
Education of preschool and elementary teachers on the use of adaptive gamification in science education

Alkinoos-Ioannis Zourmpakis,
Stamatios Papadakis* and
Michail Kalogiannakis

Department of Preschool Education,
Faculty of Education,
University of Crete,
Rethymno, Crete, Greece
Email: alkiszzz@gmail.com
Email: stpapadakis@gmail.com
Email: mkalogian@edc.uoc.gr
*Corresponding author

Abstract: The use of games regarding education is not something new. Their use, especially in the early stages of the education system, is notably widespread in helping students learn and develop various skills. Although students are considered the centre of teaching, the teacher plays a central key role. He/she is called upon to care and understand the needs of each individual student, provide the proper learning material and evaluate the whole learning process. We propose exploring how active and pre-service teachers design and integrate adaptive gamified environments into teaching science education.

Keywords: preschool and primary education; teacher education; digital technologies; adaptive gamification; science education; mobile learning.

Reference to this paper should be made as follows: Zourmpakis, A-I., Papadakis, S. and Kalogiannakis, M. (2022) 'Education of preschool and elementary teachers on the use of adaptive gamification in science education', *Int. J. Technology Enhanced Learning*, Vol. 14, No. 1, pp.1–16.

Biographical notes: Alkinoos-Ioannis Zourmpakis is currently a PhD candidate in the Department of Preschool Education at University of Crete, Greece under the supervision of Prof. Kalogiannakis Michail. He has graduated from the Department of Primary Education in Rethymno, University of Crete, Greece in 2015. Also, he completed his Master's degree (MEd) in Education Sciences – Education with the Use of New Technologies at the University of Aegean, Rhodes, Greece at the School of Humanities, Department of Primary Education in 2019. His research interests include the use of ICT in education, science education in preschool and primary education, science teaching and learning and educational robotics.

Stamatios Papadakis is a Graduate of the Economics and Business (AUEB) University, Athens, Greece, Department of Information. He received his MSc degree in Education from the University of the Aegean, Greece and a PhD degree from the University of Crete, School of Education. He has been working for a series of years as an ICT Teacher in public sector Secondary

Education. He has published many articles in journals and has presented several papers in conferences. His research interests include ICT in education, mobile learning, novice programming environments and teaching of programming in primary and secondary education.

Michail Kalogiannakis is an Associate Professor in the Department of Preschool Education at the University of Crete and Associate Tutor at School of Humanities at the Hellenic Open University. He graduated from the Physics Department of the University of Crete and continued his Postgraduate studies at the University Paris 7-Denis Diderot (DEA in Didactic of Physics), University Paris 5-René Descartes-Sorbonne (DEA in Science Education) and received his PhD degree at the University Paris 5-René Descartes-Sorbonne (PhD in Science Education). His research interests include science education in the early childhood, science teaching and learning, e-learning, the use of ICT in education, distant and adult education. He has published many articles in international conferences and journals and has served on the program committees of numerous international conferences.

1 Introduction

The development and integration of technology into everyday life has created new needs for what and how to teach in school (Voogt, 2010). Technology, which constitutes a fundamental part of today's society and life, is rapidly integrated in education as an object of teaching as well as a means of teaching, causing change in all aspects of education (Dorouka et al., 2020). New means and tools provide additional support and enhance the learning process, as well as the quality of learning while providing easy access and continuous learning, as in the case of mobile devices (Drossel et al., 2017). The influence of digital technologies and their relation to education is made clear by the emergence of new curricula, where technology's inclusion and its relevance to the curriculum is considered essential in order for students to have authentic and meaningful learning experiences (USDOE, 2010).

Science education is an integral part of modern education and curricula and therefore the integration of technology has been a key issue as it enhances the way we investigate and understand phenomena and concepts (Hug et al., 2005) and promotes an active and scientific way of thinking (Slykhuis and Krall, 2011). In recent years, Gamification, namely mechanics and elements that correlate with games used in non-relevant content, has attracted interest in various fields as a way of motivating and engaging in various processes (Kapp, 2012). The use of digital games and applications is also widespread as a way of cultural interaction and attracts a wide range of both adults and young children (Papadakis et al., 2016; Papadakis, 2018). Gamification in digital environments is widely used in a wide range of commercial activities (Seaborn and Fels, 2015). However, lately gamification is increasingly used in education due to the proliferation and use of portable technology and related mobile applications recently in education (Hwang and Wu, 2014) combined with the low cost of developing Gamification applications (Al-Azawi et al., 2016).

