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Teachers' Perspectives on Integrating Adaptive Gamification Applications into Science Teaching



Abstract: - This study explores the views of six teachers on the use of adaptive gamification environments in science education and the professional development program they followed beforehand. Specifically, all teachers were interviewed after following a teacher training program based on the Technological Pedagogical and Science Knowledge (TPASK) model and utilising an adaptive gamification environment to teach scientific concepts regarding the water cycle in a school environment. The findings highlight teachers' views on the benefits and cons of utilising the application in science education, possible improvements to the app, and attitudes towards the professional training program they followed. These findings support the development of adaptive gamification applications and the need to design and implement proper training programs for current and future teachers.

Keywords: Adaptive Gamification • Teacher perspectives • Science education.

I. INTRODUCTION

Teachers have always been concerned about increasing students' active engagement and participation in the learning process [1]. New learning environments should be designed to meet the needs and interests of modern learners while providing a learning experience that motivates students to participate in learning [2], [3]. Motivating students and achieving high levels of engagement is a significant issue as it is inextricably linked to their academic performance [4], [5].

Education has been restructuring recently due to new challenges and demands, especially after the coronavirus period [6]. It requires redefining the professional skills of teachers [7] and enhancing their training to enable and facilitate the development of essential skills such as collaboration, critical thinking, problem-solving, and scientific and digital literacy in today's world [8], [9]. However, the acquisition of these skills by students requires the ability of teachers to utilise and/or create proper classroom scenarios that inspire, motivate and engage students in the learning process [10], [11].

In recent years, as the incorporation of game elements into various aspects of our daily lives has increased significantly [12], educators and program designers are trying to increase student motivation by following this trend [13], [14]. A current trend that still attracts the interest and attention of educators and students alike is gamification. According to Kapp [15], "Gamification involves the application of game mechanics, aesthetics, and cognitive processes associated with games to non-game contexts. It aims to engage, motivate, challenge, and promote learning through digital tools".

Although gamification has been utilised and researched for a decade, there have been mixed results relating to the need for more than one-size-fits-all approach that is used [16]. The utilisation of repetitive game elements and the failure to adapt instructional approaches to align with each student's needs and preferences have been shown to increase the dropout rates of students in the long run [17]. As such, it has become crucial to consider the diverse playing styles and motivations of each student/user when designing and integrating gamification applications [18]. Adaptive gamification is still in its infancy, and it involves customising game mechanisms and features based on each user's actions, preferences, and characteristics [19]. Despite some documented methodologies, there needs to be more knowledge on adapting game elements and the most appropriate patterns for digital environments, particularly concerning specific contexts such as science education. Though gamification has plenty of advantages regarding education, its implementation remains challenging for teachers, particularly those unfamiliar with digital tools. Teachers' willingness to integrate these tools into their practice is hampered by a lack of confidence and expertise in their use in pedagogical settings [20].

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UNESCO [21] argues that teachers should be involved in designing and implementing learning strategies. Implementing effective teaching practices and promoting meaningful learning in this context requires teachers to change their perspectives and enhance their knowledge and skills [22]. Therefore, teachers need to be trained in using technological tools that incorporate adaptive gamification environments and teaching methods in these environments [23]. Based on the above, we developed an adaptive gamification environment specifically designed to teach scientific concepts related to the water cycle. After implementing a professional development program for teachers based on the TPASK methodology and using the applications in the classroom, we explored the teachers' opinions regarding the use of adaptive gamification environments in science teaching and the professional development program.

II. METHODOLOGY

2.1 Development of adaptive gamification environment

The development of the adaptive gamification environment for teaching science concepts was based on a framework that includes adaptive criteria, learning strategies, game elements and the main aspects of the teaching process in science education [24]. The design is based on two factors. The first is the player model, where the students' preferences in the game are taken into account, while their knowledge and skills are not included. Although the architecture does not directly correlate with students' misconceptions, these are taken into within the storytelling and gameplay. Teacher proficiency in using the app is the responsibility of the students.

The second factor is the learning strategies. Traditionally, teachers determine the learning strategy. However, in this framework, the system suggests the most appropriate strategy tailored to the type of player, such as problem-based learning for students who prefer autonomy. However, teachers are required to be aware of and intervene during the learning process to enhance it. The student's ability to navigate and utilise the adaptive gamification environment is also left to the teachers as part of the supporting role. The architecture of the gamification system is presented in Figure 1, explaining its dynamics, relationships and processes.

