Article

Not peer-reviewed version

# The Effects of Adaptive Gamification in Science Learning: A Comparison with Traditional Inquiry-based Learning and genders Differences

Alkinoos-Ioannis Zourmpakis , Michail Kalogiannakis , Stamatios Papadakis *

Posted Date: 12 November 2024

doi: 10.20944/preprints202411.0766.v1

Keywords: adaptive gamification; science education; learning results; inquiry-based learning; gender differences

*Article*

# The Effects of Adaptive Gamification in Science Learning: A Comparison with Traditional Inquiry-Based Learning and genders Differences

**Alkinoos-Ioannis Zourmpakis [1], Michail Kalogiannakis [1] and Stamatios Papadakis [2,*]**

[1] Department of Special Education, University of Thessaly, Volos, Greece
[2] Department of Preschool Education, Faculty of Education, University of Crete, 74100 Crete, Greece
* Correspondence: stpapadakis@uoc.gr

**Abstract:** Gamification has become a topic of interest for researchers and educators, particularly in science education, in the last few years. Students of all educational levels have consistently faced challenges when grasping scientific concepts. However, the effectiveness of gamification, especially in terms of academic performance, has shown mixed results. This has led researchers to explore a new alternative approach, adaptive gamification. Our study compared the effects of adaptive gamification with traditional inquiry-based learning. Two classes of 9-year-old students participated, with the experimental group using adaptive gamification and the control group following a more conventional teaching approach using inquiry-based lessons and experiments. Both groups were tested before and after the lessons, and their results were analyzed using SPSS. The findings revealed that while both groups showed a significant difference after the lessons, the experimental group had significantly higher scores than the control group. Particularly significant results were observed regarding learning improvements based on students' gender, with female and male students in the experimental group demonstrating significant improvement. In contrast, in the control group, only the male students displayed significant learning improvement. This research contributes significantly to the relatively new field of adaptive gamification in science education and the improvement of students' science learning, particularly in the context of gender differences.

**Keywords:** adaptive gamification; science education; learning results; inquiry-based learning; gender differences

## 1. Introduction

All aspects of everyday life, including practices in the classroom, are experiencing significant changes as a result of rapid advances in technology. At the international level, education systems are trying to integrate new technologies into the teaching process. There have been significant discussions about fundamental changes in science education due to the increasing demand for scientific and technological skills [1,2]. Moreover, integrating digital tools in science teaching enhances the understanding of abstract concepts and provides engaging and authentic learning activities [3–5]. Consequently, there has been increasing interest in integrating various digital technologies into science curricula [6,7].

In recent years, gamification has gained considerable popularity as an educational tool, incorporating game mechanisms to increase student motivation and improve learning [8,9]. It draws from educational and psychological principles, emphasizing increasing motivation, autonomy, and cognitive development [10]. The application and use of gamification in science teaching encourage the development of scientific thinking and enhance student engagement [11]. Nevertheless, the "one size fits all" approach widely used in gamification seems inadequate, as students have different

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 November 2024 doi:10.20944/preprints202411.0766.v1



motivations and learning styles, which requires adapting the elements and mechanisms of gamification applications [12]. Therefore, a new methodology based on adapting game mechanisms and elements to the needs and preferences of each learner has emerged in recent years, i.e. adaptive gamification [13,14]. While, according to the literature, some methodologies have been developed regarding the foundation and creation of adaptive gamification environments [15], more research needs to be conducted regarding student learning outcomes in education [16]. Furthermore, most methodologies often appear not designed to address a specific teaching content, raising doubts about their effectiveness and creating a need for further investigation [15,17].

Therefore, the present research study used an environment that incorporated basic principles and strategies related to the teaching of science education, incorporating adaptive criteria, learning strategies, game elements and all the main aspects of the learning process related to the teaching of science. Our primary purpose was to determine the impact of this environment on students' learning outcomes compared to more conventional teaching that also uses modern teaching approaches, such as inquiry learning. In addition, ascertaining gender differences between students regarding outcomes was also an essential objective of this research. Consequently, the research questions that were set are the following:

- What was the impact of this adaptive gamification application on students' learning outcomes?
- What were the differences in learning between the students who utilized the adaptive gamification environment and those who followed a traditional Inquiry-based Learning approach?
- Were there any differences in students learning based on their gender?

## 2. Literature Review

### *2.1. Science Education and Adaptive Gamification*

Science education, a vital component of the 21st-century education system, faces many challenges. There is often a decline in student participation and engagement, difficulty in understanding concepts, a drop in performance and a lack of positive feelings towards teaching [18–20]. Therefore, gamification applications in the educational process have gained considerable attention in recent years [21], although integrating games into the educational process is not a novelty. Gamification can improve student engagement and motivation by allowing students to experiment in safe environments without the risk of failure [22,23]. It provides intrinsic and extrinsic motivation, which can significantly improve skill acquisition and understanding of scientific concepts [24,25]. However, although there is evidence that gamification can increase students' enjoyment, engagement and motivation [26,27], its effects on learning outcomes are unclear [28,29]. This is due to several studies with contradictory or inconclusive results [29], including science teaching [4].

One of the possible causes of these results may be that gamification environments often do not consider students' differences and their needs in specific cognitive domains [30]. Therefore, there has been a need to relate gamification to the adaptive learning methodology, i.e. a type of learning that dynamically adapts the level and type of content presented to students according to their skills and abilities, often using both automated systems and teacher intervention to improve learning outcomes [31].

Adaptive gamification was based on that principle, integrating gamification and adaptive learning methodologies by personalizing learning and incorporating game elements tailored to the user's characteristics, based on their input [32], but without using excessive elements that lead to cognitive overload [33,34]. However, its application is at an early stage, as there are limited studies to guide the design and adaptation of game elements specific to the user's needs [33,34]. Furthermore, designing adaptive gamified environments presents challenges, as no universal set of game elements is effective for all students and subjects [35]. Existing methodologies are often generic and need to meet the needs of specific subjects, such as science education, which require approaches that consider different learning strategies [15,17].