Gamification, as an educational tool, has significant potential in contributing to learning participation and student's motivation in regards to teaching activities (Kapp et al., 2014). It can be used at all levels of education (Buckley and Doyle, 2014) and its

proper use is associated with increased internal motivation and user engagement (Hamari et al., 2014). However, integrating gamification elements into e-learning platforms is not the solution in education, as not adapting elements and teaching to each learner individually and presenting similar and repetitive elements lead to an increase in the level of desertion of teaching, (Majeed and Shoaib, 2019). Consequently, the need to adapt the gamification became apparent, i.e. to provide different gameplay mechanisms and characteristics based on each student's actions, preferences and characteristics (Codish and Ravid, 2014). Therefore, there is a need to verify the relationship between the gaming elements and mechanisms with the motivation of the students and the way they are used by the teachers (Böckle et al., 2017).

Although students are considered the centre of teaching in a gamified environment (environment that uses gamification), the role of the teacher is vital to the process. Everything within the learning process requires the participation of the teacher, such as the content, the needs of his students, for example in science education the teacher needs to take into account the misconceptions that students may have (Carey, 2000) and the evaluation of the learning process by enabling them, sometimes, to make online changes even within the gamified environment (Klock et al., 2015a, 2015b).

Teacher education about science education is a particularly difficult field (Sorensen et al., 2012). According to research, teachers often appear to have a lack knowledge of the content of science, pedagogy related to teaching science, inquiry-based learning practices, scientific literacy, self-efficacy and confidence resulting from insufficient education at the undergraduate level (Pre-Service Teacher preparation (PST) (Lewis et al., 2014). Evidently, there is a need to educate teachers on the use of technological tools that use adaptive gamified environments and on the teaching approaches and pedagogy that are related with them.

Also, although much emphasis has been placed on integrating technology into education in recent years, teachers are resisting using it in the classroom as an active learning tool (Jimoyiannis, 2010). Teacher education should be implemented using a theoretical framework that focuses on integrating technological means into the learning process. In this way, it will be possible to show the link between the pedagogical integration of digital technologies in science education with the effectiveness of teaching as well as the effect of such a method on self-efficacy and motivation.

The investigation on the teachers learning process and the assessment of teachers' use of adaptive gamified environments has the potential to contribute to the breadth of research related to learning outcomes of adaptive gamification.

1.1 The integration of digital technologies in science education

In today's information age the integration and use of technology in school is a necessary component in the process of learning (Bingimlas, 2009). According to Kler (2014), the use of digital technologies can greatly improve the educational process. Students often show greater willingness to participate in the teaching process, while also showing improvement in learning performance. Students have the opportunity to develop skills related to a particular field or cross-cutting and social skills such as communication and collaboration (Lacasa, 2013). What is more, teaching, monitoring of the students' progress and communication and feedback between them and the teacher can be done directly at any place and time, inside or outside of the classroom (Kraut, 2013; Papadakis et al., 2018a, 2018b). In addition, the use of digital technologies provides new

opportunities for teachers to develop new and more effective student-centred teaching methods, while helping them to develop new skills (O'Bannon and Thomas, 2015). In other words, it favours the transition from the one-size-fits-all static education to actively personalised and adaptive learning (Mohd and Shahbodin, 2015).

