**Learning To Innovate Through Play: Impact of Gamification on Students' Learning Outcomes in STEM Concepts**

**ABSTRACT**

Teaching of Science, Technology, Engineering, and Mathematics (STEM) disciplines are often perceived as the most difficult, challenging, and abstract by the students. There is a growing need to find innovative teaching methods that can disabuse students' minds and at the same time enhance their interest and learning outcomes. Gamification, the application of game-design elements in non-game contexts, has emerged as a promising approach to achieving these goals. This research investigates the effect of gamification teaching techniques on students' learning outcomes in STEM concepts. The pretest-posttest control group quasi-experimental design was used. Two intact classes of 200L were used as experimental and control groups. Findings show that students in the gamified learning environment demonstrated significantly higher engagement and improved academic performance than their peers in the traditional setting. Therefore, gamified learning environments should be integrated into the Curriculum and teachers' professional development programme.

**Keywords:** Gamification, Innovative Thinking, Learning Outcomes

**INTRODUCTION**

STEM (Science, Technology, Engineering, and Mathematics) Education is a unique approach to teaching that integrates science, technology, engineering, and mathematics as a unified whole. The crucial space that STEM education occupies in this era of technology innovation cannot be overemphasized. It is a very critical aspect of education that prepares students with the necessary skills to face the challenges of the modern-day world, where technological innovation and advancement are the order of the day, and at the same time instills in them the confidence needed to practice those skills. STEM education is highly needed by all students at all levels as it encourages innovative thinking, curiosity, gives room for collaboration among students, improves communication skills, as well as prepares students for career and adult life. It focuses on a hands-on and problem–based approach to teaching where students are actively involved and participate in the teaching and learning process, thereby making learning more flexible, fun, and interesting. However, many students at all levels find it difficult to comprehend some concepts in STEM. They either find them too difficult to comprehend or too abstract to master. Traditional teaching strategies coupled with poor laboratory facilities may hinder teachers’ ability to arouse and sustain students’ interest and engagement in the STEM classroom. This implies that teachers need to look for more strategies that can support students' learning and make them actively involved in the business of teaching and learning without compromising the output, which is an improvement in the learning outcomes. The key challenges facing modern education are often attributed to students’ lack of engagement and motivation to actively participate in the learning process (Minzi et al, 2023). There should be a way of leveraging motivation and engagement to improve the teaching and learning of STEM concepts. That is a strategy that makes students actively involved and at the same time have fun. One of the ways a teacher can achieve this is by having a gamified learning environment in which a teacher uses Gamification as a teaching and learning strategy.

Gamification in STEM education is adding a game element of software games into teaching and learning of STEM concepts to encourage students’ participation, increase student engagement and collaboration, and make the teaching and learning process more enjoyable and fun since people have a desire for competition and achievement. Gamification refers to using elements from games in non-gaming environments ( [Garland,](https://www.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2023.1253549/full#ref32) [2015](https://www.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2023.1253549/full#ref32)). The main goals of gamification are to enhance certain abilities, introduce objectives that give learning a purpose, engage students, optimize learning, support behavior change, and socialize ([Dichev](https://slejournal.springeropen.com/articles/10.1186/s40561-019-0098-x" \l "ref-CR7) [and Dicheva 2017](https://slejournal.springeropen.com/articles/10.1186/s40561-019-0098-x#ref-CR7)). It can be used at all levels of education, be it early childhood education, primary education, middle education, higher education, tertiary education, or adult education. Gamification can be designed and adapted to suit the needs of learners' developmental stage and educational level. It is a common fact nowadays that students and their handsets/ mobile phones are five and six. They often play games on their phone even while in class. It may be even better to incorporate elements of this game into teaching to further enhance learning and engagement. For this research work, the researcher used the tertiary education level, precisely the pre-service STEM teacher, with the assumption that if they are familiar with it during their training years, they will find it easy and convenient to use when practicing as a teacher. Gamification can be used online (where one needs to connect to a network) or offline (where you don’t have to connect to a network to play the game). Different types of games can be used in STEM Education. This includes: CodeCombat, Labster, Blockly Games, Tynker, Badges, Leaderboards, Points and Rewards, Quiz, Quests and Mission, Progress Tracking and Feedback, Storytelling and Narrative Elements, Simulation and Roleplaying, Puzzles and Escape room, etc. Teaching has gone beyond just standing in front of class and dishing out information; the best and efficient teacher needs to contemplate on how best to discharge his/her duties effectively with active participation and positive engagement of the students. Therefore, an instructional strategy that can fit in criteria and at the same that make teaching and learning a fun exercise is needed, which gamification is intended to do.