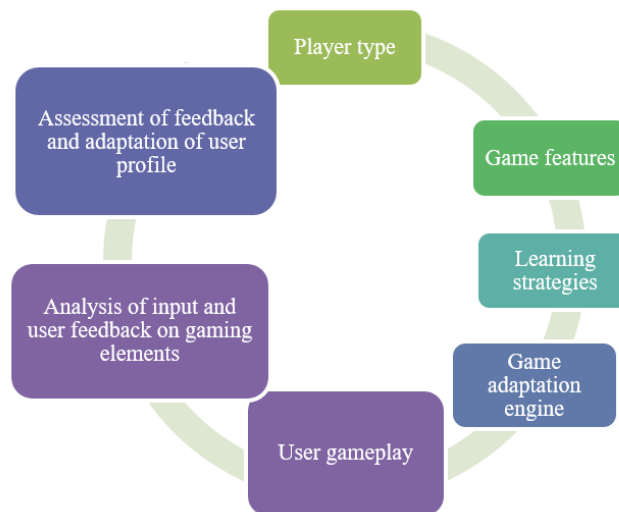


Fig. 1. The architecture of the adaptive gamification environment [24]

Initial feedback from the user is collected through a questionnaire based on the Hexad model [25]. The Hexad typology is based on internal and external motivational factors [25] and examines how these influence interactions in the context of gamification [25]. It uses a 7-point Likert scale questionnaire to classify users into six types or a percentage combination of these categories. After profiling, the application selects an item from the second or third-player category that does not belong to the dominant type. As the course progresses, users continue to give feedback. After a profile refresh, a new classification and selection of game and learning strategy elements is made and incorporated in the next section.

The profiling process begins after the initial feedback through the questionnaire. The player types are ranked based on their percentages, and the dominant type is selected along with the next two. A random selection is made in case of a tie, or the type with more in common with the dominant type is preferred.

Figure 2 shows a player with the dominant type "Player" and the secondary types "Free Spirit" and "Achiever". The top left corner shows the player's level and points, while the bottom right corner shows the money that affects the course of the game. The player earns points and increases his level by starting and completing missions,

receiving rewards such as money for character customisations or badges for essential missions. Additionally, they can choose their difficulty, the only common element among all types, which can affect the help they receive, either from the application (removal of the map) or their teacher. As they progress through the story, users rate their interest on a 5-point Likert scale tailored to their game type.



Fig. 2. Example of dominant type "Player" and the secondary types "Free Spirit" and "Achiever"

2.2 Design of professional development program

The professional development program based on TPASK was designed following the "TPK to TPACK" approach [26]. This approach starts from teachers' existing Technological Pedagogical Knowledge (TPK) and combines it with teaching specific content. In this particular instance, it correlates with Science Knowledge (SK), leading to the development of an integrated TPACK, or in this case, TPASK. The emphasis is on understanding the potential and limitations of digital tools and technologies in education.

In the project, teachers were trained in student-centred approaches to science (PK, PSK), teaching concepts related to the water cycle and students' misconceptions (SK, PSK), basic technical skills using ICTs and supporting students with technical difficulties (TK), the potential of ICTs in science education (TSK), and the application of specific pedagogical strategies (TPASK).

Teachers then used the adaptive gamification application as the primary tool. After that, an analysis and discussion on using the software to teach concepts related to the water cycle (coagulation, melting, evaporation, and boiling) were conducted.

2.3 Research Implementation

This research study involved six in-service teachers during the 2022-2023 school year. These teachers worked in third-grade classrooms at Heraklion, Crete, Greece, primary schools. These teachers participated voluntarily, driven by their interest and enthusiasm, rather than being randomly selected. The parents and guardians of the children were informed about the research and asked to give their permission before proceeding with the learning activities. Five of the six in-service teachers who participated (T1-T6) were female, and one was male. The six teachers had varying levels of teaching experience and self-assessed ICT knowledge. Semi-structured, reflective interviews were conducted post-teaching interventions and were transcribed, analysed, and coded using ATLAS.ti software. The interviews were transcribed in total and were analysed based on three axes: (a) the use of adaptive gamification in science education, (b) the training process, and (c) the school-based practice. The first axis focused on teachers' perspectives on using adaptive gamification in science education, its pros, cons, usability aspects and potential improvements in the app. The second axis concerned the content of the training process, meeting teachers' needs, any improvements to it, and post-training support. The third axis is related to the school practice, i.e., the difficulties encountered, the benefits, and problem-solving.

Following Mayring's [27] methodology, the qualitative content analysis used various coding techniques adapted to the research needs. In this study, we utilised inductive and deductive coding to explore themes supported by quantitative data where appropriate. The data were organised into meaningful codes and categories, helping to identify patterns and themes through case analysis [28], [29]. The interviews revealed key themes that highlighted the benefits of adaptive gaming (cognition, affectivity, behaviour and ease of use) according to [30] and identified training deficits (time management, resource support, student development, teaching strategy and content)

according to Bingimlas [31]. Effective professional development was assessed in three terms: a) practicality, b) relevance, c) consistency and d)effectiveness [32].