The incorporation of digital technologies into science education seems to help improve understanding of scientific concepts and interaction with the scientific content by providing new, authentic, active and engaging educational activities (Bingimlas, 2009; Papadakis et al., 2020). Specifically, the use of various digital learning tools and applications, such as mobile devices, gives flexibility and adaptability to the learners in regard to their different learning styles and preferences, while providing direct communication and feedback on their progress (Kalogiannakis et al., 2018). Furthermore, new possibilities and information are offered regarding the execution, measurement and understanding of experimental activities, such as in virtual learning environments (Smetana and Bell, 2012). However, the integration of technology in education has not succeeded in achieving major changes in the education or learning outcomes of students in general. The limited use of it in all levels of education and their non-incorporation into the educational process by the teachers are the main issues of this situation (Burns, 2013; Tondeur et al., 2016).

Although the use of technology in education is often considered a given, the type and frequency of technology that will be used in teaching is up to the teacher (Drossel et al., 2017). However, the rapid development of technologies that teachers are required to train and then consequently figure out the most beneficial and effective way to integrate them into their teaching, coupled with the high expectations of students, puts too much pressure on and discourages teachers from the use of digital technologies (Kalogiannakis and Papadakis, 2019; Teo, 2013).

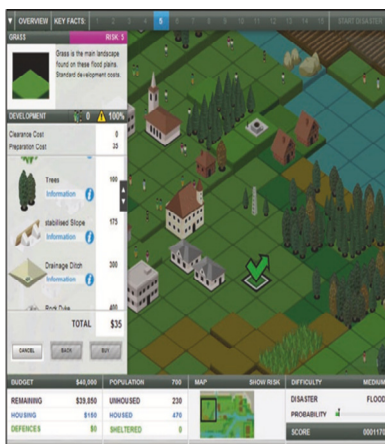
1.2 Gamification

Using games in education isn't something new. Their use, especially in the early stages of the education system (kindergarten), is particularly widespread in helping students learn and develop various skills (Kayimbasioglu et al., 2016). However, in recent years a new framework related to games has made its appearance, gamification.

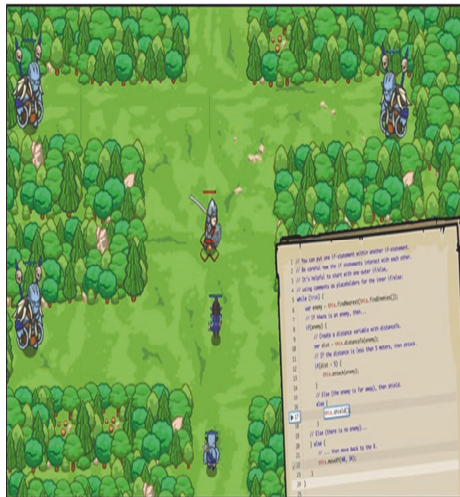
The term 'Gamification' first appeared in 2002 but began to attract the attention of researchers about a decade ago (Monterrat et al., 2015). Gamification is considered the use of games, aesthetics and thinking related to games in order to engage, motivate, resolve problematic situations, enhance and promote learning through the utilisation of digital materials (Kapp, 2012). According to Csikszentmihalyi (2008), the key principal in gamification is the ability to provide concrete challenges that are appropriate and fit the player's competency level. As the player's skills scale so will the level of difficulty. The use of educational games, such as 'serious games', differs significantly from a gamified environment. A serious game tries to draw the student's attention to the accomplishment of the game while trying to achieve some certain educational goals that are not known to the students. The problematic situations they encounter are reality-related but are modified and integrated within the game environment (Kim et al., 2019). On the contrary, a gamified environment incorporates some features of games in order to increase students' engagement, such as points or leaderboards, while the educational goals of the game are clear to the students from the start (Kim et al., 2019). The purpose of gamification in education is to create a 'real environment' for learning and solving

real-world problems (Naik and Kamat, 2016; Kim et al., 2019) while maintaining some key characteristics that are common to digital games. Those characteristics, such as interactive features, inducements, prizes or even differentiated competency levels are the main reason behind the increased levels of enjoyment and satisfaction (Ronimus et al., 2014).

