State of the Art on Serious Gaming & Computational Thinking

Final Trasnational Report

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CARDET

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1. Summary

This transnational report consists of four parts. The Part A of the report aims to provide a number of definitions of Computational Thinking and Serious Games as well as to present the core elements that make a game attractive and engaging. Following that, in the Part B of the report, a national curriculum analysis of Computational Thinking in Mathematics will be illustrated in all five participating countries: Cyprus, Romania, Greece, United Kingdom and Italy. After that, in Part C, the report will encompass national empirical studies on the application of serious games to enhance computational thinking in Math education. Then, it will outline the approaches and the tools that have been used to support training in computational thinking and/or Math education and what learning difficulties in that subject have been reported. Finally, in Part D, the results of the field research are presented. The research is conducted online using a questionnaire on the students' gaming interests to use this knowledge to develop an attractive game concept and environment.

2. Introduction

Nowadays, in the digital society of the 21st century, the exponential onset of computers is forcing a transition in which digital literacy is now a necessary ability to cultivate (Shute, Sun, & Asbell-Clarke, 2017). Most of us use computers on a regular basis and need to learn how to work with them to leverage their computing power most effectively (Shute et al., 2017). This is called Computational Thinking (CT).

CT is the new literacy. In 2006, Wing acknowledged CT as a vital skill that should be cultivated by all literate people attending compulsory education to supplement the other three key competencies which are reading, writing and mathematical skills. CT is a thinking process (or otherwise a human thinking ability) that uses analytical and algorithmic methods to formulate, evaluate and solve problems (Bocconi et al, 2016). CT, also, has been advocated by most educational policy makers as a capability that is equally important for all as numeracy and literacy (Bocconi et al, 2016). Not only it is the core for the STEM disciplines (Science, Technology, Engineering and Mathematics), but it is also useful in daily life. Human brain itself is wired to think computationally, therefore our development and future prospects need to learn how to use its full potential (Henderson, Cortina & Wing, 2007).

Specifically, the use of mathematics and computational thinking illustrates the increasing relevance of computation and emerging technology within scientific disciplines (Weintrop et al., 2015). In the mathematics criteria, the Common Core Guidelines in the United States, it was specified that learners should be capable to “use technological instruments to explore and deepen their understanding of concepts " (National Governors Association, 2010, p. 7). The use of video game tools in an educational game environment, described as "serious games", is one enjoyable and motivational method that is suggested to support the teaching and learning. As educators continue to unlock their skills, Serious Games

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are becoming increasingly widespread. At the same time, students are getting used to gaming in their everyday lives and technology is even more present around us. Former US President Barack Obama, during the 2013 edition of Computer Science Education Week, addressed young people saying: “Don't buy a new video game: make one. Do not download the latest app: draw it. Don't just use yours telephone: program it ". What he mentioned could be a very good synthesis about the urgency to use the computational thinking and the serious game like intellectual tools useful for everyone, no matter what work someone does.

There is a broad consensus among experts and in-service practitioners that the introduction of CT in school curricula is creating demand for large-scale professional development. Therefore, it is vital to focus on the current teachers’ needs and the existing learning solutions. It becomes obvious that comprehensive training activities need to be more often designed so that teachers can transfer sustainably their new skills to their classrooms more easily.

There are several grey areas in the literature, including the definition of computational thinking, the core concepts/attributes, the relationship with mathematics, the way that computational thinking can be incorporated into the curriculum. Based on the existing empirical literature, this report aims to provide a number of definitions of Computational Thinking and Serious Games, as well as the core elements that make a game attractive and engaging. Following that, a national curriculum analysis of Computational Thinking in Mathematics will be illustrated. Following this, the report will encompass national empirical studies on the implementation of serious games to enhance computational thinking in Mathematics education. Furthermore, the report will outline the approaches and the tools that have been used to support training in computational thinking and/or Mathematics education and what learning difficulties in that subject have been reported. Finally, this report will mention the results of the field research, which was conducted online using a questionnaire, on the students' gaming interests to use this knowledge to develop an attractive game concept and environment.

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3. Overview of the concepts

3.1. Definitions and characteristics

Definitions of Computational Thinking

Having as the main goal to 'foster the 21st century skills necessary to fully participate in the digital world' Bocconi et al., (2016) mentioned that Computational Thinking (CT) is a concept that has been gaining attention recently. Closely linked to coding, programming, algorithmic thinking, CT has been promoted by educational stakeholders along other skills that are regarded as fundamental for all, such as numeracy and literacy, as well as a means for developing new skills for integration into the employment market.

In the literature, there is not one unanimous current concept of computational thinking that is being used. For Bocconi et al., (2016, p. 9), Computational Thinking (CT) is: '*a thought process (or a human thinking skill) that uses analytic and algorithmic approaches to formulate, analyse and solve problems', encompassing 'the key ideas and concepts of the disciplinary areas of Informatics and Computer Science (CS).'* Wing (2006) defined the 'computational thinking' as it *"...involves solving problems, designing systems, and understanding human behaviour, by drawing on the concepts fundamental to computer science. Computational thinking includes a range of mental tools that reflect the breadth of the field of computer science" (p.33).* Wing, also, asserted that CT *"represents a universally applicable attitude and skill set everyone, not just computer scientists, would be eager to learn and use" (p. 33).* She claimed that, *"to reading, writing, and arithmetic, we should add computational thinking to every child's analytical ability" (Wing, 2006, p. 33).* Wing (2011), introduced another definition of CT and defined CT as *"the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent" (p. 1).*

Although, there is currently no distinct unanimous definition of computational thinking, based on the research literature computational thinking is a thought process that applies several key features, namely, abstraction, generalization, decomposition, algorithmic thinking, and debugging (Angeli et al., 2016).
You can see the core features of computational thinking in Table 1 below.

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Table 1. Core features of computational thinking

Feature	Definition
Abstraction	The ability to determine what data to preserve for an entity/object and what to neglect (Wing, 2011).
Generalization	The ability to propose a solution in general terms in order to adapt it to multiple problems (Selby, 2014).
Decomposition	The ability to break down a complicated problem into easier parts in order to comprehend and solve it (National Research Council, 2010; Wing, 2011).
Algorithmic thinking	The capability to prepare a step by step series of actions to solve a problem (Selby, 2014).
a. Sequencing	The ability to place actions in the right order (Selby, 2014).
b. Flow of control	The sequence in which to perform instructions/actions (Selby, 2014).
Debugging	The ability to recognise, delete, and correct mistakes (Selby, 2014).

Definitions of Serious Games

The concept of 'serious games' has been first introduced by the researcher Clark C. Abt (1970) in his book Serious Games. Abt suggested that simulations and games can improve education in the classroom as well as in an informal environment. In addition, serious games have positive effects on students as well as on learning outcomes. According to Djaouti Damien (2016) the use of serious games is considered to have an impact on 'learner motivation, trial and error learning, taking into account differences in learning rhythms, stimulating pedagogical interactions between learners'.

