the existence of several STE(A)M activities and initiatives. These aim to promote STE(A)M education through training, workshops, competitions (hackathons) and by formally incorporating related courses in the curriculum of the countries' education systems. Based on the survey results one can question whether these initiatives are mainly designed for primary and secondary education teachers, ignoring the growing need for support and professional development in STEM/STEAM for higher education instructors as well. At the same time, one might consider that the abovementioned gaps could equally indicate some degree of reluctance towards or resistance against participating in such initiatives, by higher education instructors.

In any case, the survey results indeed showcase that the majority of secondary education instructors are more familiar with STEM education and the teaching pedagogical methods employed in STEM education, than higher education instructors. As a result, they are also feeling very confident in their ability to motivate their students to study STEM subjects. Considering that teachers' (expectations) and the school's culture and attitudes (especially towards performance) are key to students' motivation, as indicated both by the literature and the national reports, it is not at all surprising that students in secondary education appear to be more aware than university students of the activities involved in STEAM careers, of the subjects they need to take for a career in STEAM as well as about sources for obtaining relevant information.

Furthermore, the results from the surveys further illustrate a missing link in the educational environment that could potentially support student's future career paths, but which currently remains problematic. This refers to career counselling in schools. The literature identifies the significance of all students' access to counseling and appropriate support services that help them make informed decisions about their future careers and a current lack of adequate support of this nature. This is a concern that can be equally raised based on the survey results from the secondary education survey, since only one in four students seeks support from the school counselors. Most students (85.5%) seek advice from family. As indicated by the results from the higher education surveys with students, the impact of family remains the most important in defining students' career choices, even later in life.

Another important aspect of students' motivation in engaging with STEM/STEAM courses and subjects is the method of instruction. Researchers have been advocating the adoption of more active learning environments that motivate learners, and encourage them through authentic inquiry to establish the relevance and meaning of scientific concepts. More recently, research has been calling for the modernization of STEM teaching and learning, with the appropriate integration of technological tools. This shift was reflected in most countries revised educational policies and official curricula, which currently advocate pedagogical approaches that support inquiry-based, technology-supported STEM education. Based on the reports of the consortium partners, there is a growing interest in both STEAM and game-based pedagogy among the researchers and the practitioners in all the participating countries (Greece, Cyprus, Germany). The above remarks are also supported by the survey results which show that instructors at both levels of education (secondary and higher) adopt several teaching methodologies that embrace a student-centered approach, inquiry learning, collaboration and the integration of technologies for finding solutions to existing real-world problems.

However, based on the national reports, the adoption of both STEAM and game-based pedagogy seems to be in an embryonic stage. The educational systems have not officially introduced either of them in their national curricula or everyday teachers' practice. So, when it comes to game-based instruction, more teachers in secondary education (almost half of them) and much less in higher education stated that they are including games in their teaching. Interestingly enough, though, students in secondary education do not feel that games are adopted in their classrooms, contrary to teachers' beliefs (only about 7% of students indicated that games are often or always included in their learning in school). This shows not only the inadequacy of existing game-based pedagogies but also a huge discrepancy between students and instructors views relating to the definition of games. Students are often very familiar with games, even complex ones. Games adopted by teachers are most often in the category of 'trivia', which are simple, easy to use games. This poses several questions relevant to students' and instructors' perceptions on how games are defined, the types of games that are most appropriate for students' increasing complex needs, as well as about the possible ways of the use of games in the classroom.

In general, when it comes to game related teaching practices and immersive technologies, most instructors in higher education and half of the instructors in secondary education have indicated in the surveys that they are not using such technologies in their classroom. Although most instructors across both surveys expressed their willingness to adopt and use such technologies, acknowledging that students can benefit from such applications, they also raised concerns relevant to: their own lack of familiarity, lack of skills, assumptions that the use of such technologies require time, lack of IT infrastructure and administrative support, even lack of wi-fi connection in their schools, not enough time to plan and design STEAM related content, difficulties of teaching students how to adapt to alternatives to lecture-based instructions, as well as other colleagues' reluctance to collaborate for the development of an integrated approach to their courses. These findings are in alignment with other research work that suggests that many teachers have difficulties in developing comfort with immersive technologies while others are negative with their uses as instructional tools. In addition, despite acknowledgment of the need for designing, modelling and programming immersive activities, there is little support in creating mixed-reality education spaces.

Many instructors in the surveys, expressed the need for more systematic and targeted professional development opportunities on the above, which also enforces findings from the literature that outline the significance of high-quality professional development for the successful design and implementation of the technology-enhanced STEAM approach. This requires reconstruction of school curricula and methods of teaching, learning, and assessment to more closely align with the affordances of new technologies, games and immersive technologies, as much as with the key STEAM concepts of innovation and creativity.

Thus, to facilitate the proliferation of emerging technologies in instructional settings and their uses in more creative ways that can have a true impact on teaching and learning, teachers should be provided with much-needed support. In the following section, a pedagogic and didactic framework has been developed based on the research (literature review, national reports and surveys) conducted during the Intellectual Output 1 so as to promote game-based, ICT-enhanced STEAM Education.