Figure 1 Gamified environments (*Top left*: CodeCombat Reproduced from CodeCombat website, 2016, available online at: <https://codecombat.com> Copyright 2016 by CodeCombat. *Top right*: Enzyme Kinetics Lab in Labster, reproduced from Labster website, 2017, available online at: www.labster.com Copyright 2017 by Labster. *Bottom left*: Land development in Stop Disasters, reproduced from Stop Disasters website, 2017, available online at: <http://www.stopdisastersgame.org> Copyright 2017 by Playthree and UN/ISDR. *Bottom right*: Kumon) (Kim et al., 2018)



	Dad	Dad Score	Tim	Tim Score	Rewards
	57	57	76	76	
	81	138	103	179	Multiply Tim's score by two
	123	261	91	449	Multiply dad's score by two
	130	652	151	600	Square difference
Winner : Tim					



1.3 Advantages and disadvantages of using gamification education

1.3.1 Benefits of using gamification in education

Games are characterised by having fun and motivating someone to perform an activity, making it more enjoyable even when by itself it is not (Kuo and Chuang, 2016). Gamification utilises the parts, features and details of games that connect and direct students towards the school environment by motivating them to engage in the educational process (Bond, 2015). Also, gamification engages students in enjoyable and engaging experiences while encouraging them to try new things and reducing their fear of failure thus creating a positive attitude towards learning (Al-Azawi et al., 2016; Papadakis et al., 2020; Vidakis et al., 2019). In addition, the use of gamification is highly correlated with the creation of socially interactive and constructive learning environments (Chan et al., 2017). Consequently, gamification in general can enhance students' participation in the learning process (Huang and Hew, 2015; Kalogiannakis et al., 2021), while at the same time making them more receptive to participating in future teachings using similar systems (Papadakis and Kalogiannakis, 2018).

Moreover, learning outcomes and students' attitudes towards learning seem to improve with the use of gamification (Yildirim, 2017). Game features, such as points or leaderboards, seems to draw more attention to students, increasing motivation and improving students' performance (Pedreira et al., 2015). However, although gamification favours active student participation, it should be used in conjunction with other student engagement strategies since by itself it can't guarantee learner engagement or positive learning outcomes (Bond, 2015).

Also, gamification is quite often associated with the use of mobile devices (Papadakis and Kalogiannakis, 2018). Mobile learning, learning using mobile devices, has been gaining popularity recently because of its unique capabilities, such as access to information from anywhere at any time, enabling new student-centred educational approaches (Ferdousi and Bari, 2015; Wilkinson and Barter, 2016). Learning through mobile devices enhances student autonomy and encourages them to discover their own personalised way of learning that suits them (Papadakis et al., 2019; Wilkinson and Barter, 2016). Additionally, game applications that use mobile devices in education are often associated with increased motivation, engagement and other emotional, cognitive and social benefits for students (Papadakis and Kalogiannakis, 2017).

1.3.2 Problems related to the use of gaming in education

Although gamification is often associated with its positive effect on education, various risks and problems remain. Gamification is not excluded from the traditional hurdles that often arise when trying to integrate a digital technology tool or application. Costs, teacher education, availability of supportive materials for teachers, age and experience of teachers using digital technology in education and their views and behaviours about digital technology are major issues affecting the integration of digital technology in the learning process and in a particular curriculum (Van Eck, 2006; Teo et al., 2015).

Also, poor planning of a gamified environment can lead to a decrease in students' internal motivation (Markopoulos et al (2015), while the use of elements that increase the level of difficulty of activities or the lack of understanding of the instructions for an activity may lead to decreasing students' performance (De-Marcos et al., 2014; Hanus and Fox, 2014).

In addition, teacher preparation and education about the use of gamification is one of the major problems with its integration into education. Creating gamified environments that respond to teachers' views is a difficult process and as a result they are not easily accepted by them while the use of gamification does not seem to be directly associated with the content of all courses (Markopoulos et al., 2015; Papadakis and Kalogiannakis, 2018). In addition, the lack of methodology and tools for the use of gamification creates problems in preparing teachers, such as a proper understanding of their students' needs and interests or purpose of integrating gamification (Moreno and Méndez, 2015). According to Domínguez et al. (2013), proper instructional design in gamification is very important as without it can lead to deviant behaviours such as anger and apathy (McDaniel et al., 2012; De Marcos et al., 2014). Thus, the need to empower and support teachers who play a key role in successfully integrating gamification into education is of prime importance (Calvo et al., 2016; Papadakis and Kalogiannakis, 2018).

