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

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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.

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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).

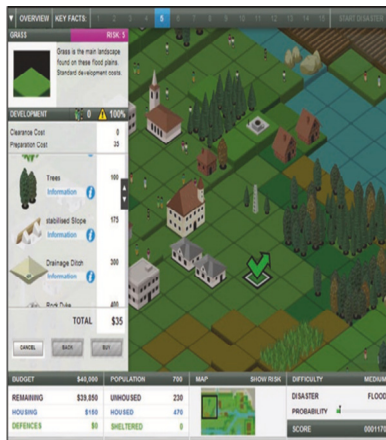

1.2 Gamification

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.

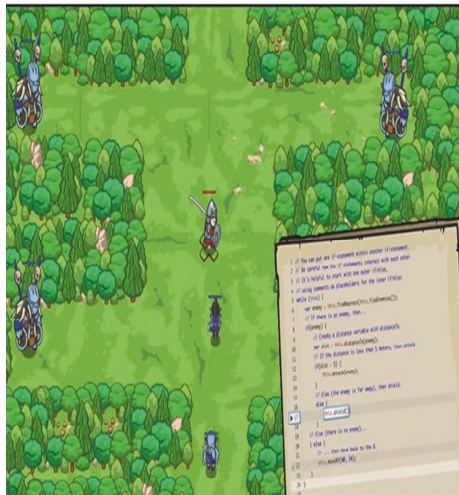
The term 'Gamification' first appeared in 2002 but began to attract the attention of researchers about a decade ago (Monterrat et al., 2015). Gamification is considered the use of games, aesthetics and thinking related to games in order to engage, motivate, resolve problematic situations, enhance and 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 players 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 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 Playerthree 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 -> 358 | Multiply Tim's score by two |
| | 123 | 261 -> 522 | 91 | 449 | Multiply dad's score by two |
| | 130 | 652 | 151 | 600 -> 1041 | 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

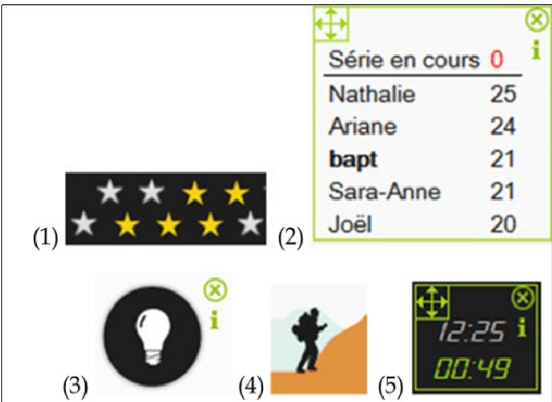
Designing an adaptive gamified environment is not an easy task since a gaming system with an ideal range of game elements has not yet been found (Seaborn and Fels, 2015). When designing an adaptive gamified environment there are four categories to consider (Bocle et al., 2017). The reason the adaptive 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.

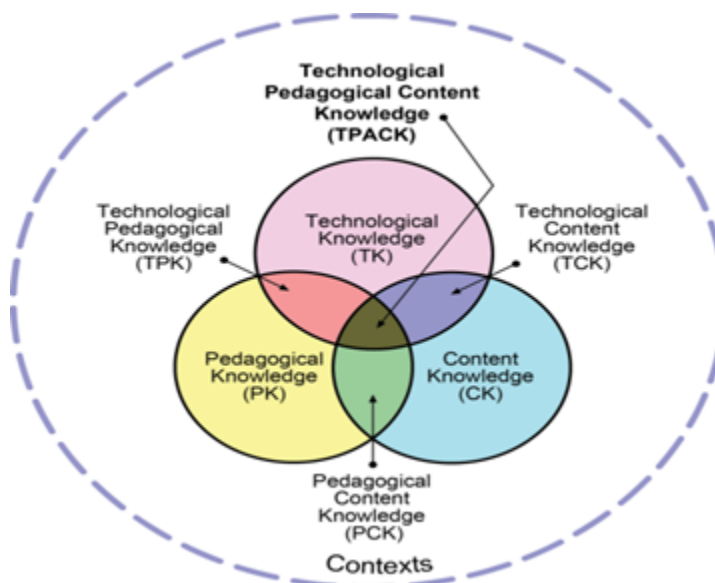
The term TPACK was proposed by Mishra and Koehler (2006), as 'the knowledge that emerges from the interplay and interrelationship of knowledge of three separate objects, Pedagogy, Content and Technology' (Koehler and Mishra, 2009). Combining technological knowledge with content knowledge and pedagogy 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. Αρα, 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.