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 November 2024 doi:10.20944/preprints202411.0766.v1



*2.2. Principles of Adaptive Gamification: Motivation Theories, User Types, and Gaming Elements*

The basic concepts of adaptive gamification are associated with motivational theories, user types, adaptive elements, and learning strategies. Based on the relevant literature, limited approaches have been reported on adaptive gamification, with even fewer relating to specific content [15,36]. Therefore, there has been a significant challenge in creating an adaptive gamification environment based on motivational theories, which consider the interaction with students' characteristics and needs and are directly linked to learning strategies in science education.

Another vital aspect of adaptive gamification is user segmentation based on personal characteristics and needs, such as psychographic, behavioural and demographic data [37]. One of the primary models used in adaptive gamification is the Hexad typology [38]. This model has been established based on the SDT motivational theory and categorizes users into six types: achiever, gamer, philanthropist, disruptor, socializer and free spirit [39]. This typology allows the application to be tailored to the needs and motivations of different users, maximizing their engagement. In this methodology, no type of player is identified by excluding the others. Instead, the different dimensions and priorities set by each user are recognized. While the type with the highest score is recognized as the dominant one for each learner and influences to the greatest extent the elements of the game as well as the learning strategy to be followed, the second and third user types also play a role, as an element from each user is added to the application as long as it does not entirely conflict with the dominant player [15].

Also, integrating gamification applications with modern learning strategies, such as flipped learning, inquiry learning, and problem-solving learning, can improve the learning process in science [40–42]. Research has shown that combining these strategies with gamification improves learning outcomes [42–44]. However, implementing different learning strategies requires significant adaptations to the gamification environment, which may limit their viability, explaining the research gap in this area. In this application, two learning strategies are used. Exploratory learning and learning through problem solving. Both strategies are suitable for science teaching [40,45,46], with each type of player adapting to a different strategy based on their characteristics. For example, philanthropists and socializers prefer learning through problem solving as they seek purpose and social interaction. In contrast, achievers and gamers benefit more from exploration, which offers a more independent process.

Furthermore, choosing and implementing gaming elements is critical in an adaptive gamification environment as they are directly linked to increased student engagement and motivation. However, in this particular research, in order to create the adaptive gamification application, we focused on adapting different elements from different categories of elements which are related:

a) The user UI, such as points, badges, etc. The use and adaptation of this category are particularly prevalent in adaptive gamification environments due to their ease of adaptation without altering the learning environment [17,47].

b) design mechanisms, such as time thresholds, competitive or cooperative play, etc. The impact of the elements of this category on learning has shown conflicting research results, making it necessary to adapt them carefully [4].

c) heuristic methods, such as goals, objectives, game style, and tasks. This category strongly correlates with learning strategies, a vital aspect of this adaptation methodology.

Based on user needs and motivational theories, the right combination of these elements aims to enhance the effectiveness of adaptive gamification by providing a personalized and motivating learning environment. Building on the principles of adaptive gamification described and the work conducted by Zourmpakis et al. [15], an adaptive gamification application called "The Water Cycle" was created using the Unity3D game engine. This environment was designed to teach concepts related to the water cycle, such as coagulation, melting, boiling, and evaporation, to 9-year-old students. The application used a 3D environment, following an RPG (role-playing game) approach, while simulating a "real" environment. Furthermore, based on the work of Papadakis et al. [48], actual videos of experiments related to the concepts being taught within the application were included.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 November 2024 doi:10.20944/preprints202411.0766.v1



Providing motivation and enjoyment is an essential element of gamification applications, but assessing the learning impact of an application or tool and improving the learning process, in general, are equally important goals, mainly because gamification seems to have mixed effects on student performance, while little is known about its effect on female and male students separately [4]. Although this methodology and application have been used previously to assess student motivation and engagement, the primary goal of a gamification application, the exact impact on student knowledge in general, the differences between students' genders, and how it compares to more traditional ways of teaching were not studied. As such, whether an increase in students' motivation could also lead to an enhancement in students' learning achievement remains unclear.

## 3. Methodology

Therefore, with a convenience sample, this quantitative semi-experimental study occurred in one school in Heraklion, Crete, Greece. Two classes of 8- to 9-year-old students participated: the experimental and control groups—the choice of what group would be the experinmental and what the control was made at random. The control group consisted of 18 students and followed a more "traditional" inquiry-based approach, following the 5E learning model and conducting simple experiments or utilizing videos in the case of coagulation. The experiments were either conducted by the students or, if they were deemed too dangerous, they were demonstrated by the teacher with the assistance of some students, like in the case of boiling. The experimental group comprised 17 students taught using adaptive gamification applications, which ran only on desktop computers. The same teacher taught both classes. However, it should be noted that the experimental group needed an additional lesson hour for the students to learn some primary navigation of the application and to answer the initial questionnaire within the application, which would allow for the establishment of the user profile. Additionally, this research followed all formal national and international rules for ethics and ethics in research by acquiring permission from the Ethics Committee of the PTPE of the University of Crete, informing all affected individuals involved in the process, i.e. students, parents, teaching staff, and requesting their permission. Moreover, all researchers were included and oversaw the entire research process.

Therefore, with a convenience sample, this quantitative semi-experimental study occurred in one school in Heraklion, Crete, Greece. Two classes of 8- to 9-year-old students participated: the experimental and control groups. The choice of which group would be the experimental group and which would be the control group was made randomly. The control group consisted of 18 students and followed a more "traditional" inquiry-based approach, using the 5E learning model and conducting simple experiments or utilizing videos in the case of coagulation. The experiments were either conducted by the students or, if they were deemed too dangerous, they were demonstrated by the teacher with the assistance of some students, such as in the case of boiling. The experimental group comprised 17 students taught using an adaptive gamification application, which ran only on desktop computers. The same teacher taught both classes. However, it should be noted that the experimental group needed an additional lesson hour for the students to learn the primary navigation of the application and to complete the initial questionnaire within the application, which allowed for the user profile establishment. Additionally, this research followed all formal national and international rules for ethics in research by acquiring permission from the Ethics Committee of the PTPE of the University of Crete, informing all affected individuals involved in the process—i.e., students, parents, and teaching staff—and requesting their permission. Moreover, all researchers were involved and oversaw the entire research process.