1.4 Adaptive gamification and design of an adaptive gamified environment

1.4.1 Adaptive gamification

As already mentioned, the use of gamification, according to research, seems to have positive effects on increasing learner engagement and enhancing learning (Domínguez et al., 2013). However, using gamification into e-learning platforms is not the solution in education, as not adapting elements and teaching to each learner individually and presenting similar and repetitive gaming elements does not reduce dropout rate (Hassan et al., 2019). The use of repetitive and similar gaming elements for all users is associated with a 'one size fit's all' approach. But according to research, motivation and pleasure are not the same for all people, and so we need to understand the characteristics and techniques that provide motivation and pleasure, taking into account each person's different needs, values and interests (Codish and Ravid, 2015; Klock et al., 2015a, 2015b). The use of adaptive gamification is a way of increasing the learner's involvement by adapting and adopting different gaming elements based on users' characteristics (Codish and Ravid, 2014). Adaptive gamification is not intended to use all of the gaming elements at once, but a specific range of learner-responsive elements as adding all the elements associated with all different types of learners involves the risk of overloading the user interface (Monterrat et al., 2015). What's more, the adaptation of learning to the needs of each individual student is also a characteristic of mobile learning (Ferdousi and Bari, 2015) thus favouring the use of adaptive gamified environments through mobile devices

1.4.2 Designing an adaptive gaming environment

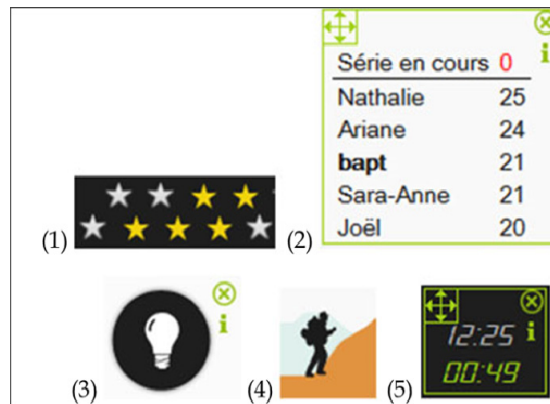
Designing an adaptive gamified environment is not an easy task since a gaming system with an ideal range of game elements has not yet been found (Seaborn and Fels, 2015). When designing an adaptive gamified environment there are four categories to consider (Bocle et al., 2017). The reason the adaptive gamified environment is created, the criteria in which the gamified environment adapts, the gaming elements that will be used and the way the gamified environment will adapt. There is also a need to analyse and understand related pedagogical approaches that can be used more effectively in adaptive gamified environments.

Proper design of an adaptive gamified environment and the use of appropriate pedagogical approaches are key to increasing the effectiveness and involvement of the learner in the long run (Böckle et al., 2017). The following table gives brief example of the 4 categories of designing an adaptive gamified environment.

Table 1 Categories and elements needed to design an adaptive gamified environment (Böckle et al., 2017)

Design of adaptive gamification environment	Reason for creating an adaptive gamified environment	Changes the status of the user (e.g. goals, motivations, beliefs, etc.) Supports participation It supports learning It creates meaning between the user and the activities
	Adaptability criteria	User profile data (e.g. gender, age, etc.) User activity data Level of knowledge Goals set by the user Content of activities Player type-personality Evaluation / Results Feedback
	Gaming elements	Difficulty levels Points /Badges / Leaderboards Custom challenges Storytelling
	Adaptation ways	Interactive recommendations Navigation / Route Adjustment Individual and Personalised content User-interface customisation

Figure 2 Gaming elements (1-Stars, 2-Leaderboards, 3-Tips, 4-walker and 5- timer) (Lavoué et al., 2019)