References

- Al-Azawi, R., Al-Faliti, F. and Al-Blushi, M. (2016) 'Educational gamification vs. game based learning: comparative study', *International Journal of Innovation, Management and Technology*, Vol. 7, No. 4, pp.132–136.
- Bingimlas, K. (2009) 'Barriers to the successful integration of ICT in teaching and learning environments: a review of the literature', *Eurasia Journal of Mathematics, Science and Technology Education*, Vol. 5, No. 3, pp.235–245.
- Böckle, M., Novak, J. and Bick, M. (2017) 'Towards adaptive gamification: a synthesis of current developments', *Proceedings of the 25th European Conference on Information Systems (ECIS)*, Guimarães, Portugal.
- Bond, L. (2015) *Mathimagicians Quest: Applying Game Design Concepts to Education to Increase School Engagement for Students with Emotional and Behavioral Disabilities*, Doctoral dissertation, University of Washington.
- Buckley, P. and Doyle, E. (2014) 'Gamification and student motivation', *Interactive Learning Environments*, Vol. 24, No. 6, pp.1–14.
- Burns, M. (2013) 'Success, failure or no significant difference: charting a course for successful educational technology integration', *International Journal of Emerging Technologies in Learning*, Vol. 8, No. 1, pp.38–45.
- Calvo, A., Rotaru, D.C., Freire, M. and Fernandez-Manjon, B. (2016) 'Tools and approaches for simplifying serious games development in educational settings', *Global Engineering Education Conference (EDUCON)*, IEEE, Abu Dhabi, pp.1188–1197.
- Carey, S. (2000) 'Science education as conceptual change', *Journal of Applied Developmental Psychology*, Vol. 21, No. 1, pp.13–19.
- Chan, K.Y.G., Tan, S.L., Hew, K.F.T., Koh, B.G., Lim, L.S. and Yong, J.C. (2017) 'Knowledge for games, games for knowledge: designing a digital roll-and-move board game for a law of torts class', *Research and Practice in Technology Enhanced Learning*, Vol. 12, No. 7, pp.1–20.