Nowadays, there is not one unanimous definition of "serious games". The term is currently established and is becoming increasingly popular. Zyda's (2005, p.26) definition of serious games, stated that entertainment is unambiguously a component: *"Serious game: a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives."* Zyda states that serious games supplements pedagogy including activities that teach, thereby imparting information or skills and as a result makes games serious. Additionally, he emphasizes, however, that pedagogy must be of less importance to the story and that the entertainment aspect comes first.

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The emphasis on the entertainment element comes in contrast with the definition of serious games proposed by Michael and Chen (2006). Michael and Chen (2006, p.21) defined Serious Games as *"games that do not have entertainment, enjoyment, or fun as their primary purpose"* This definition is consistent with that proposed by, e.g., PIXELearning (PIXELearning.com, 2006-11-14); *"The use of computer game and simulation approaches and/or technologies for primarily nonentertainment purposes".* However, Michael and Chen noted that this is not to suggest that serious games are not amusing, entertain ing, or enjoyable, only that there is an added objective over and above that. The main significance is the precision of the process or effect being stimulated for training.

Characteristics of serious games

Besides entertainment, there are important elements that make games attractive and engaging by the players. The main characteristics of electronic games are the rules, the objectives, the conflict, the challenge, the interaction and the script (Prensky, 2001a). Throughout the game the player receives feedback on the results of his actions and adjusts his actions accordingly. With the exception of free interaction games, the rules place restrictions on the user, as he tries to achieve the goals set during the design (Kirginas, 2013; Manoli & Argyropoulou, 2008).

Some factors that make serious games successful are the following:

(i) **User-centered software engineering:** an important element for the success of the serious games industry is the perspective that the designers contribute to the development teams. Indeed, in order to develop an effective serious game, in-depth understanding of the experience that the end users will get while playing the game will provide the development teams with a sensibility that is a must for the success of the technology.

(ii) **Multimodal serious games:** in order for a game in general and a serious game in particular to be convincing to the user, multiple modalities should be incorporated. For example, integrating the haptic technology in a serious game can add a hands-on element to the learning experience in educational games, as well as providing tactile and force feedback in rehabilitation games in the health care domain. However, some researchers have already proved that in some cases multimodal interaction might be distracting to the user, and thus the overall performance drops. Such cases need to be investigated and clearly identified.

(iii) **Social well-being:** stimulating a feeling of virtual presence or connectedness that can contribute to social well-being in real life is a key success factor for serious games. In this context, the development of novel forms of social communication would promote serious games.

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(iv) **Adaptive gaming**: a serious game should adapt to a particular player's capabilities, needs, and interests. For instance, the game contents may be adapted according to the player age group, gender, profession, and physical and psychological state among others.

(v) **Standardization of evaluation:** in order for the serious game domain to acquire higher credibility by the general public, heuristic evaluation standards must turn into a reality. Nowadays, there is a lack of standardized means to indicate whether a game is indeed "serious" or how "serious" a game is. If serious games are made entertaining and fun, this could facilitate their adoption by children and adults alike. However, various challenges arise and have to be overcome for an effective evaluation. For example, motivation of players evaluated in an artificial environment may not be accurate. Motivation also needs to be measured in the long run, as some games may seem as attractive in the beginning, but if the player loses interest in the short term, there will not be any real benefit from the game for the player. Another difficulty arises when evaluating a game for clinical use or for classroom use which can be hard to access. But evaluation remains definitely essential both for measuring the effectiveness of a given serious game and for allowing improvement of serious games by pointing out particular weaknesses. A performance metrics that define how serious games are evaluated is definitely welcomed by the research community.

Elements that make a game attractive and fun

According to the research, there are a lot of elements that can make a game attractive and fun. Some relevant research is presented below.

A video game, in order to attract the interest of users, must be **complex, demanding and relatively long**, as long as **easy and short games do not provide significant challenges** (Gee, 2004). Furthermore, **the script must be presented in a way that pushes players to interact with the digital environment, to compete, to collide and to face the challenges that will arise** (Manoli & Argyropoulou, 2008). Researchers soon found that a digital game with **a careful plot and interesting script** could be an engaging learning environment.

Cris Crawford presents his own study on the motivations that make people play electronic games in his article "The art of computer game design". According to Crawford, the main motivation that drives people into the game is that **they learn**. This impulse can often be unconscious, but it is still very important.

According to Hal Barwood, people play games to live the experiences that are created every moment in their effort either to overcome a difficult challenge of the game, or to escape from daily difficulties, or to feel happy finding the solution to a problem. According to this research, there are four elements that

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motivate users to choose electronic games for their entertainment: **Hard fun**: creates emotions by composing experiences through the effort to achieve a goal. **Easy fun**: focuses on keeping the user focused and not on a winning situation. The user is absorbed in the game and a feeling of curiosity is created. This gives him the impetus to consider other options and to discover other things in the game. When the balance in difficulty is not achieved, one of two different situations may occur: (1) if the challenges are too complex for the skills of the individual, a state of anxiety is created due to the game being too difficult, or (2) if the game is too simple, the skills of the player are too far above the challenges of the game, the child may easily become bored and lose motivation. **Altered states**: Many users report that the way the game makes them feel is one of the main reasons they play. That is, they have fun with the changes in their inner state during the game, as well as after it ends. The presence of other people during the game (**the people factor**): the comments of many users focus on the pleasure they feel when they play with other users, as this creates opportunities for competition, cooperation, performance and spectacle.

Mark Gallear from his own research reached to the conclusions that the first reason for a user to continue the game is **the interactive side** of games, which he characterizes as the most important. Another reason is that users have almost **complete control** over the game world. For example, if the character dies, the user can return to a previously saved location. Psychologists believe that this feature is a very attractive aspect of games for teenagers who have little control over their lifestyle. A third motivation, noted by Mark Gellear, for a user to continue the game is to **develop or improve the character or group of characters he handles**. In addition, **interest** in an object, whether it is a historical period or the **content** of a book or a movie, can be an incentive to play a game. For example, for some types of games, such as adventure games, an evolving story is an important incentive for the user to continue playing the game until the end. Video games are also a powerful attraction for many users, as they can provide a way out of a more exciting world in which users can play a **variety of roles**, such as being indigenous barbarians or space pirates. But games can also have a direct bearing on real life, like Sims. It is even possible to include **real-world missions**, such as snowboarding in a more exciting environment without the dangers that exist or the skill that is actually required.

Gender differences

In addition, research has shown that the majority of boys like to play video games, while there are definitely fewer girls who play them. Girls' interest in video games increases when they are given the opportunity to cooperate. One of the factors that affect the effectiveness of Educational electronic games is the balance between the capabilities of the learner and the challenges he encounters within acceptable limits so that the user does not feel boredom, lack of fun, anxiety and stress. When the challenge is higher

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than his/her abilities, anxiety and frustration are created, while when it is lower, the feeling of boredom is created (Csikszentmihalyi, 1975).

3.2. National Curriculum Analysis (Computational Thinking + Math Education)

In this section, a national curriculum analysis of Computational Thinking in Mathematics will be illustrated in all five participating countries: Cyprus, Romania, Greece, United Kingdom, Italy.