8 *ImTech4Ed* pedagogical and didactic approach

Findings from the desk and field research conducted by the *ImTech4Ed* consortium and presented in this document are in accord with those of previously conducted studies (e.g. Dahlstrom and Brooks, 2014; Marzilli et al., 2014; Herrero et al., 2015), which suggest that the majority of both secondary teachers and higher education instructors have positive attitudes toward the educational use of contemporary technologies, considering technology as a valuable tool that can greatly enhance student motivation and learning (Meletiou-Mavrotheris et al., 2017). Nonetheless, although the majority of educators report extensive utilization of technology in their classes, they tend to restrict their use of technology to mainly representation tools such as PowerPoint or straight forward games such as 'trivia' and to make minimal use of interactive technologies (social media, simulations, games, virtual/augmented reality tools, media manipulation software, etc.) that can promote student-centred, collaborative, and inquiry-based STEAM learning environments.

The ImTech4Ed project is built upon the premise that among the main reasons for immersive technologies' limited uptake in education this far, is the mono-disciplinary education in fields that would need to collaborate to deliver widely usable immersive educational solutions: game design, computer Science, teacher education. Currently, these fields have only little connection to each other. However, truly useful and widely usable immersive educational solutions can only be created by combining educational, technological, and design-oriented perspectives.

Immersive Education is moving beyond just the use of virtual worlds to become more embedded into the physical world around us. Literature on the convergence of the technical, pedagogical and cognitive components and interactions within immersive environments is scarce, and past attempts fall short of fully exploiting the affordances of augmented and mixed reality.

Acknowledging the fact that the increasing complexity of concepts such as augmented reality games for educational purposes require cross-disciplinary understanding and collaboration, *ImTech4Ed* was proposed in an attempt to move away from the mono-disciplinary approach in fields that would need to collaborate to design and deliver widely usable game-based educational solutions. The project builds upon recent approaches in relatively new interdisciplinary game design educational programs for bachelor and master level students that have demonstrated the value of interdisciplinary education and problem-based learning (Klemke & Hettlich, 2019) for cross-disciplinary collaboration of programmers, designers, and artists. It aims to take this approach one step further by connecting to educational science and computer science and extending to international and cross institutional scope. Consequently, *imTech4Ed* is an attempt to bring together teacher education, game design education, and computer science education allowing students from each of the disciplines to broaden their understanding of the related fields.

Five intellectual outputs are/will be delivered by the project during its lifetime:

- *ImTech4Ed* Methodological Guidelines (O1)
- Authorware Tools (O2)
- *ImTech4Ed* University student and in-service STEAM Teacher training program (O3)
- *ImTech4Ed* Immersive Game Prototypes (O4)

- *ImTech4Ed* STEAM Educational Scenarios (O5).

The intellectual outputs are/will be supported through four learning, teaching, training activities, three of which contributing to the interdisciplinary education of students by organizing interdisciplinary hackathons (C1, C2, C4), and one contributing to the educational training of teachers about the use of games and other immersive educational solutions as tools for promoting STEAM teaching and learning (C3).

The current document constitutes the *ImTech4Ed* Methodological Guidelines (O1). The Methodological Guidelines were developed in the first months of the project to guide the design of the O2-O5 and the related project activities (C1, C2, C3, C4).

In this last part of O1, we first provide a short overview of the *ImTEch4Ed* project outputs and activities, and then outline the pedagogical and didactical approach that underlie these activities and outputs so as to promote game-based, ICT-enhanced STEAM Education.

8.1 Overview of Imtech4ed Outputs and Activities

The *ImTech4Ed* project's main target groups during its lifetime are/will be (a) university students who will participate in the development of game prototypes, and (b) secondary school in-service STEAM teachers who will pilot these prototypes in their classrooms. A blended professional development program (O3) will be created, and pilot tested by the project consortium that aims at enhancing their knowledge, skills, and dispositions for applying the *ImTech4Ed* Methodological approach (O1) in STEAM game design and/or game-enhanced STEAM teaching and learning. The program will familiarize participants with the *ImTech4Ed* approach and how it can foster secondary school pupils' motivation and learning of STEAM disciplines, while strengthening the development of a cluster of other key and transversal competencies (21st century skills). Central to the course design is the functional integration of emerging technologies with existing core curricular ideas, and specifically, the integration of the game prototypes (O4) and the authorware tools and resources (O3) developed by the project consortium.

Training will be offered through combined use of e-learning and physical meetings, and will be open to (i) University students from partner institutions majoring in game design, computer science, or education, and (ii) secondary STEAM teachers in the three partner countries (CY, DE, EL). Participating university students (approx. 50 in total) and secondary school in-service teachers (approx. 5) will be trained (a) locally in CY, DE, EL, (b) remotely, through the available online material and the online Community of *ImTech4Ed* students and educators, (c) both (blended). A transnational online community will be created for the exchange of experiences, ideas and resources.

After attending the training program (O3), University students will engage in interdisciplinary activities towards developing immersive serious game prototypes. Priority and facilitation of participation in the professional development program (C3), and in the hackathons (C1, C2, C4) will be given to University students facing challenges like disabilities, health problems, a low socioeconomic background, or residence in isolated areas while maintaining gender balance.

Secondary school in-service teachers having participated in O3, will subsequently form interdisciplinary groups to jointly plan, design, and develop educational scenarios for STEAM curriculum. These educational scenarios will be designed based on the methodological guidelines outlined in O1 and will integrate the prototype games generated through the *ImTech4ed* project (O4). Participating teachers will then pilot test the game prototypes and their accompanying educational scenarios in real classroom settings, following action research procedures. Each participating teacher will work with at least one group of pupils (approx. 100 pupils in total).