In order to reveal the changes in students' learning outcomes, we utilized a pre-test and post-test approach for both classes [49]. This approach allowed us to establish whether the students in both classes were at the same learning level before the intervention and to measure their overall academic improvement. To achieve this, we followed the suggestions of Tosun and Taskesenligil [50] and created an academic achievement test that included multiple cognitive learning objectives from Bloom's taxonomy (Remembering, Understanding, Applying, Analyzing, and Evaluating).

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 November 2024 doi:10.20944/preprints202411.0766.v1



Additionally, we utilized activities that involved different types of answering, i.e., multiple choice, short answers, and fill-in-the-blank.

Moreover, to strengthen the validity and suitability of the test, we sought the assistance of three academic experts in science education [51]. We also requested assistance from the students' teachers due to the potential differences in students' abilities and their insight into their students' understanding or familiarity with the activities in the test [52]. The test was created and adjusted based on feedback from all involved parties. The final version of the test had a unanimous consensus among all parties involved [51]. Since coagulation, melting, evaporation, and boiling are strongly associated with the water cycle—a concept included in the early childhood curriculum—it was decided to use the test to assess students' knowledge before and after the intervention. The pre-tests were assessed before the intervention to ensure a similar level of knowledge between the two classes. To further increase validity, the research team that conducted this study was involved and had oversight of grading the tests and analyzing the results, which were analyzed using the SPSS statistical software platform. More specifically, all samples were analyzed using the independent samples t-test and paired sample t-test.

## 4. Results

The main focus of this study was to investigate the impact of the adaptive gamification application on students' learning. Table 1 shows that the experimental group exhibited a statistically significant difference between the pre-test and post-test (M. diff = 3.247, SD = 1.528), showcasing the enhancement of students' knowledge.

**Table 1.** Data Analysis of Experinmental group: As a group and between students' gender **(ίσως το κίτρινο να μην χρειάζεται).**

| Experimental group | | | | | |
|---|---|---|---|---|---|
| Types of test | Mean difference | | SD | | Sig-difference |
| Post-test - Pre test | 3,247 | | 1,528 | | ,000 |
| Female students | | | | | |
| Post-test - Pre test | 3,273 | | 1,828 | | ,000 |
| Male students | | | | | |
| Post-test - Pre test | 3,200 | | ,885 | | ,000 |
| Male and Female students | | | | | |
| | Female | Male | Female | Male | |
| Pre-test - Pre-test | 2,773 | 3,583 | ,717 | ,608 | ,034 |
| Post-test - Post-test | 6,045 | 6,783 | 1,7902 | 1,0381 | ,372 |

However, to clarify how different the adaptive gamification environment may benefit students' learning acquisition, it was essential to compare it with other, more "traditional" ways of teaching, including experiments, video simulations, and following the inquiry-learning strategy. Initialy, based on Table 2, the control group also showed a significant difference before and after the intervention (M. diff = 1.336, SD = 1.323), though the improvement was lower, based on the mean difference.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 November 2024 doi:10.20944/preprints202411.0766.v1



**Table 2.** Data Analysis of Control group: As a group and between students' gender.

| | Control group | | | | |
|---|---|---|---|---|---|
| | Mean | | SD | | Sig-difference |
| Post-test - Pre-test | 1,336 | | 1,323 | | ,001 |
| | Female students | | | | |
| Post-test - Pre-test | ,771 | | 1,102 | | ,069 |
| | Male students | | | | |
| Post-test - Pre-test | 1,900 | | 1,338 | | ,003 |
| | Male and Female students | | | | |
| | Female | Male | Female | Male | |
| Pre-test - Pre-test | 3,533 | 3,744 | ,986 | 1,137 | ,680 |
| Post-test- Post-test | 4,304 | 5,644 | ,876 | 1,645 | ,047 |

Looking more closely (Table 3), the control and experimental groups did not have a significant difference prior to each intervention (pre-test). However, the difference was almost significant ($p = 0.071$). Interestingly, the control group had a higher initial average ($M = 3.639$) than the experimental group ($M = 3.059$). However, after the intervention, the experimental group's mean ($M = 6.306$) was significantly higher ($p = 0.014$) than the control group's mean improvement ($M = 4.974$). Thus, the students in the experimental group improved even more than those in the control group.

**Table 3.** Data analysis comparison between both groups.

| | Groups | | | | |
|---|---|---|---|---|---|
| | Control group | | Experimental group | | |
| | Mean | SD | Mean | SD | Sig-difference |
| Pre test | 3,639 | 1,038 | 3,059 | ,772 | ,071 |
| Post test | 4,974 | 1,452 | 6,306 | 1,572 | ,014 |

Regarding the third research question and how differently each method affected each gender, we followed a comprehensive comparison. Initially, as shown in Tables 1 and 2, we asserted how it impacted the gender of each group separately. Concerning the experimental group (Table 1), both female (M. diff = 3.273, SD = 1.828) and male (M. diff = 3.200, SD = 0.885) students showed significant improvement after the intervention. In addition, and more interestingly, when comparing the male and female students of the experimental group, it is shown that they had a significant, albeit marginal, difference before the intervention (p=,034). However, there was no significant difference based on post-test scores between female and male students, indicating that the intervention benefited both genders equally, even though female students initially had lower learning scores.

Regarding the control group (Table 2), both gender types did not display the same improvement after the intervention, as only the male (M. diff = 1,900, SD=1,338) students were found to have a significant difference (p=,001). Female (M. diff =,771, SD=1,102) students did not seem to have the same substantial progress, although it was close to significance (p = 0.069) (p=,069). Moreover, male and female students in the control group had nearly identical knowledge levels in the pre-test (p = 0.680). However, male students experienced more significant gains from this type of intervention, with a significant, though marginal, improvement compared to female students (p = 0.047).