The data review process involved experienced researchers, including the supervising professor and a professor with expertise in Technological Pedagogical Content Knowledge (TPACK), to ensure accurate data categorization and resolve any uncertainties [33]. The research was based on a multiple case study approach, a robust method that allows for an in-depth, cross-sectional analysis.

III. RESULTS

The study results show that all of the teachers identified both beneficial and negative aspects of the application regarding its use in science teaching, as well as potential areas for development. Furthermore, there was an overall agreement about the positive parts of the training. Regarding the advantages the application has for learning, teachers identified cognitive and emotional benefits from using the application. More specifically, they noted better student understanding and motivation, as most teachers pointed out that the students displayed positive learning attitudes (T3, T4, T5, T6). In contrast, others identified positive changes in the routines of the students (T1, T2).

Moreover, one teacher highlighted the enhanced student cooperation (T4). Regarding the general perspectives and emphasis of the teachers on the app's benefits, half of them stressed the emotional gains (T3, T4, T5), another one focused on cognitive benefits (T2), and a few balanced the emotional and cognitive benefits (T1, T6) (Figure 3).

Another critical point that often affects an application's use in learning is its usability. Most teachers found the adaptive gamification environment easy to use and helpful in teaching science. They highlighted the program's positive impact on students' inquiry methods (T2, T3, T4) and its user-friendly navigation (T1, T3). The latter is essential in order to include it in education successfully. Nevertheless, certain teachers (T2, T5, T6) encountered challenges in accurately distinguishing learning strategies and assessing the student's progress in the courses. Moreover, many teachers encountered challenges, particularly during the initial lessons, in effectively instructing their students within the given setting (T1, T2, T5, T6) (Figure 3).

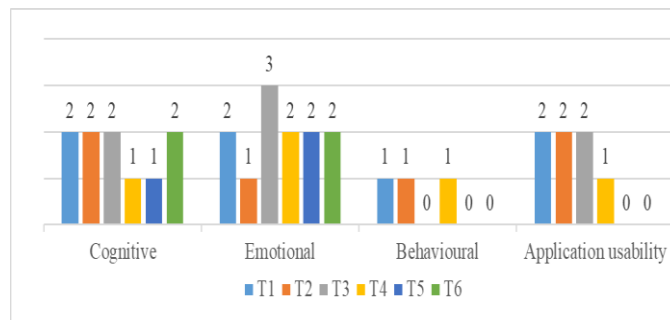


Fig. 3. The frequency of codes concerning the advantages of using the applications in science education

Regarding drawbacks, teachers mentioned issues related to student characteristics and developmental stages, i.e., cognitive levels and age appropriateness. Many teachers believed it would be easier to teach older students with the application (T1–T5). There were also reports of behavioural problems in the students, such as impatience during experiments. (T1–T4). Additionally, some teachers brought up several other problems, such as technical issues, logistical challenges, time constraints, and behaviour management challenges (T3, T4, T5). On the other hand, some other teachers (T1 and T6) noted fewer problems, focusing mainly on behaviour and classroom management (T1, T6), while another addressed logistical, technical, and subject-specific challenges (T2) (Figure 4).

Suggestions for improving the application were often linked to these drawbacks. Most of the suggestions that were made by the teachers in order to improve the application focused on increasing student interaction and simplifying gameplay, such as adjusting vocabulary (T2, T4, T5), reducing dialogue (T1), boosting interactivity (T6), and addressing repetitiveness (T2). Moreover, more than half of the teachers encountered technical problems during the learning courses (T1, T2, T5), most related to school infrastructure. Additionally, a few teachers stressed the need for more inclusive features (T3, T4) (Figure 4).

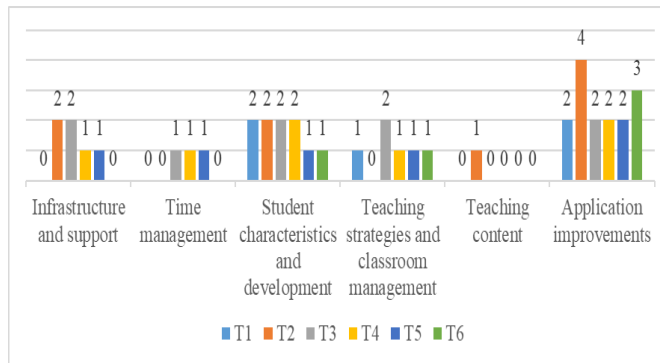


Fig. 4. The frequency of codes concerning disadvantages and improvements in the use of the applications in science education