The project outputs will be released to the public, so that they can be independently used as a training resource by interested stakeholders: in-service STEAM teachers, teacher educators, University students and in the fields of computer science and game design, educational researchers, policy makers, government officials, science communicators, designers from game industry, and other relevant end-users.

8.2 Imtech4ed Pedagogical Theoretical Framework

In this section, we provide an overview of the pedagogical theoretical framework underpinning *InTech4Ed.* This framework is grounded on and structured under five interrelated bodies of educational research, namely:

- Transdisciplinary STEAM Education Model
- Game-based STEAM Learning
- Participatory Design Framework
- Principles of Adult Education
- Technological, Pedagogical, Content Knowledge (TPACK) Conceptual Framework.

Each of these is developed in the rest of this section, to outline their basic theoretical premises as well as their specific applications in the design of the program outputs.

8.2.1 Transdisciplinary STEAM Education Model

A particularly innovative aspect underlying the *ImTech4Ed* project design is the adoption of the STEAM approach. STEAM education is an integrated approach to the teaching and learning of the different disciplines developed on the basis of STEM, an interdisciplinary approach that overcame the strict individual borders of Science, Technology, Engineering, and Mathematics by treating sciences as a single whole.

The global shift towards STEM education, observed at the beginning of the 21st century emerged as a recognition of the need of cultivating human resources equipped with the critical thinking, problem-solving and innovation skills required to adapt to the needs of the rapidly changing and complex digital era. Recognizing that modern socio-economic issues are too complex and multi-dimensional to be dealt with exclusively in the light of a single science, STEM education adopted a unified understanding of the components of STEM, treating them as a single whole (Sanders, 2009). This interdisciplinary approach removed the barriers between the sciences, thereby redefining the science - technology relationship and linking them to the real world (Sánchez Milara & Cortés, 2019).

STEAM education is an extension of the interdisciplinary STEM model through the addition of the arts (Yakman, 2008), which include: (i) performing arts such as dance, theater, music, (ii) fine arts such as painting, sculpture, (iii) linguistics and liberal arts such as sociology, education, philosophy. Arts was added to the original STEM framework in order to promote learning in more connected and holistic ways (see Figure 1). As proponents of the STEAM movement point out, an integrated STEM and Arts curriculum is essential to foster true creativity and innovation by allowing students to use systematic thinking skills that combine the mind of a scientist or technologist with that of an artist or designer (Bazler and Sickle, 2017; Meletiou-Mavrotheris, 2109).

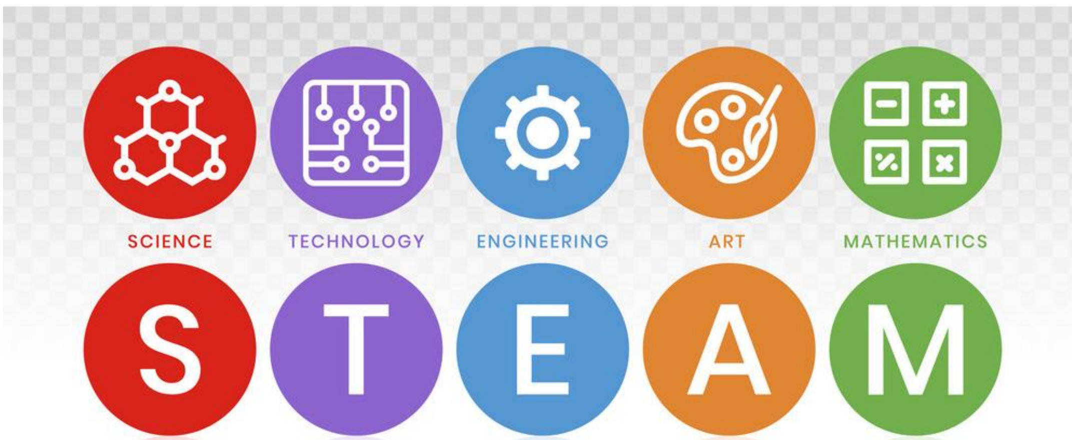


Figure 1: The transdisciplinary STEAM approach (Source: VectorStock.com/33677144)

Although the Arts appear to be incompatible with STEM fields, as they are usually based on artistic inspiration and often use free, unobstructed thinking, imagination and paradox, they are in fact complementary rather than antithetical when it comes to the generation of new, creative ideas and thought processes. The STEAM approach recognizes that it is precisely these qualities of the Arts that introduce a different way of thinking that can fuel the artistic and scientific community, but also society at large, with interesting and innovative ideas and actions (Liao, 2016). At the same time, the diversity of the Arts field provides students with the appropriate tools to explore human nature, to come into harmony with the emotional, social and cultural world around them and to develop a capacity for empathy (Catterall, 2017). In this way, students who are not attracted to STEM or cannot express themselves properly through STEM can also be attracted to Science.