**Table 4.** Data analysis comparison between the male students of both groups.

| Male students | | | | | |
|---|---|---|---|---|---|
| | Control group | | Experimental group | | |
| | Mean | SD | Mean | SD | Sig-difference |
| Pre test | 3,744 | 1,137 | 3,583 | ,608 | ,757 |
| Post test | 5,644 | 1,645 | 6,783 | 1,038 | ,158 |

**Table 5.** Data analysis comparison between the female students of both groups.

| Female students | | | | | |
|---|---|---|---|---|---|
| | Control group | | Experimental group | | |
| | Mean | SD | Mean | SD | Sig-difference |
| Pre test | 3,533 | ,986 | 2,773 | ,717 | ,061 |
| Post test | 4,304 | ,876 | 6,045 | 1,790 | ,016 |

However, the analysis yielded different results for female students across groups. In particular, the female students in the experimental group (M = 2.773) had lower pre-test scores than those in the control group (M = 3.533), although this difference was not statistically significant (p = 0.061). Nevertheless, the female students of the experimental group (M=6,045) showed a drastic improvement in their learning achievements, statistically surpassing the female students in the control group (M = 4.304). This finding highlights the potential advantages of an adaptive gamification environment in enhancing female students' learning acquisition.

## 4. Discussion

Research on adaptive gamification and its effect on learning has gradually increased [15,36]. However, more is needed to know about its effects in the context of science education [27]. Additionally, most studies tend to develop and utilize adaptive gamification applications in a general manner, regardless of their context, without incorporating specific aspects such as learning strategies [15,53]. Consequently, this approach may limit its potential for both motivation and learning [36]. However, in this study, it became clear how it can affect students' knowledge acquisition and how differently it affects male and female students.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 November 2024 doi:10.20944/preprints202411.0766.v1



First of all, according to this study's findings, it is evident that an adaptive gamification environment, designed following a methodology that emphasizes adaptability within a specific context—i.e., science education—and aims to reinforce the teacher's role as a facilitator can significantly benefit students' knowledge acquisition. However, as it was shown, the use of a more "traditional approach", such as an inquiry-based approach with the use of video simulations and simple experiments, can also help students, as it is also supported by other studies [54,55], at least in terms of learning outcomes. Nonetheless, the adaptive gamification application proved even more beneficial for students in the experimental group, as their learning achievements increased significantly more than those in the control group, even though their knowledge levels were not significantly different before the learning interventions. Since the adaptive gamification application integrates two prominent learning strategies in science education—i.e., inquiry-based learning and problem-based learning—this could indicate that adaptive gamification can enhance students' learning acquisition while leveraging these strategies [40,56] and potentially even beyond that. This finding also aligns with studies that question the efficacy of a purely "traditional inquiry-based learning approach" [57,58].

Moreover, our results provide valuable insights into how each approach affects each gender's learning achievements. In the control group, all students initially appeared to have similar knowledge levels. However, in the post-test, their results appeared quite different, with the male students showing significant enhancement, whereas the female students displayed only some improvement (not statistically significant). Consequently, the "traditional approach "can increase students' knowledge acquisition, but it appears more helpful for male than female students. This is also supported by some relevant studies [59,60]. However, it should be noted that in other cases, the impact of inquiry-based learning seems to be on the same level regardless of gender [61,62].

In contrast, for the experimental group, male and female students were not on the same knowledge level before the intervention, as female students initially scored significantly lower than their male counterparts. Nevertheless, after the intervention, both female and male students exhibited significant improvement, indicating that adaptive gamification can positively impact the learning of both genders. Studies have also suggested that gamification applications in education can benefit learning acquisition for both genders [63,64]. However, more about adaptive gamification in science education needs to be known, and even less regarding gender-based effects. Moreover, even though male students had significantly higher scores on the pre-test than females, they were not in the post-test. This result cannot conclusively show that lower-scoring students, such as female students, benefit more, although gamification studies have reported similar effects [63]. Nevertheless, Hassan et al. [65] believe adaptive gamification can motivate both genders to learn equally. Consequently, adaptive gamification has the potential to support both genders on an equal level, though further research is needed to draw concrete conclusions.

What is more, comparing the genders across both groups yielded exciting insights. Male students were on similar learning levels before the intervention. Both groups showed a significant increase, and while the male students in the experimental group scored higher, there was no statistically significant difference. In contrast, this was not the case when comparing female students across groups. Even though the female students of the control group had a higher learning achievement before the courses, the difference was not statistically significant.

Nonetheless, the post-test results indicated a different outcome, as female students in the experimental group showed a substantial enhancement in knowledge, especially compared to female students in the control group. Thus, it is evident that the adaptive gamification environment can increase female students' learning, even more so than the "traditional approaches". This finding contrasts with most studies, which suggest that non-gamified courses primarily benefit male students [66] or have an equal effect on both genders [64,67]. Consequently, further research is required to determine whether adaptive gamification enhances female students' knowledge acquisition more effectively than "traditional approaches".

## 6. Limitations

The research team monitored all procedures, data, analysis, and conclusions, limiting potential bias. However, this research contains some limitations. Although we investigated the effects of motivating students in an adaptive gamification environment, we did not compare these results with those from a "conventional" gamification environment. Consequently, this study is limited in comparing adaptive to gamification environments that follow the standard "one-size-fits-all" approach.

Moreover, the small sample size and its geographical limitation, i.e., an urban area, make it difficult to generalize these findings. Apart from gender differences, no other socio-cultural differences among the students were considered. Furthermore, conducting more longitudinal research would help verify and confirm these results while reducing the potential for any novelty effect. Although the results may vary in other subject domains, it is essential to note that the application was developed specifically for the science learning environment, and the results should mainly be interpreted in that context [36].