The entire school curriculum was re-examined in the light of CT: not only it succeeded in posing the problem, but also in obtaining its introduction in curriculum, starting from primary school in England (from the school year 2014-2015), in Italy (from the school year 2015-2016), Australia, France, Poland and Finland (from the 2016-2017 school year). A federal law of United States, which has included IT among the subjects belonging to Science-Technology-Engineering-Math (STEM), and the initiative "Computer Science For All ”by President Obama, have opened the doors to the introduction of CT in the curricula of the States of the Union.

Paving the way to curricula reforms within Europe, **England** (UK) was one of the first EU countries to introduce CT and coding in the national curriculum for primary and secondary schools in September 2014, stressing not only the importance of computation and programming, but of conceptualizing CT as well (Bocconi et al., 2016). As a result of the 2012 study published by the Royal Society, *Shut down or restart? The way forward for computing in UK schools* (The Royal Society, 2012) – a review of computing education in the UK, the following conclusion was reached: the ICT subject is too technological and it should be defined into clearer areas. Thus, ICT was removed from the national curriculum and the new subject of computing was introduced, covering at present all three strands of: digital literacy, information technology and computer science. Becoming mandatory for pupils aged 5-16 years in England,’ computer science and CT became part of the foundation subjects in England, together with English, mathematics and the sciences’ (Voogt et al., 2015).

The National curriculum in England: computing programmes of study (11 September 2013) states that ‘A high-quality computing education equips pupils to use computational thinking and creativity to understand and change the world.’ It also emphasises the fact that computing ‘has deep links with mathematics, science and design and technology, and provides insights into both natural and artificial systems.

In **Greece**, along the same lines, Greek Ministry of Education is currently planning the integration of CT and/or related concepts into compulsory primary and secondary education and proceed to the curricula

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reforms. Several efforts made to introduce Computer Science as a separate subject in primary and secondary education, where students aged 9 to 16 gain a deeper understanding and get familiar with the computational processes from a technological point of view. In addition, students interested in Economics/ Informatics studies are obliged to pass their final exams including Computer Science (problem decomposition, algorithm/procedures).

In **Poland**, since 2017, teaching of Computational Thinking is included in the Computer Science subject's national curriculum, from the 1 to 8 grade in primary schools and high school's students' (from the age of 7 to 18) (Kwiatkowska, 2017). In the mathematics curriculum for the grades 6-8, the terms perfecting the abstract thinking and, consequently, learning how to reason and make correct conclusions in new situations, as well as those related to complex and unusual issues, are introduced. It also can be included as part of the Computational Thinking (Podstawa Programowa – Matematyka – Szkoła Podstawowa IV-VIII, n.d.). Serious games in education are in Poland also supported by teachers educational institutions. The free portal www.piktografia.pl supported by the Centre for Education Development (CED - Polish national teacher training institution), offers only a few serious games for children and young people, but they are complemented by a rich set of materials for teachers, supporting the use of games in work with students. In turn, the paid educational portal based on games www.squla.pl advertises itself with an offer of 65,000 quizzes, games and puzzles. Teaching magazines such as "Mathematics" also periodically publish papers on serious games in educational applications at different stages of education.

In **Italy**, with the document on "good school", the Italian government has opened the debate on the introduction of CT at school also in Italy. The debate on the document produced two curriculum proposals (one for primay school and the other for upper secondary school) and two recommendations documents (one for the introduction of computer science in the curriculum and the other for the introduction of the CT as a cross-cutting competence). Law 107 (2015) includes CT among educational objectives of the school (paragraph 7). The following National plan Scuola Digitale (Digital School) reiterates this decision and hopes for one redefinition of "digital competence" and a revision of "Indications for the curriculum" (page 74). Computational thinking has been implemented by MIUR (Ministry of Education, University and Research) with the introduction of Coding in schools starting from primary. In parallel, the MIUR promoted the project Planning the Future which, since the 2014-2015 school year, has been experimenting with "coding" activities for the introduction of CT at school.

In the MIUR circular 08/10/2015 the introduction of the CT is justified as follows: "The scientific-cultural side of computer science, also defined Computational thinking, helps to develop skills logic and ability to solve problems in a creative and efficient way, qualities that are important to all future citizens. The

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simplest and most fun way to develop Computational thinking is through programming (coding) in a game context. As also foreseen in the National Digital School Plan, an appropriate education in computational thinking, which goes beyond the initial digital literacy, it is indeed essential for the new generations to allow them to facing the society of the future not as passive consumers unaware of technologies and services, but as subjects aware of all the aspects at stake and as actors actively involved in their development.”.

In **Cyprus**, there is no lesson focus entirely on Computation Thinking. Despite that, the national curriculum regarding Mathematics relied on the five CT skills, in secondary education. The five CT capabilities, specifically, abstraction, generalization, decomposition, algorithmic thinking, and debugging, are embedded in maths activities. Concisely, it seems that the curriculum targets to involve students in computational thinking processes. It is noted that, modifications of the curriculum may be existed across different classrooms and schools.

3.3. Application of serious games to enhance computational thinking - focus on Math Education

Curricula that used serious games to specialize in learning programming have found positive effects on students as well as on learning outcomes (Ater-Kranov et al., 2010). Games are now being adopted by teachers as a key teaching tool, while such serious games are incorporated into traditional lesson plans so that students learn concepts through playing (Kazimoglu, Kiernan, Bacon, & Mackinnon, 2012). This comes as no surprise because computer games contain interactive, engaging and immersive elements that have educational affordances (Frazer et al., 2014). The main idea is to shorten the time between theory and practice and merge abstract concepts with practical experiences and therefore to inspire students to learn (Vahldick et al., 2014).

Research in **Greece** found that playing serious games to learn programming is linked to a range of perceptual, cognitive, behavioral, affective and motivational impacts and outcomes (Theodoropoulos et al., 2017). According to Malliarakis et al., (2014), most of these games involve a scenario designed to cover a basic programming task and learn algorithmic thinking and help students communicate and collaborate with their classmates, whereas some games cover more advanced learning objectives. However, the CT education domain is still in its infancy and requires research for developing theories of the learning mechanisms occurring in computer games (Kazimoglu, Kiernan, Bacon, & MacKinnon, 2012). Hence, the impact of serious games on CT development has only evaluated to a small extent. It also should be taken into account, that CT education is particularly challenging for students underrepresented in the fields of

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computing and engineering, such as girls and other learners from nondominant groups (Eordanidis et al., 2017). For these students, programming learning methods and digital games have been used together in such a way that one benefits from another.

In young children's education, the programming of toy robots (e.g., Bee-Bot) is also widely applied in **Greece** (e.g. Atmatzidou & Demetriadis, 2016). For this activity, in particular, the learner needs to split the actions (that wants the robot is to carry out) in a sequence of movement, paying attention to spot similar actions in different situations that can be repeated without re-programming them. Hence, the learner carries out useful practices of abstraction and decomposition. This resonates with the different affordances of physical and virtual environments supporting multiple pathways to CT.

Meanwhile, in the **Cypriot** educational system, there are no studies that have explored the usefulness of serious games as technological means to enhance the computational thinking. Nevertheless, there are few studies that have examined the effect of using educational robotics to enhance student's CT skills at a primary and a secondary school (Ioannou & Angeli, 2016; Ioannou & Makridou, 2018; Angeli & Makridou, 2018; Constantinou & Ioannou, 2018).