The key feature of the STEAM methodology is transdisciplinarity, which focuses on addressing authentic problems through the complex use of tools across all disciplines (Liao, 2016). The STEAM transdisciplinary approach transcends through all the cognitive fields with the aim of studying an object as it really is, that is, as a multi-dimensional and complex system. STEAM constitutes a holistic approach to learning that is situated at the same time, across and beyond each technological, scientific and creative discipline, emphasizing learning through practice and linking the components of STEAM with the real world and students' daily life. This transdisciplinary approach supports dialogue and collaboration both between different subjects, and between students. In addition, STEAM practices help to develop students' creativity, critical thinking and ingenuity and sharpen different types of intelligence (Gardner's multiple intelligence theory). This promotes the increased cognitive development of students in the STEAM fields as well as the development of important 21st century skills that are mainly summarized in the 4C's: Communication, Collaboration, Critical Thinking, Creativity (Partnership for 21st Century, 2009; Nganga, 2019).

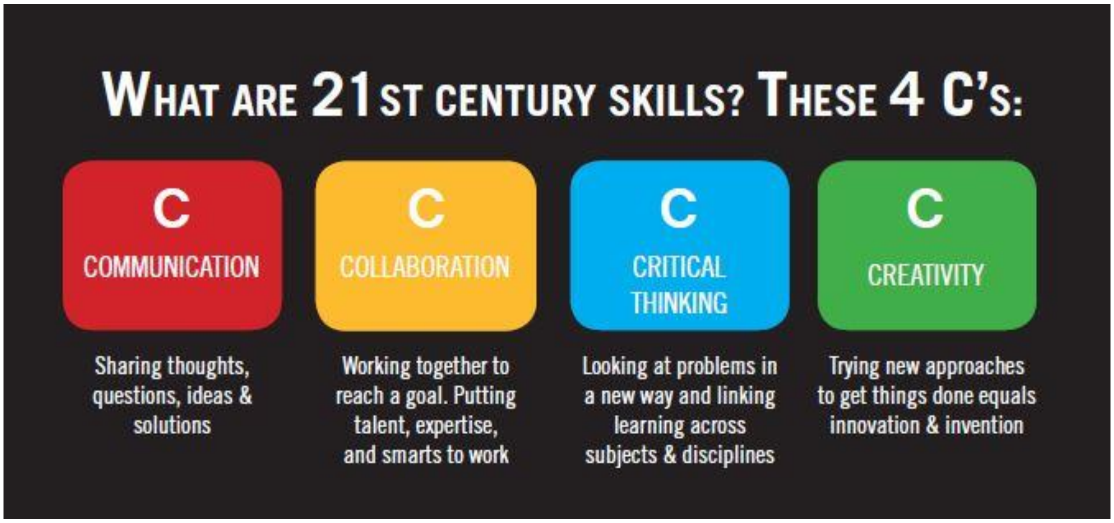


***Figure 2**:* The 4C's 21st Century Skills (Source: https://www.fablabconnect.com/the-4-cs-for-21st-century-skills/)

The STEAM educational model is based on contemporary learning theories such as social constructivism, constructionism, connectivism and situated cognition. This model aims to offer an active and participatory learning environment that takes place in authentic, transdisciplinary contexts and focuses on collaborative problem solving. It also enables students to interact, explore, invent, and discover using real-world problems and situations, thereby helping to develop learners' creativity, critical thinking and inventiveness by combining different scientific fields.

The holistic approach to STEAM disciplines adopted by *ImTech4Ed* promotes relevancy of learning, and better prepares students for their future complex life and work environments. The STEAM approach can also help reverse the "STEM pipeline" problem, i.e. young people's tendency to make study and occupation choices outside of science and engineering, by stimulating and nurturing under-represented groups of students' attitudes and interest towards STEAM studies and careers.

Certainly, the project also acknowledges the number of challenges that arise from trans-disciplinarity as part of STEAM education. One potential problem is the challenge of integrating different subjects into a single curriculum. For successful subject-area integration, teachers need to work together and plan ahead. Furthermore, it may be difficult to find teachers who are experts in all the different fields that transdisciplinary instruction necessitates. In order to equip educators with the necessary knowledge and skills, it may be essential to provide them with specialized training and professional development opportunities. In addition, it can be difficult to accurately gauge the success of transdisciplinary education. Assessment strategies that more accurately evaluate integrated learning may need to be developed if traditional methods are to capture the complex nature of transdisciplinary knowledge and skills. These challenges can be addressed through effective planning, teacher support, and collaborative efforts.

Thus, an important condition for a wide-scale adoption of the STEAM culture and practices is the provision of pre-service and in-service teacher training in the STEAM approach. Offering high quality professional development is essential for equipping teachers with the knowledge and skills required to adapt to the new trends and needs. The *ImTech4Ed* professional development program will strengthen the profile of the teaching profession in STEAM education by training both pre-service and in-service educators in STEAM pedagogy, and in the instructional use of games and other immersive digital technologies as tools for enhancing their students' learning and for dealing with diversity in their STEAM classrooms.

8.2.2 Game-based STEAM Learning

Digital game industry is one of the main sectors of the global media and entertainment market and according to Netscribes Gaming Market Research, it is expected to expand at a CAGR of 15.7% and to be worth $264.9 billion by 2023. The increased proliferation of smartphones and tablets, coupled with the improvement in technology and the ease of access to internet connectivity, is providing considerable push to the gaming market globally. With international markets for digital games (videogames, console games, phone games, tablet games, etc.) comparable with markets for movies and music, gaming has become a mainstream activity with prominent presence in children's and young people's daily activities (Prensky, 2006). Moreover, games have also lately penetrated into traditionally non-gaming segments of society. Specifically, gaming has become a common leisure-time activity for older groups of people, but also for girls and women. The cliché of young teen male gamers no longer applies. Recent statistics in the US indicate that almost half (47%) of the gamers are female, and 30 percent older than 50. Similar trends are observed in EU countries (Wendel, 2015).