Regarding their initial training, teachers generally showed positive feedback regarding its' practicality and effectiveness in familiarising them with the application. However, some issues were also raised, i.e., more time on specific aspects of the adaptation process (T4), additional hands-on practice (T2), and better interaction among trainees and trainers (T3) (Figure 5). What is more, the teachers stressed the need to increase focus on knowledge that is associated with technical problems, such as those they encountered (T1, T3, T4, T6), while one teacher emphasised the need to increase focus on the understanding of the instructional strategies within the application (T5) (Figure 5). Overall, the training was beneficial, and the teachers recognised the need for improved technical support and more comprehensive instruction.

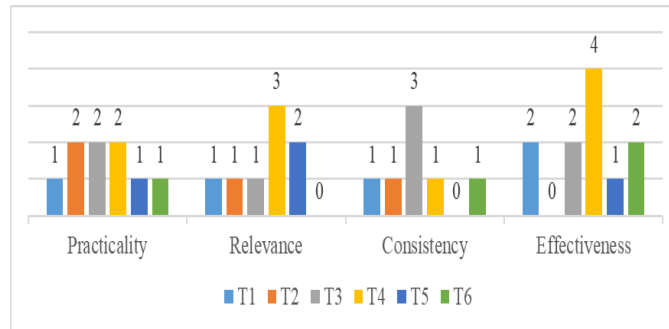


Fig. 5. The frequency of codes concerning teachers' views on training

IV. DISCUSSION

Teachers' views on adaptive gamification, like any other educational technological tool, affect its successful integration and utilisation [34]. Teachers report that adaptive gamification improves science education learning and student motivation. Additionally, teachers believe that the application positively impacted students' attitudes toward learning in line with the goals of gamification [35], [36]. Although cognitive and emotional benefits were widely reported, fewer teachers noted behavioural benefits, consistent with previous findings [30]. Most teachers emphasised gamification's cognitive and affective benefits to increase motivation and learning outcomes [37]. They also highlighted the usability and positive impact of the app in promoting inquiry-based learning and ease of navigation [38]. However, some teachers needed help identifying the learning strategies within the app, which impacted its perceived usefulness. In addition, many teachers noted that although the app was age-appropriate, the science content, concepts in changes in matter and the water cycle needed to be improved based on the age of the students (3rd-grade students) [39]. However, effective feedback is crucial in gamification to enhance the learning experience [30], and students often showed impatience during the experiments, which sometimes led to negative emotions or behaviours. Other difficulties, consistent with long-standing challenges in integrating technology in education [31], [40], included time constraints, technical issues and managing behaviour when using the application.

To improve the adaptive gamification environment, teachers proposed reducing repetitive tasks, technical issues, and complexity and improving inclusivity for students with special learning needs [41]. Moreover, the teachers' perceptions of the professional development programme were largely positive, with some teachers indicating that they had gained increased motivation and confidence in their ability to utilise similar applications [42]. However, some requested more practical training in using applications in the classroom. The relevance of the training was emphasised, with some teachers appreciating the opportunity to identify teaching strategies. In contrast, others expressed a desire to focus more on how to use the app [43]. The consistency of the training was

also highlighted, with the need for better support in dealing with technical issues, reflecting the low level of technical infrastructure in schools [44]. Overall, the effectiveness of the training was recognised. In particular, it improved teaching by integrating technological tools [45].

V. LIMITATIONS

Several limitations limit the applicability of the study's findings and conclusions. In particular, the small convenient sample size and the qualitative approach prevent broad applicability, together with the gender imbalance of the sample and the subjective nature of the qualitative content analysis, which depends heavily on the researcher's interpretation.

VI. CONCLUSION

Adaptive learning gamification is still in its first stages, with very few studies, especially regarding science education and teacher professional development [24], [36]. From a teacher's perspective, this study contributes to the research on adaptive gamification and technology integration in science education. It highlights all the positive effects a fully integrated adaptive gamification application can have on students' motivation and attitudes towards learning. However, as emphasised by the teachers, factors such as students' cognitive level, prior knowledge, experience, and age should be considered, especially during curriculum changes. In addition, technical difficulties related to the application and school infrastructure were highlighted, as well as usability aspects, both positive and negative. These findings help support the development of adaptive gamification environments and indicate the need to include teachers during such application [18]. In addition, the study highlights the practical value of the training programme for teachers and its impact on their training and effectiveness in the classroom.

To sum up, the design and implementation of appropriate training programmes for current and future teachers is essential, as they play a critical role in the learning process and impact students' experience of technology [36], [38].

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