Additionally, there is an international competition for students in primary and secondary education, namely Bebras, for Computational Thinking, organized in Cyprus by the Cyprus Association of Informatics in collaboration with the Association of Informatics Teachers and under the auspices of the Ministry of Education, Culture, Sports and Youth. The goal is to promote Computational Thinking among students in a way that enhances students' skills beyond science and math and upgrades their analytical and algorithmic problem-solving skills.

Furthermore, there is an analytical tool, namely Dr Scratch that assesses Scratch projects in a number of computational fields. This analyser is a helpful method for analysing students' own projects, or those of Scratch students. In a fun way, learners can learn how to develop their programming abilities. Also, feedback is provided on many aspects which are associated to CT.

Finally, Google for Education released the Google Exploring Computational Thinking tools (along with the CT for Educators available online lesson) to many specialist organisations working internationally to promote CT teaching and learning. The resources (e.g. lesson plans, videos etc.) were developed to provide educators and administrators with an enhanced understanding of CT, and to help those who want to incorporate CT into their own content, teaching practice and learning in the classroom.

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In **Italy**, MIUR has long been encouraging the use of gaming and gamification at school. An example of this is the National Digital School Plan, which supports the use of digital technologies and the Digital School Award which aims to promote innovative projects in the field of education, including the use of gaming and gamification, centered on students, as subjects in continuous training, integrating multimedia culture with school and family culture through an education to, with and for the media.

Here follow some examples of "serious games" with which it is possible to play online, to be used at home with parents or together with teachers and their own "virtual" class or not:

Twenty months (https://www.wearemuesli.it/)

A collection of interactive stories on the Resistance and Liberation from Nazi-Fascism. 20 stories inspired by real events in the Sesto San Giovanni area (Milan) and its surroundings during the Second World War. Available for free in Italian and English, and in PC and Mac version.

Function & GO (http://seriousmathgames.unict.it/index.html)

A serious games for learning basic mathematical concepts. The target of the training are the students of the penultimate and last year of high school.

If you love me don't die (Bury me my Love) (https://burymemylove.arte.tv/)

It tells the story of Nour, a young Syrian migrant who embarks on a dangerous journey to her safety aided by her husband Majd.

Escape Room for education

Themed scenarios (an investigator's study, a scientist's laboratory, a hospital, a castle, a crypt, etc.) from which one must escape by finding the so-called "final key", passing through insidious and stimulating paths.

The Great Palermo (https://www.wearemuesli.it/palermo)

The game is called "A story of food and transformation". It develops as an interactive visual novel based on the culture of food in the Sicilian city, explored by the protagonist Gaetano.

uManager (https://www.youtube.com/watch?v=fDXDkAxWloE&feature=emb_logo)

uManager is a very intersting experience, a customizable learning environment, result of a research process started in 2011 at CNR. The main element of this environment is a Serious Game designed to foster the development of business and financial skills and abilities for high school students of second degree. On the other hand, uManager offers teachers the ability to manage sessions of game with respect to specific

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educational objectives and monitor activities of pupils. uManager enables students to try their hand at managing a tourist village, stimulating own decision making and problem solving skills, as well as management skills related to resource management, in a motivating environment and, at the same time, adhering to reality.

In **Poland**, there is no empirical studies regarding application of serious games to enhance computational thinking that focus on Math Education. Studies in Poland are rare and focused on children. The group of 8-years-old pupils have shown, for example, that 8 to 16 lessons using serious games are sufficient to improve calculus technique and logical thinking in solving tasks (Stucki, 1999). Similar results analysed in terms of Bloom's taxonomy were obtained in a group of children aged 7-10, among whom a significant increase in mathematical competences was noted after a semester of using serious games and online teaching materials (Kaczmarek, 2003). One of possible reasons for the limited interest of Polish researchers in the effectiveness of games in education may be cultural factor (Mączka, 2016). A comparison of the effectiveness of early mathematics teaching in Poland and Japan with the use of serious games indicated that the rationale for the better mathematical competence of Japanese students may be the extensive use of the problem-based method in Japan, applied in few, but very carefully and long analysed tasks. In Poland, on the other hand, as in the USA and Western European countries, games are treated as an element making learning more pleasant, i.e. reducing effort and partly even taking time away from "proper work", and thus competing with serious educational tasks. As a result, despite encouragement from experts and teacher training institutions, only 4.1% of mathematics class time was devoted to didactic games during initial mathematics teaching in Poland in 2008 and 2010 (Mączka, 2016), and games for adults are rare.

In **United Kingdom,** two UK students aged 13–14, developed a video game. 'Playing Beowulf'' was a project funded by the an Arts and Humanities Research Council (AHRC) with the aim of promoting 'further engagement with the epic Anglo-Saxon poem Beowulf by bringing together a thousandyear-old text, digital technologies and new means of creative expression'.

Regarding the way that CT can successfully be integrated into linking subjects , such as Mathematics, a good example is given by the ScratchMaths project, developed by University College London (UCL) and funded by the Educational Endowment Foundation (EEF), that further explores the way students engage with mathematics through coding. The project aims to demonstrate that during a CT lesson, students can learn how the brain functions, while learning computer science concepts at the same time, through modelling of the brain (Henrique de Paula et al., 2018).

Another initiative worth mentioning is the development of a resource hub, containing puzzle-based activities teaching computing topics and computational thinking for classroom use. The resources are

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suitable for all ages and are meant to improve logical thinking skills, computational thinking, algorithmic thinking, evaluation, data compression, image representation, binary, code cracking, search algorithms, graph algorithms. The puzzles and Computational Thinking hub was produced by Teaching London Computing , with support from Google's CS4HS programme and with additional support from the Department for Education, Mayor of London and EPSRC through the CHI+MED research project.

As additional support for teachers providing CPD classes, a valuable tool guide for teachers is offered by Discovery Education Community, a global network of teachers and education professionals passionate about enhancing the learning experience of their students through the use of digital media connects members across the UK and around the world. Their main goals are: to strenghten the way teachers teach and students learn and to add meaning and relevance to the school curriculum, helping teachers and students to reach their potential. The Discovery Education Coding focuses on providing support for teaching coding in primary schools, ensuring that pupils acquire a 'secure understanding of coding concepts like algorithms, sequences and variables - as well as developing computational thinking skills through decomposition, logical reasoning and problem-solving', while allowing both students and teachers to enhance their creativity through the creation of their own apps and by sharing them with peers. They offer: guided lessons, video tutorials, interactive resources for students, social media support, virtual conferences and face-to-face events.

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4. Training approaches

The introduction of CT in compulsory education requires support measures to prepare teachers. The integration of CT into the curriculum at all educational levels is creating demand for large-scale in-service continuous professional development. The training opportunities found in the literature focus mainly on pedagogical approaches rather than technological. Most training seems to be designed for all subject teachers, sometimes with a particular focus on STEM teachers.