This broad acceptance and proliferation of digital games in daily life, has led to a widespread interest in the potential applications of a specific category of games, labelled serious games, as tools for enhancing players' motivation, learning, and development. Serious games are applications with three components: entertainment, experience, and multimedia (Laamarti, Eid, & El Saddik, 2014). They are developed with game technology and design principles, and thus have the look and feel of a digital game and an entertainment dimension. However, they are not confined to entertainment, but also have the potential to enhance the player's experience in a specific context (e.g. education, training, health, interpersonal communication, etc.) through providing an environment that conveys some message or input, be it knowledge, skill, or in general some content (Laamarti, Eid, & El Saddik, 2014). This environment is characterized by multimodal interaction (Arnab, Petridis, Dunwell, & de Freitas, 2011) since a digital serious game contains different media, which could be a combination of text, graphics, animations, audio, haptics, etc.

Serious games, as well as other categories of digital games, have attracted lots of attention among educators in different STEAM subjects and fields due to the fact that they deviate from traditional approaches and combine entertainment with situated learning, thus making the process more creative and appealing, and often more effective. Many educational designers see games as a possible solution to the problem of the "Net Generation's" disengagement with traditional instruction. Several STEAM educators have been investigating ways in which this massively popular leisure activity could be utilized to capture students' interest and facilitate STEAM learning, in either formal or informal educational settings.

A wide consensus exists in the scientific community about the potential educational benefits of digital games. Several meta-analyses, point to the benefits of game-enhanced learning (e.g., Boyle et al., 2016; Zhonggen, 2019). For example, a systematic review and meta-Analysis by Clark, Tanner-Smith, and Killingsworth (2014) confirmed the overall findings from prior meta-analyses, concluding that games significantly enhance learning relative to nongame conditions. The greatest strengths of digital games as an educational medium, according to Clark et al.'s (2014) meta-analysis, involve their affordances for supporting higher order cognitive, intrapersonal, and interpersonal learning objectives. Using games, students can collaboratively engage in authentic problem-solving activities and become reflective and self-directed learners (Jackson et al., 2013; Van Eck et al., 2015). They can build valuable skills such as logical and strategic thinking, planning, multi-tasking, self-monitoring, communication, negotiation, pattern recognition, accuracy, speed of calculation, and data-handling. At the same time, games enable teachers to observe students' problem-solving strategies in action and assess their performance (Koh et al., 2012). Appropriate selection and instructional integration of digital games can also help to narrow differences in academic achievement (Cavanagh 2008), since the literature indicates that low-performing students have the greatest benefit from the educational use of digital games (Takeuchi & Vaala 2014).

Similarly, the research community stimulates on the potentials of immersive technologies in education. These technologies offer students immersive and interactive experiences that go beyond traditional classroom settings. By transporting students to virtual environments or overlaying digital information onto the real world, immersive technologies create a highly engaging and multisensory learning environment. This provides students with the opportunity to explore and gain a deeper understanding of the properties and relationships of objects that are inaccessible in daily life (Walker et al., 2017). They provide opportunities for students to explore and experience subjects in a more vivid and a concrete way, and better comprehend abstract and difficult to understand concepts (Ozdemir, 2017) , which can also lead to improved cognition and learning (Laine et al. 2016). Immersive technologies also promote active learning, as students become active participants rather than passive observers (Chiusaroli & Arduini, 2023). For example, AR offer a means of learning close to the real world (Cai et al., 2014) and students can manipulate objects, conduct experiments, and solve problems in a hands-on and experiential manner. These technologies also facilitate collaborative learning, as students can engage in shared virtual spaces, collaborate on projects and educational games, and communicate with peers and teachers in real-time.

Thus, placing a focus on game-enhanced learning and immersive technologies can provide a powerful perspective for enhancing STEAM pedagogy. However, there is wide variability in the content, scope, design, and appropriateness of digital games (Guernsey, Levine, Chiong & Severns, 2012). Many of the available games fail to achieve the correct balance between the fun element and the main purpose of the game, and to have the desired impact on players' experience (Hansen, Mavrikis, & Orvieto, 2013; Laamarti et al., 2014). Also, digital games tend to be drill-and-practice and to focus on development of skills, rather than on high-level thinking (Chau, 2014). Furthermore, some of their features might lead to off-task behaviour (Rowe, McQuiggan, Robison, & Lester, 2009), because their focus might be on entertainment rather than education, and/or they might be too time consuming and complex to be effectively employed in classroom settings. Also, while digital games can be used to challenge social injustices, many of the popular games tend to reflect the dominant culture and to perpetuate existing stereotypes. Due to the anonymity afforded by the internet, online gaming communities often become a refuge for racist, sexist, and homophobic expressions (Crocco, 2011).

The success of digital games as an instructional tool will ultimately depend on the abilities of teachers to take full advantage of their educational potential (Southgate, Budd, & Smith, 2017). The literature indicates that the majority of teachers lack the vision and the personal experience of what game-enhanced teaching could look like, and tend to view games as instructional tools to be used for motivational purposes, or for reviewing already acquired concepts (Williamson, 2009; Takeuchi & Vaala, 2014).