## 5. Conclusions

The present study offers vital insights and demonstrates the potential of adaptive learning systems and gamification in science education and, potentially, education in general. In the recent health and economic crisis, there has been a growing need for flexible, constant, remote and personalized learning that can motivate learners to engage in the learning process, promote the development of various skills and have substantial learning improvements [68–70]. Additionally, these new learning technologies and methodologies must be compatible with established, more "traditional" learning methodologies to facilitate a smoother transition for teachers into their roles as facilitators and increase efficacy [14,15]. However, there is a shortage of studies regarding adaptive gamification, especially in science education [16,36].

All gamification applications aim to increase student motivation, enhancing engagement and learning acquisition. In this study, we investigated the impact of this particular adaptive learning methodology and application on students' learning outcomes and compared it with a more "traditional" methodology. Although it would have been helpful to assess the motivation levels of both groups of students, it should be noted that previous research has demonstrated the overall positive effects this specific adaptive gamification environment can have on students in science education [16]. Nevertheless, this study's results help demonstrate the potential impact of adaptive gamification on students' science learning, a vital aspect of 21st-century education [71].

Moreover, students have exhibited varying performance in science learning based on gender, with female students generally showing lower learning outcomes, motivation, and prior knowledge [60,72,73]. Additionally, historically, females have been underrepresented in STEM fields [74,75]. However, this study shows that this adaptive learning methodology can significantly improve learning outcomes for both genders. This improvement was especially evident when comparing female students participating in the "traditional" inquiry-based learning intervention. These results are pretty substantial as they could support gender parity in science and STEM fields, where gender diversity is crucial for fostering innovation and productivity in complex STEM environments [76], offering both financial and intellectual benefits [77,78].

Additional studies addressing the limitations of our research and exploring the effectiveness and motivational aspects of this or similar adaptive gamification applications in science education would further assist in generalizing these results. Using a larger sample size and investigating the long-term effects of adaptive gamification applications would help clarify their sustained benefits and potential to reduce dropout rates among students in science education.

**Author Contributions:** All co-authors contributed to data collection and/or analysis of project results. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Data Availability Statement:** The data presented in this study are available on request from the corresponding author.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References

1. Voogt, J.; Roblin, N.P. A Comparative Analysis of International Frameworks for 21st Century Competences: Implications for National Curriculum Policies. *Journal of Curriculum Studies* **2012**, *44*, 299–321, doi:10.1080/00220272.2012.668938.
2. Fensham, P.J. The Future Curriculum for School Science: What Can Be Learnt from the Past? *Res Sci Educ* **2022**, *52*, 81–102, doi:10.1007/s11165-022-10090-6.
3. Bingimlas, K.A. 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* **2009**, *5*, doi:10.12973/ejmste/75275.
4. Kalogiannakis, M.; Papadakis, S.; Zourmpakis, A.I. Gamification in Science Education. A Systematic Review of the Literature. *Education Sciences 2021, Vol. 11, Page 22* **2021**, *11*, 22, doi:10.3390/EDUCSCI11010022.
5. Vidakis, N.; Barianos, A.K.; Trampas, A.M.; Papadakis, S.; Kalogiannakis, M.; Vassilakis, K. Generating Education In-Game Data: The Case of an Ancient Theatre Serious Game. In Proceedings of the Proceedings of the 11th International Conference on Computer Supported Education (CSEDU 2019); Heraklion, 2019; pp. 36–43.
6. Devolder, A.; van Braak, J.; Tondeur, J. Supporting Self-regulated Learning in Computer-based Learning Environments: Systematic Review of Effects of Scaffolding in the Domain of Science Education. *J Comput Assist Learn* **2012**, *28*, 557–573, doi:10.1111/j.1365-2729.2011.00476.x.
7. Smetana, L.K.; Bell, R.L. Computer Simulations to Support Science Instruction and Learning: A Critical Review of the Literature. *Int J Sci Educ* **2012**, *34*, 1337–1370, doi:10.1080/09500693.2011.605182.
8. Kapp, K.M. The Gamification of Learning and Instruction: Game-Based Methods and Strategies for Training and Education. *Int J Gaming Comput Mediat Simul* **2012**, *4*, 81–83, doi:10.4018/jgcms.2012100106.
9. Zainuddin, Z.; Chu, S.K.W.; Shujahat, M.; Perera, C.J. The Impact of Gamification on Learning and Instruction: A Systematic Review of Empirical Evidence. *Educ Res Rev* **2020**, *30*, 100326, doi:10.1016/J.EDUREV.2020.100326.
10. Busarello, R.I.; Ulbricht, V.R.; Fadel, L.M.; de Freitas e Lopes, A.V. Gamification Approaches to Learning and Knowledge Development: A Theorical Review. In *New Advances in Information Systems and Technologies*; Springer International Publishing, 2016; pp. 1107–1116.
11. Kalogiannakis, M.; Papadakis, S. Combining Mobile Technologies in Environmental Education: A Greek Case Study. *International Journal of Mobile Learning and Organisation* **2017**, *11*, 108–130, doi:10.1504/IJMLO.2017.084272.
12. Böckle, M.; Novak, J.; Bick, M. Towards Adaptive Gamification: A Synthesis of Current Developments. In Proceedings of the Twenty-Fifth European Conference on Information Systems (ECIS); AISeL: Guimarães, Portugal, 2017; pp. 158–174.
13. Botte, B.; Bakkes, S.; Veltkamp, R. Motivation in Gamification: Constructing a Correlation Between Gamification Achievements and Self-Determination Theory. In Proceedings of the International Conference on Games and Learning Alliance; Springer Science and Business Media Deutschland GmbH, 2020; Vol. 12517 LNCS, pp. 157–166.
14. Zourmpakis, A.I.; Papadakis, S.; Kalogiannakis, M. Education of Preschool and Elementary Teachers on the Use of Adaptive Gamification in Science Education. *International Journal of Technology Enhanced Learning* **2022**, *14*, 1–16, doi:10.1504/IJTEL.2022.120556.
15. Zourmpakis, A.-I.; Kalogiannakis, M.; Papadakis, S. A Review of the Literature for Designing and Developing a Framework for Adaptive Gamification in Physics Education. *The International Handbook of Physics Education Research: Teaching Physics* **2023**, 1–26, doi:10.1063/9780735425712_005.
16. Zourmpakis, A.I.; Kalogiannakis, M.; Papadakis, S. Adaptive Gamification in Science Education: An Analysis of the Impact of Implementation and Adapted Game Elements on Students' Motivation. *Computers* **2023**, *12*, doi:10.3390/computers12070143.
17. Monterrat, B.; Lavoué, É.; George, S. Adaptation of Gaming Features for Motivating Learners. *Simul Gaming* **2017**, *48*, 625–656, doi:10.1177/1046878117712632.
18. Brígido, M.; Borrachero, A.B.; Bermejo, M.L.; Mellado, V. Prospective Primary Teachers' Self-Efficacy and Emotions in Science Teaching. *European Journal of Teacher Education* **2013**, *36*, 200–217, doi:10.1080/02619768.2012.686993.
19. Hicks, S.; MacDonald, S.; Martin, E. Enhancing Scientific Literacy by Targeting Specific Scientific Skills. *Teaching Science* **2017**, *63*, 26–37.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 November 2024 doi:10.20944/preprints202411.0766.v1