In that, **Hellenic Education Society of STEM** (E3STEM) (http://e3stem.edu.gr/wordpress/?lang=en) has been established where a community of University Professors, Researchers, School educators and School Advisors can share a common vision for the role of STEM epistemology in promoting education, enhance their knowledge on CT, and promote the STEM epistemology, computing, computational science and computational thinking, and to advance understanding and education of the STEM methodology alongside with contemporary learning theories and didactic models by participating in seminars and several training programs organized by the association. Thus, participants are able to increase their sense of self-efficacy and improve their views on the need to include computational thinking in their lessons. They also can recognize the importance of working with other colleagues and thus manage to create remarkable lesson plans based on Computational Thinking. Pedagogical approaches addressed in such professional development interventions include storytelling, problem solving, inductive pedagogies with a main focus on computational models and simulation. Often, training activities are designed specifically to be hands-on so that teachers can more easily transfer their new skills to their classrooms. While several MOOCs have been developed, a face-to-face component of teacher training is still relevant.

Besides this, there has been noted focus on training for pre-service teachers. Four training approaches are highlighting; where the first approach entails the Partner4CS Professional Development model that includes not only a summer institute, but also follow-up classroom-based support and online support (Mouza et al., 2016). The second one is the integration of CT in existing modules on problem solving and critical thinking within a required educational psychology course for pre-service teachers (Yadav et al., 2014). A third approach comprises a series of pre-professional development interventions to assist teachers in utilizing CT and programming as an instructional tool within other subject areas (i.e., music, language arts, mathematics, and science). In the fourth approach, trainee teachers use the Flash Action Script to write pseudocode to solve a problem (CT skill) and translate that into Action Script (programming skills).

The lack of education of teachers in terms of Computational Thinking skills and consequently their inability to introduce corresponding activities in their lessons is mainly pointed out (Kong, Lai & Sun, 2020). In that,

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the factor of the duration of the learning activities that the teachers receive entails the main learning difficulty.

In **the United Kingdom**, according to the Royal Society Report (2012), it is quite challenging to recruit skilled computing teachers. Until the introduction of CT in the national curriculum by the British Government, there were not specific university courses and the Postgraduate Certificate in Education (PGCE) in Computer Science only became available at some universities starting with 2013-2014. Following a survey on the need of training for teaching CT, within a 5 year period until 2017, the Government's recruitment target for both postgraduate and undergraduate teacher training courses was of only 68%. It was also concluded that in order for prospective teachers to be able to familiarize themselves with the pedagogical aspect and curriculum knowledge, they would already have to possess a thorough level of knowledge of CT, taking into account its technical nature. Unfortunately, there is currently a lack of candidates having this knowledge and although pre-service courses are available in England, the courses' quality is a concern until an accreditation system is provided. Another finding of the survey brings into attention the fact that most teachers primarily responsible for CT also teach other subjects, such as business studies (23%), mathematics (16%) and design and technology (12%). These teachers also need support in order to adapt. They require high-quality CPD (Continuing Professional Development), therefore intensive training is a must in order to increase their knowledge of CT, of the curriculum and pedagogical approaches, while they also need to acquire experience in teaching the subject.

In UK, teachers participating in the Royal Society Report survey have said that, apart from teacher network meetings (e.g. CAS- Computer At School hubs) as the primary means of CPD training, external training courses and Massive Open Online Courses (MOOCs) closely followed. Other tools include: webinars, CAS toolkits (e.g. Quickstart), CAS Barefoot workshops, lesson observations and peer review.

It is proposed as a necessary element for the effective training of teachers, the creation of more comprehensive training programs and support frameworks. Indicatively, the researchers propose the creation of annual distance learning programs, as well as the development of electronic repositories, where teachers can share good practices and teaching scenarios with other colleagues. In that, trainee teachers will have more time to manage and assimilate content knowledge of Computational Thought, knowledge of technological content but also knowledge about the environments they can utilize.

Approaches and tools have been used to support training in computational thinking

In the review of many research papers on Computational Thinking by Kalelioglu, et al., (2016), where the concept is characterized as a collection of basic intellectual tools and practices derived from computation,

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but focused to all fields far beyond computer science, its main dimensions are identified, which are: subtraction, problem solving, algorithmic thinking, pattern recognition and design-based thinking.

Also, Djurdjevic-Pahl, Pahl, Fronza, and El Ioini (2017), stated that the dimensions and strategies that compose the concept of Computational Thought, are: logic, algorithms, deconstruction, patterns, subtraction, evaluation, trial and error, creation, debugging, persistence and cooperation.

In an effort to group the basic dimensions of Computational Thought, Duncan, Bell and Atlas (2017) mentioned the following dimensions: algorithms-automation, subtraction, decomposition, generalization, logical organization and data analysis and evaluation of solutions.

A similar attempt to present the basic aspects and dimensions of the concept is made by Corradini, Lodi, & Nardelli, (2017). According to them, there are four general categories which are: a) mental processes, which include: algorithmic and logical thinking, problem deconstruction, subtraction, pattern recognition and generalization b) methods, which include: automation, collection, analysis and representation of data, parallelization, simulation, evaluation and programming c) practices, including: experimentation, repetition, tinkering, test and debug, reuse and remix, and d) transversal skills, which refer to general ways of perceiving and operating by utilizing skills used by IT scientists, such as creating, communicating and collaborating, using computation to identify and understand the computational aspects of the world (reflect, learn, meta-reflect), tolerance for ambiguity and persistence in complex problems.

Furthrmore, according to Fesakis et al. the key aspects and dimensions of the concept are the following (Fesakis, et al., 2018): creative problem solving, algorithmic approach to problem solving, transfer of problem solving, logical reasoning, subtraction, generalisation, representation and organisation of data, systemic thinking, evaluation and social impact of computation.

Approaches and tools have been used to support training in computational thinking and Math education

Mathematical thinking comprises the use of skills in mathematics to solve mathematics problems, as for example equations and functions (Sneider et al., 2014). Harel and Sowder (2005) provided a description about mathematical thinking: as universal through several problems and "…governs one's ways of understanding" (p. 31). Mathematical thinking involves of three segments: assumptions about math, processes in problem solving, and explanation for solutions. According to Wing (2008), problem solving processes are the key commonality among CT and mathematical thinking. Figure 1 illustrates the complete set of shared computational and mathematical thought concepts: problem solving, modelling, analysis and interpretation of data, and statistics and probability.