1.4.3 A proposal for educating teachers in using adaptive gamified environments in science education

As we previously highlighted, the contribution of the teacher is paramount in learning and even more so in the successful integration of digital technologies, like adaptive gamification. In this regard, we propose a framework to investigate the way in which current and future teachers design and integrate adaptive gamified environments in science education and the effect that the process has on teachers' motivation and self-efficacy, as well as in students' learning performance. More specifically, in this framework we will examine the produced teaching scenarios and teachers' insights on the utilisation of adaptive gamification in science education, the issues that arise in the use of those teaching scenarios in the classroom, and their impact on student performance. In addition, teachers' views on the usefulness and utilisation of gaming elements and mechanisms will be explored as well as their impact on student motivation. In this research context, national and international research ethics guidelines will be followed (Petousi and Sifaki, 2020).

For this reason, we will develop adaptive gamified environments to be used in both computers and mobile devices using a specialised game engine software (Unity3D). This software is a free game engine that can build 2D, 3D, virtual, augmented (Tredinnick et al., 2017) and gamified environments (Wang, 2018) in both mobile and desktop format. All gamified environments will be able to be used individually or in combination with other specific activities selected and relevant to the teaching approach of each teacher. The adaptive gamified environment will belong to the fully adaptive category according to Böckle et al. (2017) but will also require the assistance of the teacher. The adaptation process will be based on a player model, on their relevance score and progress tailoring gamification mechanics, dynamics, elements and functionalities. Thus, the adaptation will occur in both the start and during the use of the application. In the start of the adaptive gamification application, the teacher will insert data about the player type of each user setting the first parameters. Subsequently, the application will then be adapted based on the students' actions and performance while associating them with the player type. Finally, the application will give feedback to teachers on student performance, player type and their preference for gamification dynamics, mechanics and elements.

It is clear that the role of teachers in using the above adaptive gamification model is particularly important. They are required to evaluate what type of player each individual student is, the appropriate pedagogical strategies and materials they will use with the adaptive gamification application for each specific teaching content and how they will use the feedback received from the application. Consequently, a theoretical framework is necessary in order to educate teachers how to design educational practices in which they integrate knowledge about content, technology and pedagogy.

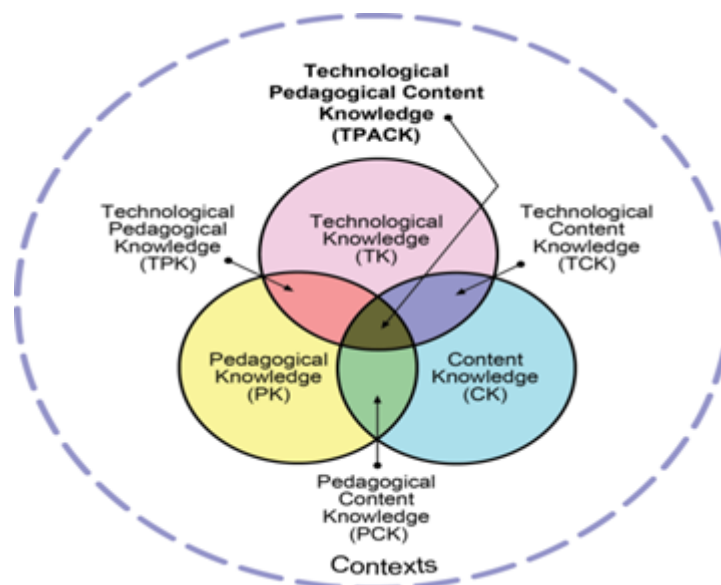
The term TPACK was proposed by Mishra and Koehler (2006), as 'the knowledge that emerges from the interplay and interrelationship of knowledge of three separate objects, Pedagogy, Content and Technology' (Koehler and Mishra, 2009). Combining technological knowledge with content knowledge and pedagogy helps integrate ICT into teaching (TPACK). TPACK also contributes to research on teacher education as it enables the analysis and development of a complex phenomenon, such as the integration of technology (Koehler and Mishra, 2009), while helping us to shape the various knowledge teachers require in order to incorporate and make the best of technology into educational practices (Voogt and McKenney, 2017) (Figure 1).