- Codish, D. and Ravid, G. (2014) 'Adaptive approach for gamification optimization', *Proceedings of the 7th International Conference on Utility and Cloud Computing*, IEEE, London, pp.609–610.
- Codish, D. and Ravid, G. (2015) 'Detecting playfulness in educational gamification through behavior patterns', *IBM Journal of Research and Development*, Vol. 59, No. 6, pp.1–14.
- Cox, S. and Graham, C.R. (2009) 'Using an elaborated model of the TPACK framework to analyze and depict teacher knowledge', *TechTrends*, Vol. 53, No. 5, pp.60–71.
- Csikszentmihalyi, M. (2008) *Flow: The Psychology of Optimal Experience*, 1st ed., HarperCollins.
- De-Marcos, L., Domínguez, A., Saenz-de-Navarrete, J. and Pagés, C. (2014) 'An empirical study comparing gamification and social networking on e-learning', *Computers & Education*, Vol. 75, pp.82–91.
- Domínguez, A., Saenz-de-Navarrete, J., De Marcos, L., Fernández-Sanz, L., Pagés, C. and Martínez-Herráiz, J. (2013) Gamifying learning experiences: practical implications and outcomes', *Computers and Education*, Vol. 63, pp.380–390.
- Dorouka, P., Papadakis, S.J. and Kalogiannakis, M. (2020) 'Tablets & apps for promoting robotics, mathematics, STEM education and literacy in early childhood education, international journal of mobile learning and organisation', Vol. 14, No. 2, pp.255–274.
- Drossel, K., Eickelmann, B. and Gerick, J. (2017) 'Predictors of teachers' use of ICT in school – the relevance of school characteristics, teachers' attitudes and teacher collaboration', *Education and Information Technologies*, Vol. 22, No. 2, pp.551–573.
- Ferdousi, B. and Bari, J. (2015) 'Infusing mobile learning into undergraduate courses for effective learning', *Procedia – Social and Behavioral Sciences*, Vol. 176, pp.307–311.
- Hamari, J., Koivisto, J. and Sarsa, H. (2014) 'Does gamification work? – A literature review of empirical studies on gamification', *proceedings of the 47th Hawaii International Conference on System Sciences*, Hawaii, USA, pp.3025–3034.
- Hanus, M.D. and Fox, J. (2015) 'Assessing the effects of gamification in the classroom: a longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance', *Computers & Education*, Vol. 80, pp.152–161.
- Hassan, M.A., Ume Habiba, U., Majeed, F. and Shoaib, M. (2019) 'Adaptive gamification in e-learning based on students' learning styles', *Interactive Learning Environments*, pp.545–565. Doi: 10.1080/10494820.2019.1588745.
- Huang, B. and Hew, K.F. (2015) 'Do points, badges and leaderboard increase learning and activity: A quasi-experiment on the effects of gamification', *Proceedings of the 23rd International Conference on Computers in Education*, China, pp.275–280.
- Hug, B., Krajcik, J. and Marx, R. (2005) 'Using innovative learning technologies to promote learning and engagement in an urban science classroom', *Urban Education*, Vol. 40, No. 4, pp.446–472.
- Hwang, G.J. and Wu, P.H. (2014) 'Applications, impacts and trends of mobile learning – a review of 2008–2012 publications in selected journals', *International Journal of Mobile Learning and Organisation*, Vol. 8, No. 2, pp.83–95.
- Jang, S.J. and Chen, K.C. (2010) 'From PCK to TPACK: Developing a transformative model for pre-service science teachers', *Journal of Science Education and Technology*, Vol. 19, No. 6, pp.553–564.
- Jimoyiannis, A. (2010) 'Designing and implementing an integrated technological pedagogical science knowledge framework for science teachers professional development', *Computers and Education*, Vol. 55, No. 3, pp.1259–1269.
- Kalogiannakis, M. and Papadakis, S. (2019) 'Evaluating pre-service kindergarten teachers' intention to adopt and use tablets into teaching practice for natural sciences', *International Journal of Mobile Learning and Organisation*, Vol. 13, No. 1, pp.113–127.
- Kalogiannakis, M., Nirgianaki, G-M. and Papadakis, S. (2018) 'Teaching magnetism to preschool children: the effectiveness of picture story reading', *Early Childhood Education Journal*, Vol. 46, No. 5, pp.535–546.