20. Steidtmann, L.; Kleickmann, T.; Steffensky, M. Declining Interest in Science in Lower Secondary School Classes: Quasi-experimental and Longitudinal Evidence on the Role of Teaching and Teaching Quality. *J Res Sci Teach* **2022**, *59*, 693–694, doi:10.1002/tea.21703.
21. Orhan Göksün, D.; Gürsoy, G. Comparing Success and Engagement in Gamified Learning Experiences via Kahoot and Quizizz. *Comput Educ* **2019**, *135*, 15–29, doi:10.1016/j.compedu.2019.02.015.
22. Loganathan, P.; Talib, C.; Thoe, N.; Aliyu, F.; Zawadski, R. Implementing Technology Infused Gamification in Science Classroom: A Systematic Review and Suggestions for Future Research. *Learning Science and Mathematics* **2019**, *14*, 60–73.
23. Kim, S.; Song, K.; Lockee, B.; Burton, J.; Kim, S.; Song, K.; Lockee, B.; Burton, J. Gamification Cases in STEM Education. In *Gamification in Learning and Education*; Springer International Publishing, 2018; pp. 125–139.
24. Hamari, J. Do Badges Increase User Activity? A Field Experiment on the Effects of Gamification. *Comput Human Behav* **2017**, *71*, 469–478, doi:10.1016/j.chb.2015.03.036.
25. Sanga Lamsari Purba, L.; Sormin, E.; Harefa, N.; Sumiyati, S. Effectiveness of Use of Online Games Kahoot! Chemical to Improve Student Learning Motivation. *Jurnal Pendidikan Kimia* **2019**, *11*, 57–66, doi:10.24114/jpkim.v11i2.14463.
26. Chans, G.M.; Portuguez Castro, M. Gamification as a Strategy to Increase Motivation and Engagement in Higher Education Chemistry Students. *Computers* **2021**, *10*, 132, doi:10.3390/computers10100132.
27. Papadakis, S.; Zourmpakis, A.-I.; Kalogiannakis, M. Analyzing the Impact of a Gamification Approach on Primary Students' Motivation and Learning in Science Education. In; 2023; pp. 701–711.
28. Marín, B.; Frez, J.; Cruz-Lemus, J.; Genero, M. An Empirical Investigation on the Benefits of Gamification in Programming Courses. *ACM Transactions on Computing Education* **2019**, *19*, 1–22, doi:10.1145/3231709.
29. Zainuddin, Z. Students' Learning Performance and Perceived Motivation in Gamified Flipped-Class Instruction. *Comput Educ* **2018**, *126*, 75–88, doi:10.1016/j.compedu.2018.07.003.
30. Koivisto, J.; Hamari, J. The Rise of Motivational Information Systems: A Review of Gamification Research. *Int J Inf Manage* **2019**, *45*, 191–210, doi:10.1016/J.IJINFOMGT.2018.10.013.
31. Werbach, K.; Hunter, D.; Dixon, W. *For the Win: How Game Thinking Can Revolutionize Your Business*; Wharton digital press: Philadelphia, 2012; Vol. 1;.
32. Vidakis, N.; Barianos, A.K.; Trampas, A.M.; Papadakis, S.; Kalogiannakis, M.; Vassilakis, K. In-Game Raw Data Collection and Visualization in the Context of the "ThimelEdu" Educational Game. In Proceedings of the Computer Supported Education: 11th International Conference, CSEDU 2019; Springer International Publishing: Heraklion, Crete, Greece, May 2020; pp. 629–646.
33. Codish, D.; Ravid, G. Personality Based Gamification – Educational Gamification for Extroverts and Introverts. In Proceedings of the Proceedings of the 9th CHAIS Conference for the Study of Innovation and Learning Technologies: Learning in the Technological Era; Ra'anana: The Open University of Israel, 2015; pp. 36–44.
34. Monterrat, B.; Desmarais, M.; Lavoué, É.; George, S. A Player Model for Adaptive Gamification in Learning Environments. In Proceedings of the Artificial Intelligence in Education: 17th International Conference; Springer International Publishing: Madrid, June 2015; Vol. 9112, pp. 297–306.
35. Seaborn, K.; Fels, D.I. Gamification in Theory and Action: A Survey. *International Journal of Human Computer Studies* **2015**, *74*, 14–31, doi:10.1016/j.ijhcs.2014.09.006.
36. Hallifax, S.; Serna, A.; Marty, J.-C.; Lavoué, É. Adaptive Gamification in Education: A Literature Review of Current Trends and Developments. In; 2019; pp. 294–307.
37. Bennani, S.; Maalel, A.; Ben Ghezala, H. Adaptive Gamification in E-learning: A Literature Review and Future Challenges. *Computer Applications in Engineering Education* **2022**, *30*, 628–642, doi:10.1002/cae.22477.
38. Rinjeni, T.P.; Rakhmawati, N.A.; Nadlifatin, R. A Systematic Literature Review on Personalized Adaptive Gamification. In Proceedings of the 2022 International Conference on Computer Engineering, Network, and Intelligent Multimedia (CENIM); IEEE, November 22 2022; pp. 218–223.
39. Tondello, G.F.; Wehbe, R.R.; Diamond, L.; Busch, M.; Marczewski, A.; Nacke, L.E. The Gamification User Types Hexad Scale. In Proceedings of the Proceedings of the 2016 annual symposium on computer-human interaction in play ; Association for Computing Machinery, Inc, October 16 2016; pp. 229–243.
40. Tsai, F.-H. The Development and Evaluation of a Computer-Simulated Science Inquiry Environment Using Gamified Elements. *Journal of Educational Computing Research* **2018**, *56*, 3–22, doi:10.1177/0735633117705646.
41. Huang, B.; Hew, K.F. Implementing a Theory-Driven Gamification Model in Higher Education Flipped Courses: Effects on out-of-Class Activity Completion and Quality of Artifacts. *Comput Educ* **2018**, *125*, 254–272, doi:10.1016/j.compedu.2018.06.018.
42. Jenkins, D.A.; Mason, D. Gamification in General Chemistry. In Proceedings of the Active Learning in College Science; Springer: Cham, 2020; pp. 439–449.
43. Erdoğdu, F.; Karatas, F.O. *Examining the Effects of Gamification on Different Variables in Science Education Identifing Turkish Society's Level of Scientific Literacy View Project Identifing Turkish Society's Level of Scientific Literacy View Project*; 2016;