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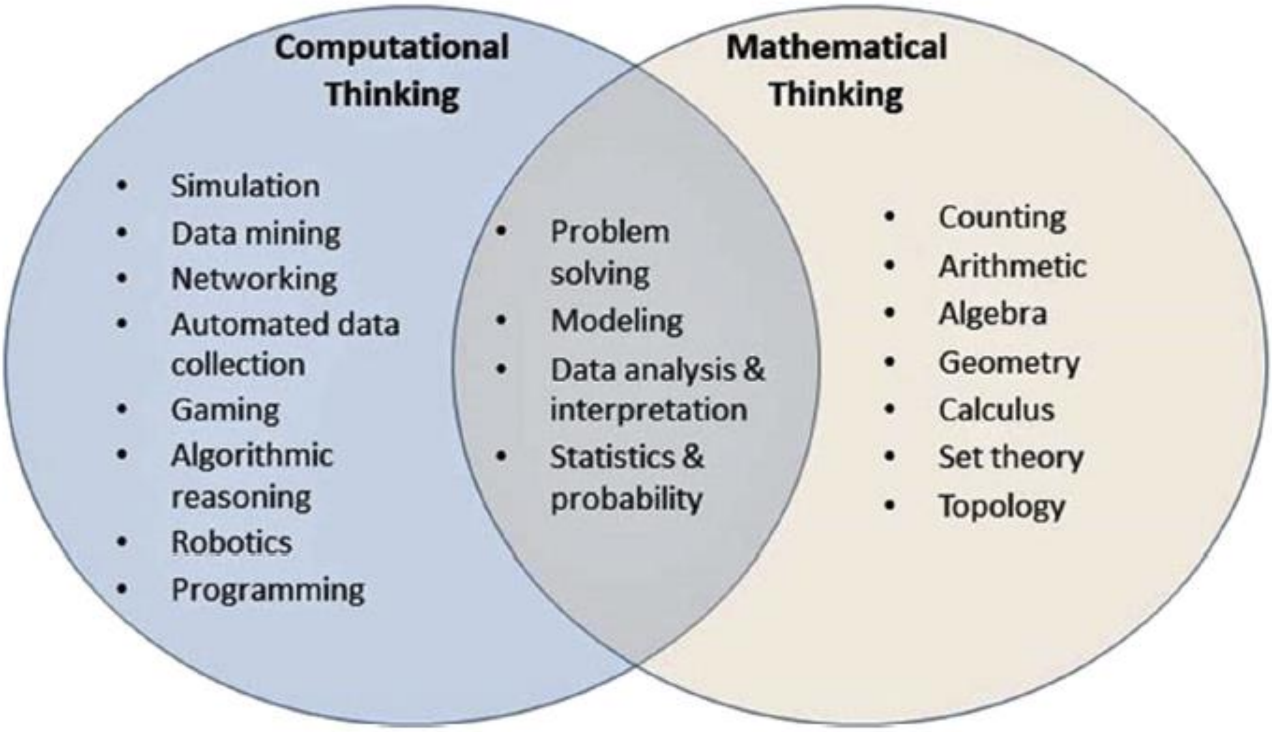

Fig. 1. Similarities and differences between CT and mathematical thinking. Adapted from Sneider et al. (2014).

Figure 1. The complete set of shared computational and mathematical thought concepts (Sneider et al., 2014, p. 11)

In Sneider et al.'s article (2014, p.11), it was mentioned that "Mathematical and computational thinking in [grades] 6–8 builds on K–5 experiences and progresses to identify patterns in large data sets and using mathematical concepts to support explanations and arguments.

• Use digital tools (e.g., computers) to analyse very large data sets for patterns and trends.
• Use mathematical representations to describe and/or support scientific conclusions and design solutions.
• Create algorithms (a series of ordered steps) to solve a problem.
• Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems.
• Use digital tools and/or mathematical concepts and arguments to test and compare proposed solutions to an engineering design problem." (NGSS Lead States 2013, Appendices, p. 59)

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Also, according to Namukasa, Patel and Miller (2017), supported the view that teaching practices that allow basic CT and mathematics activities in classrooms, seem to associate with practices that allow innovative teaching and learning in mathematics:

a) Instruction with hands-on tools and materials;
b) Instruction using problem-solving;
c) Incorporating subjects as seen in the efforts of STEM, STEAM or i-STEM;
d) An emphasis on understanding, and thinking processes and practices by aiming on mastery of capabilities, facts and procedures;
e) Instruction through examination, research, inquiry, construction and performance of knowledge, or project-based learning;
f) Learning practices that are used in 21st century.

Namukasa et al., (2017) grouped the tools for Computational Thinking that were used in Grades 4-8 underneath three broader categories: Block/Visual Coding Languages, Digital Tangibles, Apps and Games (see Figure 2).

Table 3. CT Tools used in Grades 4-8.

Computational Thinking Tools				
Block/Visual Coding Languages	**Digital Tangibles**			**Apps and Games**
Block coding languages	*Robots and Robotic Systems*	*Digital Making and Electronics Design Materials*	*Programming Blocks*	*Programming Apps, Games and Web-based simulations*
Scratch	Sphero, Ollie	Makey Makey	Osmo Coding	OSMO Tangram,
Tickle	Lego Mindstorms EV3	Chibitronics—		Tickle, Kodable, Lightbot
Scratch Jr.	Kibo	Conductive Paint	Kibo	Blockly Maze and Block Turtle
	Mbot, Osbot		Cubetto	

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In **Poland**, Computational Thinking was introduced into schools as part of the Computer Sciences and its taught primarily by programming. The second method is by the educational games. In the lower grades CT is taught by the use of the visual programming languages and in the higher grades by textual programming languages (Kwiatkowska, 2017).

What learning difficulties in that subject have been reported?

Students with numeracy or other learning difficulties in mathematics show deficits in many areas of their perception and cognitive development. In particular, they have deficits in visual perception, auditory perception, fine motor skills, have poor memory and other memory difficulties, have difficulties in speech and language comprehension of the mathematical code and have deficits in abstract reasoning.

Specifically, deficits in visual perception appear: (a) as a form-deficit, i.e. the child does not complete the exercises on a page, "jumps" / crosses lines, when performing an exercise, reads incorrect multi-digit numbers, (b) as a deficit that is, the child depicts mirror arithmetic digits (e.g. 6 instead of 9), inverts the sequence of multi-digit numbers when copying them, does not distinguish between coins correctly, does not distinguish clockwise correctly and has difficulty interpreting and handling mathematical symbols (e.g. x instead of +), (c) as a spatial organization deficit, i.e. the child has difficulty writing the numbers on the line of the notebook, has difficulty distinguishing between "before" and "after" in spatial sequences, it is difficult to distinguish between "right" and "left", it is difficult to distinguish the sizes of shapes, it is difficult to write fractional numbers, it transfers prisoners to wrong columns in the execution of operations, has difficulty in using the arithmetic line, has difficulty in comparing multi-digit numbers and in understanding the positional value of digits, has difficulty in constructing and interpreting graphs.

Deficits in auditory perception appear as difficulty in oral exercises, in solving problems that occur orally and in distinguishing terms and words that are phonologically similar (e.g. thirty-fourth and four hundredth). Deficiencies in fine-tuning appear as slow spelling, misspellings and duplication of numbers, and difficulty adjusting the size of the digits in the available space or page. Memory deficits relate to both short-term memory and working memory and long-term memory, which are characterized by the student's difficulty in retaining mathematical data, the difficulty of automatically retrieving the steps of algorithms, propaedeutic and learned spatial-temporal concepts. In addition, memory deficits increase the difficulty of solving complex problems and exercises.

Deficits in speech refer to the difficulties in the recitative speech, in the understanding of the mathematical terms, such as reduced, product, quotient, rest, prisoner, etc. There are also difficulties and / or expressive

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speech. For example, the student finds it difficult to express orally and using mathematical terms what he thinks, he finds it difficult to orally describe the steps of an algorithm or a strategy that follows. Deficiencies in abstract reasoning refer to the student's difficulties in converting linguistic or numerical information into mathematical expressions. It also makes it difficult to understand mathematical symbols (e.g. =,), to solve oral problems and to compare sizes and quantities.