- Kalogiannakis, M., Papadakis, S. and Zourmpakis, A.-I. (2021) 'Gamification in science education. A systematic review of the literature', *Education Sciences*, Vol. 11, No. 1, p.22. <http://dx.doi.org/10.3390/educsci11010022>
- Kapp, K.M. (2012) *The Gamification of Learning and Instruction*, Wiley, San Francisco.
- Kapp, K.M. Blair, L. and Mesch, R. (2014) *The Gamification of Learning and Instruction Fieldbook*, Wiley, San Francisco.
- Kayimbasioglu, D., Oktekin, B. and Haci, H. (2016) 'Integration of gamification technology in education', *Procedia Computer Science*, Vol. 102, pp.668–676.
- Kim, S., Song, K., Lockee, B. and Burton, J. (2019) 'Gamification in learning and education: enjoy learning like gaming', *British Journal of Educational Studies*, Springer, Cham, pp.1–3.
- Kim, S., Song, K., Lockee, B., Burton, J. (2018) 'Gamification cases in STEM education', *Gamification in Learning and Education*, Springer, Cham, pp.125–139.
- Kler, S. (2014) 'ICT integration in teaching and learning: empowerment of Education with technology', *Research Scholar (JRF), Issues and Ideas in Education*, Vol. 2, No. 2, pp.255–271.
- Klock, A., Gasparini, I., Pimenta, M. and Oliveira, M. (2015a) 'Everybody is playing the game, but nobody's rules are the same: towards adaption of gamification based on users's characteristics', *Bulletin of the IEEE Technical Committee on Learning Technology*, Vol. 17, No. 4, pp.22–25.
- Klock, A.C., Felipe da Cunha, L., Fabrias de Carvalho, M., Eduardo Rosa, B., Jaqueline Anton, A. and Gaspirini, I. (2015b) 'Gamification in e-learning systems: a conceptual model to engage students and its application in an adaptive e-learning system', in Zaphiris, P. and Ioannou, A. (Eds): *Learning and Collaboration Technologies*, Springer, Cham, pp.595–607.
- Koehler, M. and Mishra, P. (2009) 'What is technological pedagogical content knowledge?', *Contemporary Issues in Technology and Teacher Education*, Vol. 9, No. 1, pp.60–70.
- Koh, J.H.L. and Divaharan, S. (2011) 'Developing pre-service teachers' technology integration expertise through the TPACK-developing instructional model', *Journal of Educational Computing Research*, Vol. 44, No. 1, pp.35–58.
- Kraut, R. (Ed.) (2013) *Policy Guidelines for Mobile Learning*, UNESCO.
- Kuo, M.-S. and Chuang, T.-Y. (2016) 'How gamification motivates visits and engagement for online academic dissemination – an empirical study', *Computers in Human Behavior*, Vol. 55, pp.16–27.
- Lacasa, P. (2013) *Learning in Real and Virtual Worlds: Commercial Video Games as Educational Tools*, Palgrave Macmillan, New York.
- Lavoué, E., Monterrat, B., Desmarais, M. and George, S. (2018) 'Adaptive gamification for learning environments', *IEEE Transactions on Learning Technologies*, Vol. 12, No. 1, pp.16–27.
- Lewis, E., Dema, O. and Harshbarger, D. (2014) 'Preparation for practice: elementary preservice teachers learning and using scientific classroom discourse community instructional strategies', *School Science and Mathematics*, Vol. 114, No. 4, pp.154–165.
- Licorish, S.A., Owen, H.E., Daniel, B. and George, J.L. (2018) 'Students' perception of Kahoot!'s influence on teaching and learning', *Research and Practice in Technology Enhanced Learning*, Vol. 13, No. 9, pp.1–23.
- Markopoulos, A.P., Fragkou, A., Kasidiaris, P.D. and Davim, J.P. (2015) 'Gamification in engineering education and professional training', *International Journal of Mechanical Engineering Education*, Vol. 43, No. 2, pp.118–131.
- McDaniel, R., Lindgren, R. and Friskics, J. (2012) 'Using badges for shaping interactions in online learning environments', *Proceedings of the IEEE International Professional Communication Conference*, IEEE, Orlando, pp.1–4.
- Mishra, P. and Koehler, M.J. (2006) 'Technological pedagogical content knowledge: a new framework for teacher knowledge', *Teachers College Record*, Vol. 108, No. 6, pp.1017–1054.