The *ImTech4Ed* project recognizes and leverages the power of digital games as tools for enhanced STEAM pedagogy. It is grounded in the theory of situated learning and game-based learning for engaging students in authentic STEAM learning experiences and thus for promoting the development of core soft skills and STEAM competences, with the use of innovative digital tools such Augmented Reality and Virtual Reality games. The project will offer teachers an active and long-term participatory form of professional development on game-enhanced STEAM Education, that links theory and practice via the co-design, implementation, and evaluation of game prototypes supporting the development of students' knowledge and key competencies in the fields of STEAM. As a result, via the teachers' professional development which will be in combination with the co-design of the games, the project will have a great impact on building their professional profile. Teachers will be trained via the co-design and enactment of modern and interactive digital tools in order to advance their teaching practice in STEAM education, which is an innovative element itself to the national curriculum. Moreover, the participatory design framework adopted by the project (see next section), will lead to the design of improved game-based educational solutions that will better address end-users' (students' and teachers') needs.

8.2.3 Participatory Design Framework

Participatory Design (PD) is a common practice outside the field of education and aims to involve the users of a product in the design process, to ensure the usability, acceptability, and effectiveness of the final product (Simonsen & Robertson, 2012). Re-contextualizing this practice in education, PD refers to initiatives which place in-service teachers and their students as active participants in the design, in the belief that this bottom-up approach could result in more effective digital applications, while also providing a supportive context for teachers' professional development (DiSalvo, Yip, Bonsignore, & DiSalvo, 2017). Participating in the co-design of educational technologies allows teachers and their students to result in technology-enhanced learning environments which address their needs and expectations, while also providing teachers with a flexible understanding of the relationship between the learning pedagogy, the student activity, and its instructional goals (Kyza & Nicolaidou, 2017). PD has become widely popular within the interaction design community, but to date has had little influence within game design processes (Khaled & Vasalou, 2014).

ImTech4Ed aims to address the main obstacles reported in the literature as preventing the successful adoption of digital games and other immersive technologies for STEAM learning, by bringing together teacher education, game design education, and computer science education to engage in participatory game co-design to conceptualize and develop optimal technological solutions. The adoption of the PD framework, will promote out-of-the-box thinking and creativity in the design and use of digital games and other immersive technologies for STEAM education.

ImTech4Ed will connect currently separate college-level programmes (education, game design, computer science), while at the same time involving secondary teachers and their students in PD of games and other immersive technologies. Engagement in collaborative, project-based game co-design will help student teachers to better understand and utilize state-of-the-art learning technologies in their educational practice. Game design students will contribute their design experience but likewise learn from educational and technical backgrounds, while computer science students will contribute profound technical skills and benefit from interdisciplinary cooperation with their design oriented and educational oriented counterparts. Including in-service teachers in the design of game prototypes, will ensure that the final "products" will be linked to the educational curriculum, as well as to their teaching practices and needs. Likewise, the PD will ensure the inclusion of the "voices" of students, as the end-users, for the development of digital games and other technological tools aligned with their expectations, thus resulting in a motivating and engaging learning environment for students.

Through their involvement in the project, research partners will also broaden their research perspectives on the design and application of serious games and other immersive educational technologies, exploring new participatory methods of interdisciplinary collaboration in technology-focused Research & Development (R&D).

8.2.4 Authoring tools

The role of authoring tool in STE(A)M education and the PD framework is very important. These tools empower educators and students to create their own immersive experiences, customizing content to align with specific learning objectives. On the one hand, they enable teachers to create meaningful, immersive experiences for STE(A)M education scenarios (e.g. interactive simulations, virtual experiments, and 3D models that facilitate hands-on learning), while on the other hand, students (and teachers) can participate collaboratively on the development of immersive STEM projects. Additionally, in game-based education, authoring tools allow teachers and students to design and develop educational games. This process not only enhances students' creativity and critical thinking but also provides them with a sense of ownership and agency in their learning. Students can collaborate in the co-design and co-development of educational games, fostering teamwork and problem-solving skills. Therefore, there is a growing need for tools that allow collaboration and co-creation.

Research has highlighted the necessity for new methods and tools in the creation of interactive 3D content for immersive learning environments (Bacca et al. 2014). In a review on augmented reality game-based learning, Pellas et al. (2019) emphasized the importance of AR authoring tools that require minimal coding expertise, enabling teachers with limited technical skills to create content that facilitates and enhances the learning process. These tools should also promote collaboration by providing a platform for content creators, including teachers and students, to work together in problem-based and project-based environments. However, discovered that out of 51 AR platforms reviewed, only nine were suitable for non-technical users, and merely three were offered as free and unrestricted resources (ARTutor, Metaverse, Vedils). From these three tools, available at the time of the research, none of them supported collaboration. This limited availability of user-friendly and freely accessible tools could hinder the educational community's adoption of immersive technologies. Additionally, the absence of support towards collaboration functionalities may limit the effectiveness of their application. So, further development of authoring tools with new functionality aspects is crucial for the adoption of immersive technologies in educational STE(A)M activities.