In addition, very significant difficulties arise from the lack of attention that can coexist with other difficulties and exacerbate them, especially when specific steps have to be followed e.g. in the algorithms of operations, or when it comes to mental calculations, or prisoners, etc. Very often, it is the mistakes of carelessness, when he copies or dictates numbers, and when he thinks or says and writes. The characteristics of the student with difficulties in mathematics include the lack of strategies, when faced with a mathematical task, or the ineffective use of the limited strategies he uses. Thus, it is difficult to process information, that is, to identify important information in verbal problems and focus on irrelevant or insignificant details (e.g. an unknown word that does not affect the meaning of the problem). Finally, the student who has difficulty in mathematics usually has low learning motivation, is a passive recipient in the learning process and attributes his failure and success to external, out of his control, factors such as luck. He has problems systematizing his thinking when solving problems, has remarkable difficulty in self-control and self-monitoring during his work on mathematical works, is impulsive, and finally, has significant deficits in basic mathematical knowledge that he should have acquired at an earlier time (previous grade or previous grade).

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5. National Results from the questionnaire

CARDET as the partner responsible for the conduction of field research has drafted the **Questionnaire on Game Interests** for the Intellectual Output 1 – IO1 (ANNEX 1). The questionnaire aims to find out about the gaming interests of the students in lower and higher secondary education in order to use this knowledge to develop an attractive game concept and environment. The questionnaire includes both close-ended and open-ended questions that allows participants to express their satisfaction on specific aspects of game interests. The questionnaire was developed online using the Google Forms software in order to be able to be administered online. This option works well in terms of saving time as the online software automatically performs the collection of the questionnaires and allows visual representation of the data. Also, it offers convenience and easy access to participants as they can fill the questionnaire from everywhere and when they choose according to their own time schedules. Every aspect of the questionnaire is being analysed in detail below.

Description of Sample

Demographic characteristics for each country can be found in Table 1.

Table 1. Demographic characteristics

Country	**Number of participants**	**Age**	**Gender**	
			Boys	**Girls**
Cyprus	47	13-19 years old	38.3%	61.7%
Greece	39	13-18 years old	58.9%	41.1%
Italy	98	15-23+ years old	49.1%	50.09%
Poland	190	11-18 years old	50%	50%
United Kingdom	20	12-15 years old	40%	60%

Firstly, participants were asked whether they had played an 'educational game' before. In UK and in Poland the majority of the students (approximately 80%) answered 'yes' in contrast with Cyprus, Greece and Italy that half of the students answered 'yes'. Interestingly, in Cyprus and Greece, an important percentage of

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students answered that they 'do not know' if they played or not an educational game. A very small percent of students from all countries answered 'no'.

After that, students were asked whether they thought that it is important to solve problems related to mathematics in a game. The majority of the students from all countries were answered positively this question. Students seems to acknowledge the importance of an educational game.

Following that participants were asked how much time per week, on average spent playing. In Cyprus, Greece and Italy the majority of the participants answered that they play between 0 and 2 hours per week. In contrast, in UK, it seems that student spend a lot of time playing game. Specifically, over 40% of participants spend more than 8 hours per week playing games, followed by 20% stating they play on average 4-6 hours per week. Interestingly, in Poland, the majority of participants stated that they play either 0-1h per week or more than 8h per week.

Then, students were asked about the device that they use the most. In Cyprus, Greece and Italy, the majority of the participants use a smartphone to play games. In contrast, in UK when asked to choose the type of device they use most to play, most participants accounting for 40% said they use an Xbox, while 30% prefer to play games on their Smartphone. Also, in Poland, 50% of participant use PC to play, while 32% plays on the mobile phone.

In the next question, students were asked why they are playing games. The responses were varied but the most common responses that were mentioned from all students were: Pleasure, Excitement, Competition, Challenge, Relaxation and Leisure.

In regards to the question 'What type of game do you prefer?' students' responses were varied among countries. In Cyprus, Greece and UK, the majority of the students preferred action games with next preferred type of game the strategy games. In Italy, most of the participant play sports and strategy type of games. Similarly, in UK some of the students mentioned that they prefer to play sports games in the same extend as strategy games. In contrast, in Poland, the majority of the participant play FPS type of games, followed by the adventure and online type of games.

In terms of interaction during the game, in Cyprus, Italy, Poland and UK, a high percentage of participants stated they prefer games in a multiplayer mode, with two or more player option. Playing alone is on the second place and playing in a two-player mode is on the third place. In contrast, in Greece, the majority of the participants prefer the two-player option.

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After that, participants were asked whether they would like to compare their performance with that of other players. A large fraction of students, in Cyprus, Greece, Italy, Poland and UK answered 'yes' to this question. Although, a significant percentage of students in UK (40%) and Poland (>50%) answered 'no', that they don't want to compare their performance.

Then, students were asked whether they would like to create their own character, with the majority of the participants from all countries responding positively to this question, indicating that they would like to create their own character.

Following that, participants were asked to select 3 features of games that they find most appealing. Most of the participants from all countries stated that the challenges (having different levels in the games), graphics (having vivid graphics), storyline and clear goal are the most appealing features in a game.

Regarding the question 'What type of setting do you prefer?' the majority of the participants in Cyprus stated that they prefer the Real World setting (61.7%), followed by 31.9% of the participants who stated the Imagination setting. In Italy and UK, participants prefer almost equally both settings. In contrast, in Poland, the majority of the students prefer the Imagination setting (62%) instead of the Real World setting (34%).

Also, the questionnaire incudes a five-level Likert scale question in which students were asked as to what extent they agreed or disagreed with some statements. The statements related about elements that keep players immersed through the educational content of the game.

1. I learn better if I can relate the experiences of an educational game to experiences in real life
2. I learn better when each new piece of knowledge builds on pre-existing knowledge
3. I enjoy games that seem too hard
4. I find feedback on my actions in-game helps me to progress
5. I prefer playing games which have clear goals to achieve
6. I feel I learn more when I am engaged in a role I play in a game
7. I feel I can understand a subject being taught to me if I can experiment with the ideas that are taught
8. I feel more engaged in games when using knowledge about the game's story and world to solve problems
9. I feel more engaged in the game if the rewards/bonuses are adjusted to the difficulty of the performance

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- The majority of the students from all countries answered that they 'agree' or 'strongly agree' with the above statement. Interestingly, in Poland, most of the participants were undecided whether they agree or disagree regarding the statement 1 and 6.

Finally, the majority of students from Cyprus, Greece, Italy and Poland would like to be notified when we have more news about the development of the game. In contrast, in UK, exactly half of the participants would like to be notified and the other half would not like to be notified.