- Mohd, C.K.N.C.K. and Shahbodini, F. (2015) 'Personalized learning environment (PLE) experience in the twenty-first century: review of the literature', in Abraham, A., Muda, A. and Choo, YH. (Eds): *Pattern Analysis, Intelligent Security and the Internet of Things: Advances in Intelligent Systems and Computing*, Springer, Cham, Vol. 355, pp.179–192.
- Monterrat, B., Desmarais, M., Lavoue, E. and George, S. (2015) 'A player model for adaptive gamification in learning environments', in Conati, C., Heffernan, N., Mitrovic, A. and Verdejo, M. (Eds): *Artificial Intelligence in Education. AIED 2015. Lecture Notes in Computer Science*, 9112(pp.297–306). Springer, Cham.
- Moreno, J. and Méndez, N.D. (2015) 'Teaching sciences in K-12 using 2D educational massive online games', *Anais temporários do LACLO*, Vol. 10, No. 1, pp.394.
- Naik, V. and Kamat, V. (2016) 'Adaptive and gamified learning environment (AGLE)', *Proceedings of the IEEE 7th International Conference on Technology for Education*, IEEE, Warangal, pp.7–14.
- O'Bannon, B.W. and Thomas, K.M. (2015) 'Mobile phones in the classroom: preservice teachers answer the call', *Computers and Education*, Vol. 85, pp.110–122.
- Papadakis, S. (2018) 'The use of computer games in classroom environment', *International Journal of Teaching and Case Studies*, Vol. 9, No. 1, pp.1–25.
- Papadakis, S. and Kalogiannakis, M. (2017) 'Combining mobile technologies in environmental education: a Greek case study', *International Journal of Mobile Learning and Organisation*, (Special Issue on Mobile Learning Applications and Strategies), Vol. 11, No. 3, pp.256–277.
- Papadakis, S. and Kalogiannakis, M. (2018) 'Using gamification for supporting an introductory programming course: the case of classcraft in a secondary education classroom', in Brooks, A., Brooks, E. and Vidakis, N. (Eds): *Interactivity, Game Creation, Design, Learning, and Innovation*, Springer, Switzerland, Cham, Vol. 229, pp.366–375.
- Papadakis, S., Kalogiannakis, M. and Zaranis, N. (2018b) 'The effectiveness of computer and tablet assisted intervention in early childhood students' understanding of numbers: an empirical study conducted in Greece', *Education and Information Technologies*, Vol. 23, No. 5, pp.1849–1871.
- Papadakis, S., Kalogiannakis, M., Orfanakis, V. and Zaranis, N. (2016) 'Using scratch and app inventor for teaching introductory programming in secondary education: a case study', *Int. J. Technol. Enhanced Learn*, Vol. 8, Nos. 3/4, pp.217–233.
- Papadakis, S., Kalogiannakis, M., Sifaki, E. and Vidakis, N. (2018a) 'Access moodle using smart mobile phones: a case study in a Greek University', in Brooks, A., Brooks, E. and Vidakis, N. (eds): *Interactivity, Game Creation, Design, Learning, and Innovation*, Springer, Switzerland, Cham, Vol. 229, pp.376–385.
- Papadakis, S., Trampas, A-M., Barianos, A-K., Kalogiannakis, M. and Vidakis, N. (2020) 'Evaluating the learning process: the "ThimelEdu" educational game case study', in Lane, H., Zvacek, S. and Uhomobhi, J. (Eds): *Proceedings of the 12th International Conference on Computer Supported Education (CSEDU'20)*, Vol. 2, pp.290–298.
- Papadakis, S., Zaranis, N. and Kalogiannakis, M. (2019) 'Parental involvement and attitudes towards young Greek children's mobile usage', *International Journal of Child-Computer Interaction*, Vol. 22.
- Pedreira, O., Garcia, F., Brisaboa, N. and Piattini, M. (2015) 'Gamification in software engineering – a systematic mapping', *Information Software Technology*, Vol. 57, pp.157–168.
- Petousi, V. and Sifaki, E. (2020) 'Contextualizing harm in the framework of research misconduct: findings from discourse analysis of scientific publications', *International Journal of Sustainable Development*, Vol. 23, Nos. 3/4, pp.149–174, <https://doi.org/10.1504/IJSD.2020.10037655>
- Poon, J. (2013) 'Blended learning: an institutional approach for enhancing students' learning experiences', *Journal of Online Learning and Teaching*, Vol. 9, No. 2, pp.271–289.