In addition to the challenges faced by instructors in selecting an appropriate tool, extensive research is often required, making the provision of guidance on available tools and platforms crucial. Recognizing this need, ImTech4Ed endeavours to provide comprehensive support to the educational community by delivering an authoring tools guide. This guide aims to streamline the process of selecting immersive technology authoring tools, empowering educators to create more meaningful and impactful immersive activities for their STE(A)M projects. By offering valuable insights and recommendations, ImTech4Ed aims to alleviate the burden of research and equip instructors with the necessary resources to make informed decisions that align with their specific needs and pedagogical objectives. With this guidance, educators can confidently embrace immersive technologies, leveraging their full potential and promote the development of vital 21st-century skills.

8.2.5 Principles of Adult Education

During the design of program targeting college level students and in-service teachers, it is vital to take into consideration the main principles of adult education. Several studies have been conducted over the last forty years to investigate the ways in which adults develop the required knowledge and skills to effectively function in everyday life and in work situations (e.g. Carraher, Carraher & Schliemann 1985; Lave and Wenger 1991; Saxe 1991; Van der Kamp and Scheeren 1996; Greeno et al., 1999; van Groenestijn, 2007, Young,Rathwell, & Callary, 2020). The main conclusions of these studies are the following:

- Adults are free to learn. There is no compulsory education for adults
- Learning happens in a functional situation. There is a need for learning
- Learning in practice is authentic. Whereas in school situations learning often takes place through text books, and with the help of artificial hands-on materials, in practice this can be done in the actual situation with authentic materials
- Knowledge acquired in practice is almost always functional and applicable. Whereas in schools students often learn something because they should know it (“knowledge-for-knowledge”), in practice subjects are learned because people need it or want to know it, to be able do their jobs or other things (“knowledge-as-a-tool”)
- Every learning situation is a socio-cultural determined situation: Learning is an interactive and social act in which everybody takes part
- Learning in practice focuses on “shared cognition”, rather than on “individual cognition”. In work settings employees are often complementary to one another. People learn to ask questions, to discuss the problems they meet, to look jointly for solutions and to work cooperatively
- The way in which learning in practice takes place is often via showing - imitating - participating and applying: There is no need to create specific instructional settings. People spontaneously work cooperatively when the situation requires to do so
- For learning in practice people construct or re-construct their own “rules-of-thumb” and informal “rules and laws” for managing actions, situations, materials and the environment in which they work.

Consequently, in adult education there has been a gradual move from a pedagogical —teaching adults – perspective into a more andragogical one— helping adults learn, and a general acknowledgement of the fact that (van Groenestijn, 2007):

- Adult education should prevent any dependency of adults on teachers and should emphasize adults' own competencies and potential for growth and development
- Adult educators are only facilitators of learning and should help adults learn to teach themselves
- Adults should take responsibility for their own learning in instructional settings as they do so in their everyday life situations
- The actual real-life situations are the source as well as the focus of learning in adult education
- Learning starts in the actual lived-in situation of adults – in workplace settings and/or in social communities - and aims to develop knowledge and skills that are usable and applicable in these situations
- Learning in informal ways in the course of activity in a meaningful setting is much more effective than learning in traditional classroom settings.

Drawing upon the relevant literature, *ImTech4Ed* will use adult appropriate strategies. Rather than adopting a transmission of knowledge instructional model, the *ImTech4Ed* professional development program will facilitate inquiry, problem-based learning. The in-service teachers and the college level students (education, computer science and game design majors), participating in the program will be responsible for their own learning, facilitated by an environment rich in challenges and interactions. Particular emphasis will be given to drawing upon and extending participants' workplace experiences. The training will be followed by a teaching experimentation in the classrooms of the in-service teachers participating in the program. We believe that this can help to further determine the actual potential of the *ImTech4Ed* model, as an approach for promoting STEAM teaching and learning.

8.2.6 Technological Pedagogical Content Knowledge (TPACK) framework

TPACK is a powerful and influential conceptual framework, proposed by Mishra and Koehler (2006) in response to the absence of theory guiding the integration of technology into education. Building on Shulman's (1986) idea of Pedagogical Content Knowledge, TPACK emphasizes the importance of developing integrated and interdependent understanding of three primary forms of knowledge: technology, pedagogy, and content (see Figure 3). The framework 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. Thus, teacher Information Communication Technology (ICT) training cannot be treated as context-free, but should be accompanied with emphasis on how technology relates to the pedagogy and content. The aim is to move teachers beyond technocentric strategies that focus on technology, and to promote their critical reflection on the instructional use of ICT.

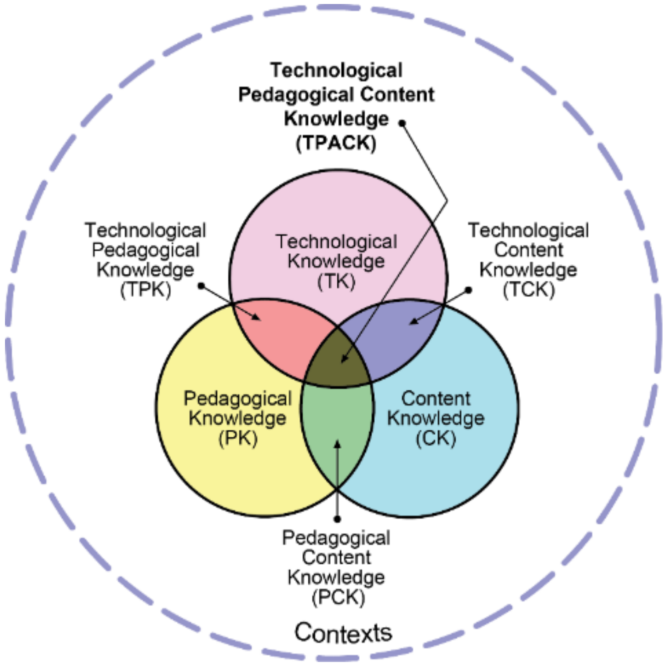


Figure 3: TPACK framework (Source of TPACK image: http://tpack.org/)