The main objective of TPACK is to acquire knowledge from the teacher on how technology means have the capabilities to shape the pedagogy and content representations to teach a particular topic/object (Jang and Chen, 2010). In order for teachers to achieve this, they must possess the following knowledge (Koh and Divaharan, 2011):

- 1 *Content Knowledge*: Knowledge of the content of the teaching subject.
- 2 *Pedagogical Knowledge*: Knowledge of teaching methods.
- 3 *Technological Knowledge*: Knowledge and familiarity with ICT.
- 4 *Pedagogical Content Knowledge*: The knowledge of pedagogical methods of teaching with the content of the subject.
- 5 *Technological Content Knowledge*: The knowledge of representation of content with technology.
- 6 *Technological Pedagogical Knowledge*: Knowledge of the application of ICTs in different teaching methods.
- 7 *Technological Pedagogical and Content Knowledge*: All the knowledge related to the integration of ICT in the learning process.

The TPACK model in teacher education in Science Education takes into account the studies on each component and then the creation of teaching scenarios that should contain the above components. Απλ, the TPACK model not only can be used as a method to educate teachers but also as a tool to evaluate teaching scenarios (Zelkowski et al., 2013). Specifically, in each teaching scenario we should observe (Cox and Graham, 2009):

- The use of pedagogical activities (Pedagogical Knowledge).
- The use of specific representations of the concept of teaching (Content Knowledge).
- Familiarity with ICT (Technological Knowledge).
- The way he uses a particular representation in combination with an activity to help students understand the concept of teaching (Content Pedagogy).
- The way ICTs are used to represent teaching concepts (Technological Content Knowledge).
- How ICTs are used to achieve pedagogical goals (Technological Pedagogical Knowledge).
- How ICTs are used as part of concept-related pedagogical activities (Technological Pedagogical Content Knowledge).

Figure 3 The TPACK model (tpack.org)

2 Conclusions

As we already mentioned, the purpose of this paper is to provide insight on the state of adaptive gamification and teacher education in the context of science education. What is more, we will try to implement a framework on who to prepare and educate active and pre-service teachers in order to design and integrate adaptive gamified environments into teaching science education in preschool and elementary school.

The key questions that we look to investigate and answer within this framework are:

- 1 What is the degree of readiness, self-efficacy and motivation of pre-service and in-service teachers to incorporate adaptive gamified environments into science education?
- 2 How does the pedagogical integration of adaptive gamified environments in science education affect teachers and students' performance?
- 3 What gaming elements and mechanisms are considered more useful and are utilised from teachers in adaptive gamified environments in science education and which provide students with more motivation?

Although this research is on its first stages, the originality of this proposal lies in the fact that it is the first research carried out in the field of primary science education that seeks to investigate teacher education on the use of adaptive gamification, a new and innovative research field. Also, this research is one of the few surveys carried out in Greece that includes 'smart' mobile devices and is carried out within the whole spectrum of primary education (preschool and elementary education).

3 Discussion

Student's attention and engagement are of vital importance in order to increase students' learning. Quite few technological means have been deployed to positively influence student's attention and engagement, such as gamification. Initially, gamification has shown some encouraging signs in this regard, but student dropout rates remain quite high (Hassan et al., 2019). Thus, a more personalised and adaptive way was focused by the researchers in their efforts to reduce dropout rates and keep students attention, an already difficult task. Early findings on adaptive gamification give promising results but there seems to be a little to almost no mention about the insights, concerns and readiness of pre-service and in-service teachers (Papadakis et al., 2018a, 2018b). Also, their preparation and education on implementing adaptive gamified environments and utilising their potential is of critical concern, considering the key role a teacher has (Poon, 2013; Licorish et al., 2018).

This research is an exploratory proposal designed to highlight the current state of pre-service and in-service teachers, the learning pathway they need to follow, and the knowledge they need to be able to use and integrate adaptive gamified environments into the educational process. Adaptive gamified environments along with other assistive technologies, such as mobile learning, have great potential but in order to maximise their potential they need to be paired with appropriate pedagogical strategies otherwise we run the risk of hindering students' learning rather than improving it.

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