- Ronimus, M., Kujala, J., Tolvanen, A. and Lyytinen, H. (2014) 'Children's engagement during digital game-based learning of reading: the effects of time, rewards, and challenge', *Computers and Education*, Vol. 71, pp.237–246.
- Seaborn, K. and Fels, D.I. (2015) 'Gamification in theory and action: a survey', *International Journal of Human Computer Studies*, Vol. 74, pp.14–31.
- Slykhuis, D. and Krall, R. (2011) 'Teaching science with technology: a decade of research', in Koehler, M. and Mishra, P. (Eds): *Proceedings of Society for Information Technology and Teacher Education International Conference*, AACE, Chesapeake, pp.4142–4151.
- Smetana, L.K. and Bell, R.L. (2012) 'Computer simulations to support science instruction and learning: a critical review of the literature', *International Journal of Science Education*, Vol. 34, No. 9, pp.1337–1370.
- Sorensen, P., Newton, L. and McCarthy, S. (2012) 'Developing a science teacher education course that supports student teachers' thinking and teaching about the nature of science', *Research in Science and Technological Education*, Vol. 30, No. 1, pp.29–47.
- Teo, T. (2013) 'Influences of contextual variables on the intention to use technology in education: a latent variable modelling approach', *Campus-Wide Information Systems*, Vol. 30, No. 2, pp.95–105.
- Teo, T., Fan, X. and Du, J. (2015) 'Technology acceptance among pre-service teachers: does gender matter?', *Australasian Journal of Educational Technology*, Vol. 31, No. 3, pp.235–251.
- Tondeur, J., van Braak, J., Ertmer, P.A. and Ottenbreit-Leftwich, A. (2016) 'Understanding the relationship between teachers' pedagogical beliefs and technology use in education: a systematic review of qualitative evidence', *Educational Technology Research and Development*, Vol. 65, No. 3, pp.555–575.
- Tredinnick, R., Boettcher, B., Smith, S., Solovy, S. and Ponto, K. (2017) 'Uni-CAVE: a Unity3D plugin for non-head mounted VR display systems', In *Virtual Reality (VR)*, IEEE, Los Angeles, CA, pp.393–394.
- United States Department of Education (USDOE) (2010) *Transforming America Education: Learning Powered by Technology*, Alexandria: US Department of Education. Available online at: <http://www.ed.gov/technology/netp-2010> (accessed on 15 November 2019).
- Van Eck, R. (2006) 'Digital game-based learning: it's not just the digital natives who are restless', *EDUCAUSE Review*, Vol. 41, No. 2, pp.1–16.
- Vidakis, N., Barianos, A-K., Trampas, A-M., Papadakis, S. Kalogiannakis, M. and Vassilakis, K. (2019) 'Generating education in-game data: the case of an ancient theatre serious game', in McLaren, B., Reilly, R., Zvacek, S. and Uhomobhi, J. (Eds): *Proceedings of the 11th International Conference on Computer Supported Education (CSEDU'19)*, Heraklion, Crete, Greece, 2–4 May, Vol. 1, pp.36–43.
- Voogt, J. (2010) 'Teacher factors associated with innovative curriculum goals and pedagogical practices: differences between extensive and non-extensive ICT-using science teachers', *Journal of Computer Assisted Learning*, Vol. 26, No. 6, pp.453–464.
- Voogt, J. and McKenney, S. (2017) 'TPACK in teacher education: are we preparing teachers to use technology for early literacy?', *Technology, Pedagogy and Education*, Vol. 26, No. 1, pp.69–83.
- Wang, D. (2018) 'Gamified learning through unity 3D in visualizing environments', *Neural Computing and Applications*, Vol. 29, No. 5, pp.1399–1404.
- Wilkinson, K. and Barter, P. (2016) 'Do mobile learning devices enhance learning in higher education anatomy classrooms?', *Journal of Pedagogic Development*, Vol. 6, No. 1, pp.14–23.
- Yildirim, I. (2017) 'The effects of gamification-based teaching practices on student achievement and students' attitudes toward lessons', *Internet and Higher Education*, Vol. 33, pp.86–92.
- Zelkowski, J., Gleason, J., Cox, D.C. and Bismarck, S. (2013) 'Developing and validating a reliable TPACK instrument for secondary mathematics preservice teachers', *Journal of Research on Technology in Education*, Vol. 46, No. 2, pp.173–206.