TPACK has, in recent years, become central to research into technology education and teacher professional development in many different disciplines (e.g. Chai, Koh, & Tsai, 2010; Zhang & Tang, 2021). In STEM/STEAM disciplines, several studies targeting pre-service and/or in-service teachers undertaken during the past decade have been grounded in the TPACK model (e.g. Hill & Uribe-Florez, 2020; Meletiou-Mavrotheris & Prodromou, 2016). Conducted studies illustrate the usefulness of TPACK as a research framework for facilitating and assessing STEM/STEAM teachers' professional growth in the instructional use of ICT for the development of students. As suggested by the literature, better understanding of TPACK among pre-service and in-service teachers can help enhance integration of technology in their teaching practices, and this, in turn, can foster STEM/STEAM learning.

ImTech4Ed puts emphasis on secondary- school teachers' professional development. The project acknowledges the need for strengthening teachers in relation to their ICT skills and confidence for integrating cutting-edge technologies, such as digital serious games, and augmented and virtual reality in their classrooms. One of the core objectives of the *ImTech4Ed* project is the development of teachers' Technological Pedagogical Content Knowledge (TPACK) of game-enhanced STEAM pedagogy. The project aims at the development and delivery of a high-quality Professional Development program, that will be jointly co-authored by the project's interdisciplinary team of researchers and educators in the fields of STEAM education, game design, computer science, engineering, and e-learning. As part of the provided TPD the participating teachers will familiarize themselves with existing serious games and other immersive technologies, while they will also have the opportunity to reflect on and reform the current teaching practices via the co-design and integration of digital game prototypes in their classrooms.

Concurring with Phillips (2013), the *ImTech4Ed* 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 recognizes that 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).

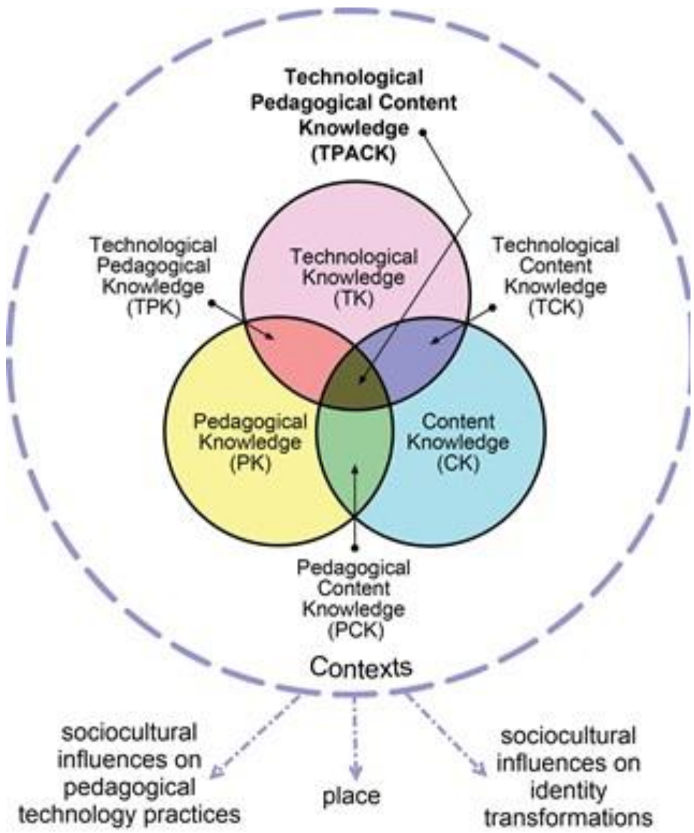


Figure 4: Phillips' re-contextualized TPACK framework (Source of the initial TPACK image: http://tpack.org/)

The project has adopted Phillips' re-contextualized TPACK framework. As shown in Figure 4, the re-contextualized TPACK 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. In line with Phillips' model, *ImTech4Ed* will adopt 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.

While current research on the application of digital serious and other immersive technologies in secondary education is fragmented and limited, often taking place in out-of-school activities with small student samples, *ImTech4Ed* promotes a scaled-up implementation of emerging technologies in authentic educational contexts. The teaching experimentation and research to be conducted in partner schools, will help to fill a serious gap in technology-enhanced learning research, pointed out by Beavis et al. (2015) – the lack of research that accounts for the realities of school. It will promote systematic efforts towards the integration of emerging technologies in real classroom settings. In-service teachers will have the opportunity to design lesson plans or educational scenarios that will be based on the project theoretical and methodological guidelines and will integrate the prototype games generated through the co-design process, while working with interdisciplinary teams. The educational scenarios will adopt an interdisciplinary STEAM approach that will support a holistic study of topics and concepts and will be integrated into realistic-authentic contexts in order to link the learned concepts to students' daily lives. The pilot testing of prototypes in a real school setting will allow the evaluation of their usability, usefulness, applicability, and aptness for the desired purpose, leading to the delivery of prototypes that could be explored in educational practice.

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