As stated above, the questionnaire also contained one open-ended question which allowed participants to provide more information. **The students were asked to write any other game elements that they consider important to be included in the game in order to make it more engaging and attractive.** The specific responses are presented below:

- Updates
- No time limit to do the tasks
- Creativity of the game
- Interesting storytelling/content/scenarios – objectives, long/never-ending story; difficult, shocking plot, to be unveiled by the player or influenced by the player through their choices; many subplots.
- Secondary objectives to the main storyline of the game
- Teachings for real life
- Different, interesting missions for each of the levels
- Interesting setting (a mix of fantasy and reality) and animals in the game
- Science Fiction
- Very realistic: physics and scenarios
- Interesting and well-designed characters – vast number of them and ability to gain them. Back-story of the characters revealed at the beginning.
- Interesting music
- Voice chat in the game
- Detailed game /clear and easy to use
- Interesting dialogues
- Good mechanic of the game, optimization and the ability to ray track
- Balance in the player's levels
- A lot of users and different levels of difficulty
- Daily challenges and rewards
- Particular attention to competitions
- Interesting graphic

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- English language elements
- Trivia and riddles
- Realistic physics in the game
- Co-operation and rivalry with different players in open world
- Many goals, so the players can utilize their creativity
- Ability to download modes/updates of the game
- Quests
- More lives/chances in the game
- Real life
- Friends or Foes motif
- Modifications in the gameplay and unique maps.
- In-game shop
- More updates and levels
- More believable and advanced game mechanic
- Challenges, international contests
- Creation of characters, maps, settings, etc. by the players
- Ability to find game items
- Skins for characters and a world open for exploration.
- Quick loading
- Promotion of the game
- Up to date
- Social interaction: Play online with other people and communicate with others
- Making the game colourful
- Not to give all the details to the player to let him experiment
- Making sure that the games runs smoothly on different devices
- Freedom in doing actions for the player: creation of characters, scenarios, settings, etc
- Possibility to choose a personalized game mode
- Variety
- Emotional involvement

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6. Conclusions and recommendations

Taking all into a consideration, it is evident that most of the students have played an 'educational game' before and they think it is important to solve problems related to mathematics in a game. The majority of students, spend playing games on average 0-2 hours per week but there is a signigicant percentage of students that play more than 8 hours. The majority of the students used a smartphone to play a game and they prefer to play action, strategy games, sports games, and FSP games in a real world setting. In terms of interaction, they prefer to play a game with 2 or more players and they would like to compare their performance with that of other players. Most of them they would like to create their own character. The students, also, mentioned that, the most appealing features of the games are challenges, graphics, storyline and clear goal. The majority of them play for pleasure, excitement, competition, challenge relaxation and leisure. Additionally, students supported that they learn better if they can relate the experiences of an educational game to experiences in real life and when each new piece of knowledge builds on pre-existing knowledge. Furthermore, they enjoy games that seem too hard and they find feedback on their actions in-game helps them to progress. They prefer playing games which have clear goals to achieve. They feel that they learn more when they are engaged in a role they play in a game and they can understand a subject being taught to them if they can experiment with the ideas that are taught. Finally, they are more engaged in games when using knowledge about the game's story and world to solve problems and if the rewards/bonuses are adjusted to the difficulty of the performance.

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8. Annex

CTApp: Questionnaire on Game Interests

CTApp is a project funded by the European Union.

The Research Team is comprised of 5 partner organisations from 5 different EU countries (Poland, United Kingdom, Cyprus, Italy and Greece). The project aims to create a mobile game that encourages young people to acquire computational thinking skills.

Through this questionnaire related to games, the Research Team aims to find out about the gaming interests of the students in order to use this knowledge to develop an attractive game concept and environment.

Instructions and useful information for participants:

The approximate duration of taking this survey is 5-8 minutes.

GDPR: All the information gathered through this questionnaire will be strictly used explicitly for scientific research. The responses will be handled in a discreet manner, confidentiality and anonymity are granted to all participants. The answers will be saved in a properly secured place, with no authorisation to anyone apart from the Research Team. All relevant data will be destroyed-deleted after the pass of 2 years.

If for any reason during the survey, you feel uncomfortable, you can stop anytime.

You can contact the Survey Creators using the email provided below for any assistance and further information.

Contact email: andrea.filippou@cardet.org

We remain at your disposal for any further communication.

With Warm Regards

CTApp Consortium

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1. **What is your gender?**

Answer
Male
Female
Other

2. **What is your age? ....**
3. **What grade are you in? ....**

4. **Have you played an 'educational game' before?**

Yes No DO NOT KNOW

5. **Do you think it is important to solve problems related to mathematics in a game?**
YES NO DO NOT KNOW

6. **How much time per week, on average, do you spend playing?**

Answer
0h - 1h
1h - 2h
2h - 4h
4h - 6h
6h -8h
more than 8h
Other

7. **What is the device where you play the most?**

Answer
PC
PS4
Xbox
Nintendo Switch
Nintendo 3DS
Smartphone
Tablet
Other

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8. Why are you playing games? Select up to three options

Pleasure
Relaxation
Excitement
Challenge
Leisure time
Prevention of boredom
Relieve stress
Curiosity
Feeling good
Release tension
Fantasy
Emotional stimulation
Competition
Cooperation
Control
Avoidance of other activities
Recognition
Other

9. What type of game do you prefer?

Answer
Action
Platform
FPS ("First Person Shooter")
Open World
Adventure
Strategy
RPG
Sports
Racing
Online
Simulation
Casual
Other

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10. In terms of interaction during the game what do you prefer? Tick one answer.

- Playing the game alone
- Possibility to play with a group, because of short duration of the game
- Two player option in real life
- Two or more player option
- Other ....

11. Would you like the fact that you could compare your performance with that of other players?

YES NO DO NOT KNOW

12. Would you like to create your own character?

YES NO DO NOT KNOW

13. Tick 3 features of games that you found most appealing

- Challenges: having different levels in the games
- Feedback: knowing how many points were scored
- Graphics: Having realistic graphics
- Clear goal
- Story line
- Sound
- Other ....

14. What type of setting do you prefer?

Answer
Fantasy
Real world
Other

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15. The following statements relate to keep players immersed through the educational content of the game. How much do you agree or disagree with the following statements about games? Circle your answer.

I learn better if I can relate the experiences in an educational game to experiences in real life

Strongly Agree Agree Undecided Disagree Strongly Disagree

I learn better when each new piece of knowledge builds upon knowledge learned earlier

Strongly Agree Agree Undecided Disagree Strongly Disagree

I enjoy games that feel too hard

Strongly Agree Agree Undecided Disagree Strongly Disagree

I find feedback on my actions in-game helps me to progress

Strongly Agree Agree Undecided Disagree Strongly Disagree

I prefer playing games which have clear goals to achieve

Strongly Agree Agree Undecided Disagree Strongly Disagree

I feel I learn more when I am engaged in a role I play in a game

Strongly Agree Agree Undecided Disagree Strongly Disagree

I feel I can understand a subject being taught to me if I can experiment with the ideas that are taught

Strongly Agree Agree Undecided Disagree Strongly Disagree

I feel more engaged in games when using knowledge about the game's story and world to solve problems

Strongly Agree Agree Undecided Disagree Strongly Disagree

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I feel more engaged in the game if the rewards/bonuses are adjusted to the difficulty of the performance?

Strongly Agree Agree Undecided Disagree Strongly Disagree

16. Do you want to be notified when we have more news about the game?"

Answer
Yes
No

17. Please write any other game elements that you consider important to be included in the game in order to make it more engaging and attractive.

....
....
....

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