44. Aşıksoy, G. The Effects of the Gamified Flipped Classroom Environment (GFCE) on Students' Motivation, Learning Achievements and Perception in a Physics Course. *Qual Quant* **2018**, *52*, 129–145, doi:10.1007/s11135-017-0597-1.
45. Chan, K.Y.G.; Tan, S.L.; Hew, K.F.T.; Koh, B.G.; Lim, L.S.; Yong, J.C. Knowledge for Games, Games for Knowledge: Designing a Digital Roll-and-Move Board Game for a Law of Torts Class. *Res Pract Technol Enhanc Learn* **2017**, *12*, 1–20, doi:10.1186/s41039-016-0045-1.
46. Panis, I.; Setyosari, P.; Yuliati, L. Design Gamification Models in Higher Education: A Study in Indonesia. *International Journal of Emerging Technologies in Learning* **2020**, *15*, 244–255.
47. Deterding, S.; Dixon, D.; Khaled, R.; Nacke, L. From Game Design Elements to Gamefulness: Defining "Gamification." In Proceedings of the Proceedings of the 15th international academic MindTrek conference: Envisioning future media environments; ACM Press: New York, 2011; pp. 9–15.
48. Papadakis, S.; Zourmpakis, A.I.; Kalogiannakis, M. Analyzing the Impact of a Gamification Approach on Primary Students' Motivation and Learning in Science Education. In Proceedings of the International Conference on Interactive Collaborative Learning ; Springer International Publishing., 2023; Vol. 633 LNNS, pp. 701–711.
49. Creswell, J.W.; Hanson, W.E.; Clark Plano, V.L.; Morales, A. Qualitative Research Designs. *Couns Psychol* **2007**, *35*, 236–264, doi:10.1177/0011000006287390.
50. Tosun, C.; Taskesenligil, Y. The Effect of Problem-Based Learning on Undergraduate Students' Learning about Solutions and Their Physical Properties and Scientific Processing Skills. *Chem. Educ. Res. Pract.* **2013**, *14*, 36–50, doi:10.1039/C2RP20060K.
51. Petousi, V.; Sifaki, E. Contextualising Harm in the Framework of Research Misconduct. Findings from Discourse Analysis of Scientific Publications. *International Journal of Sustainable Development* **2020**, *23*, 149–174, doi:10.1504/IJSD.2020.115206.
52. Kimani, G.N.; Kara, A.M.; Njagi, L.W. Teachers' Factors Influencing Students' Academic Achievement in Secondary Schools in Nyandurua County, Kenya. *International Journal of Education and Research* **2013**, *1*, 1–14.
53. Kalogiannakis, M.; Papadakis, S.; Zourmpakis, A.-I. Gamification in Science Education. A Systematic Review of the Literature. *Educ Sci (Basel)* **2021**, *11*, 22, doi:10.3390/educsci11010022.
54. Firman, M.A.; Ertikanto, C.; Abdurrahman, A. Description of Meta-Analysis of Inquiry-Based Learning of Science in Improving Students' Inquiry Skills. *J Phys Conf Ser* **2019**, *1157*, 022018, doi:10.1088/1742-6596/1157/2/022018.
55. Sonsun, P.; Hemtasin, C.; Thongsuk, T. Development of Science Learning Activities Using Inquiry-Based Learning Management to Improve the Academic Achievement of Secondary School Students. *Journal of Education and Learning* **2023**, *12*, 86, doi:10.5539/jel.v12n3p86.
56. Bantaokul, P.; Polyiem, T. The Use of Integrated 5Es of Inquiring-Based Learning and Gamification to Improve Grade 8 Student Science Learning Achievement. *Journal of Educational Issues* **2022**, *8*, 459, doi:10.5296/jei.v8i1.19802.
57. Cairns, D.; Areepattamannil, S. Exploring the Relations of Inquiry-Based Teaching to Science Achievement and Dispositions in 54 Countries. *Res Sci Educ* **2019**, *49*, 1–23, doi:10.1007/s11165-017-9639-x.
58. Jerrim, J.; Oliver, M.; Sims, S. The Relationship between Inquiry-Based Teaching and Students' Achievement. New Evidence from a Longitudinal PISA Study in England. *Learn Instr* **2022**, *80*, 101310, doi:10.1016/j.learninstruc.2020.101310.
59. Nunaki, J.H.; Damopolii, I.; Kandowangko, N.Y.; Nusantari, E. The Effectiveness of Inquiry-Based Learning to Train the Students' Metacognitive Skills Based on Gender Differences. *International Journal of Instruction* **2019**, *12*, 505–516, doi:10.29333/iji.2019.12232a.
60. Sagala, R.; Umam, R.; Thahir, A.; Saregar, A.; Wardani, I. The Effectiveness of STEM-Based on Gender Differences: The Impact of Physics Concept Understanding. *European Journal of Educational Research* **2019**, *volume-8-2019*, 753–761, doi:10.12973/eu-jer.8.3.753.
61. Enebechi, R.I. Effect of Inquiry-Based Learning Approach on Senior Secondary Scholl Students' Retention in Biology. *British International Journal of Education And Social Sciences* **2021**, *8*, 9–19.
62. Ramdani, A.; Jufri, A.W.; Gunawan, G.; Fahrurrozi, M.; Yustiqvar, M. Analysis of Students' Critical Thinking Skills in Terms of Gender Using Science Teaching Materials Based on The 5E Learning Cycle Integrated with Local Wisdom. *Jurnal Pendidikan IPA Indonesia* **2021**, *10*, 187–199, doi:10.15294/jpii.v10i2.29956.
63. Khan, A.; Ahmad, F.H.; Malik, M.M. Use of Digital Game Based Learning and Gamification in Secondary School Science: The Effect on Student Engagement, Learning and Gender Difference. *Educ Inf Technol (Dordr)* **2017**, *22*, 2767–2804, doi:10.1007/s10639-017-9622-1.
64. Zahedi, L.; Batten, J.; Ross, M.; Potvin, G.; Damas, S.; Clarke, P.; Davis, D. Gamification in Education: A Mixed-Methods Study of Gender on Computer Science Students' Academic Performance and Identity Development. *J Comput High Educ* **2021**, *33*, 441–474, doi:10.1007/s12528-021-09271-5.

65. Hassan, M.A.; Habiba, U.; Majeed, F.; Shoaib, M. Adaptive Gamification in E-Learning Based on Students' Learning Styles. *Interactive Learning Environments* **2019**, *29*, 545–565, doi:10.1080/10494820.2019.1588745.
66. Bernik, A.; Vusić, D.; Milkovic, M. Evaluation of Gender Differences Based on Knowledge Adaptation in the Field of Gamification and Computer Science. *International Journal of Emerging Technologies in Learning (iJET)* **2019**, *14*, 220, doi:10.3991/ijet.v14i08.9847.
67. Almusharraf, N.; Aljasser, M.; Dalbani, H.; Alsheikh, D. Gender Differences in Utilizing a Game-Based Approach within the EFL Online Classrooms. *Heliyon* **2023**, *9*, doi:10.1016/j.heliyon.2023.e13136.
68. Essa, S.G.; Celik, T.; Human-Hendricks, N.E. Personalized Adaptive Learning Technologies Based on Machine Learning Techniques to Identify Learning Styles: A Systematic Literature Review. *IEEE Access* **2023**, *11*, 48392–48409, doi:10.1109/ACCESS.2023.3276439.
69. Hazeena, K. An Adaptive Personalized E-Learning Platform With Cognitive Varwk Adaptation And Gamification. *Journal of Namibian Studies : History Politics Culture* **2023**, *33*, 2103–2116.
70. Oliveira, W.; Hamari, J.; Shi, L.; Toda, A.M.; Rodrigues, L.; Palomino, P.T.; Isotani, S. Tailored Gamification in Education: A Literature Review and Future Agenda. *Educ Inf Technol (Dordr)* **2023**, *28*, 373–406, doi:10.1007/s10639-022-11122-4.
71. Council, N.R. Exploring the Intersection of Science Education and 21st Century Skills: A Workshop Summary. **2010**.
72. Piatek-Jimenez, K.; Cribbs, J.; Gill, N. College Students' Perceptions of Gender Stereotypes: Making Connections to the Underrepresentation of Women in STEM Fields. *Int J Sci Educ* **2018**, *40*, 1432–1454, doi:10.1080/09500693.2018.1482027.
73. Aurah, C. Investigating the Relationship between Science Self-Efficacy Beliefs, Gender, and Academic Achievement, among High School Students in Kenya. *Journal of Education and Practice* **2017**, *8*, 146–153.
74. Kang, H.; Calabrese Barton, A.; Tan, E.; D. Simpkins, S.; Rhee, H.; Turner, C. How Do Middle School Girls of Color Develop STEM Identities? Middle School Girls' Participation in Science Activities and Identification with STEM Careers. *Sci Educ* **2019**, *103*, 418–439, doi:10.1002/sce.21492.
75. Kricorian, K.; Seu, M.; Lopez, D.; Ureta, E.; Equils, O. Factors Influencing Participation of Underrepresented Students in STEM Fields: Matched Mentors and Mindsets. *Int J STEM Educ* **2020**, *7*, 16, doi:10.1186/s40594-020-00219-2.
76. Page, S.; Cantor, N.; Lewis, E. *The Diversity Bonus: How Great Teams Pay off in the Knowledge Economy*; Princeton University Press: New Jersey, 2019;
77. Dezsö, C.L.; Ross, D.G. Does Female Representation in Top Management Improve Firm Performance? A Panel Data Investigation. *Strategic Management Journal* **2012**, *33*, 1072–1089, doi:10.1002/smj.1955.
78. Galinsky, A.D.; Todd, A.R.; Homan, A.C.; Phillips, K.W.; Apfelbaum, E.P.; Sasaki, S.J.; Richeson, J.A.; Olayon, J.B.; Maddux, W.W. Maximizing the Gains and Minimizing the Pains of Diversity. *Perspectives on Psychological Science* **2015**, *10*, 742–748, doi:10.1177/1745691615598513.