**STATEMENT OF THE PROBLEM**

Students’ mastery of STEM concepts and application of 21st-century skills has been an issue attracting the attention of researchers and STEM educators. This is crucial for the subject, most especially in this era of technological innovation and advancement. Students often find some concepts in STEM difficult to master and abstract. Teachers need strategies that a student-centered with active participation to teach them and make the class fun and educational. Most students dislike concepts like Heat and Temperature and other concepts for being mathematically oriented and abstract. As a result, teacher needs a strategy that can encourage critical thinking, build students’ motivation and confidence, improve their communication skills, promote collaboration and teamwork, and at the same time align with the 21st-century learning goals, which can be achieved with a gamified learning environment. Though previous researchers have worked on it but this laudable method does not translate to use by the classroom teachers, some of whom are not ready to change the classroom practice acquired during training. So if gamification is emphasized and used in training the Pre-service teachers, they will be familiar with it and find it convenient and easy to use when practicing. The study, therefore, determines the impact of gamification as a teaching strategy on pre-service teachers’ achievement in some concepts in STEM education. The study also investigates the moderating effect of gender and mode of entry of pre-service teachers into the university.

**LITERATURE REVIEW**

**Gamification in Science Education**

A game is a form of play undertaken for entertainment, education, competition, or other purposes. A game refers to a structured play with rules, goals, and challenges for entertainment (Cheng et al., 2015). It always involved rules, principles that govern the interaction among the players, whose participation is voluntary. Gamification is the application of strategic game mechanics to increase students’ engagement in a classroom setting. It is the use of game elements in a non-game situation. Game elements are, for example, levels, points, badges, leader boards, avatars, quests, social graphs, or certificates (Zainuddin et al., 2020). Gamification is a concept that has been with us from time immemorial. Recently, its application has been introduced and formally adopted into the educational setting.

**Theoretical Foundation of Gamification in Science Education**

Gamification in Science Education is rooted in the idea of integrating principles of game design and a gamified environment into teaching and learning of STEM concepts to create effective and impactful learning experiences. It is based on the constructivist approach to teaching and learning, where learning is viewed as an active process where students construct knowledge through experience and interaction with their environment. A gamified environment provides hands-on, innovative, problem-solving tasks where students can explore and discover science concepts. There are other theories, too, that can be linked to gamification since it has to do with motivation, interest, enjoyment, reward, incentives, etc. Self Determination Theory (SDT) (Deci & Ryan, 1985), Flow theory (Csikszentmihalyi, 1990), Behaviorism and Reinforcement theory (Skinner, 1957), Situated Learning theory (Lave & Wenger, 1991). Goal-setting theory (Locke & Latham, 2002) and Social Learning theory (Bandura, 1986) are all linked to Gamification.

**Gamification, Cognitive Development, and Learning Outcomes**

Gamification has emerged as a promising strategy that can be used to address challenges such as declining interest, commitment, attitude, and performance in STEM subjects. There is a need for interactive and innovative teaching methodologies that can promote active learning, which enhances cognitive development and knowledge retention. Several studies have shown that gamification can increase student engagement and learning outcomes.  Huang et al. (2020) found that gamification elements such as badges and leaderboards significantly increased students’ behavioral engagement in flipped learning environments. Also, Plass et al. (2015) found that gamified STEM lessons improved students' problem-solving and critical-thinking skills. Moreover, gamification facilitates experiential learning by allowing students to apply theoretical concepts in simulated environments, thus bridging the gap between abstract knowledge and practical application (Deterding et al., 2011). Similarly, Sánchez-Mena and Martí-Parreño (2017) reported that gamification led to higher levels of student participation and a more enjoyable learning experience in higher education settings. Gamification provides instant feedback to students on their performance in a given activity, thereby allowing them to monitor their progress.

**Research Objectives**

The specific objectives of the study are:

1. To examine the impact of gamification on pre-service teachers’ achievement in STEM concepts
2. To examine the impact of pre-service teachers’ mode of entry into the University on their achievement in STEM concepts
3. To examine the impact of pre-service teachers’ gender on their achievement in STEM concepts

**Research Questions**

The following research questions were answered in the course of this study:

1. What is the impact of gamification as a teaching strategy on pre-service teachers’ achievement in STEM concepts
2. Does the mode of entry of pre-service teachers into the university have an impact on their achievement in STEM concepts
3. Does the gender of pre-service teachers have an impact on their achievement in STEM concepts

**Research Hypotheses**

The following null hypotheses were tested in the course of this study at a 0.5 level of significance:

H01: There is no significant main impact of treatment on pre-service teachers’ achievement in STEM concepts

H02: There is no significant main impact of the Mode of entry on pre-service teachers’ achievement in STEM concepts

H03: There is no significant main impact of gender on pre-service teachers’ achievement in STEM concepts

**MATERIALS AND METHODS**

The pretest-posttest, control group, quasi-experimental research design was adopted for this study. The 200L pre-service teachers studying Integrated Science (Basic Science) at Nigeria University constitute the population of this study, out of which a sample was drawn. Two state universities were purposively selected based on their relative distance to each other. The universities were randomly assigned to the treatment and control groups. From the selected university, an intact class of 200L Integrated Science (Basic Science) was used for the study. The students offer six courses in their first semester, 200L, which include Physics for Basic Science II, which was chosen for this study because it contains some topics that are mathematical and abstract, and the students have done the prerequisite for it at the 100L.

Four instruments were used to collect the necessary data for this study. They are: Operational Guide for PBL Gamification Technique: This was used for teaching the experimental group. It was an instructional guide developed by the researcher based on the principle of incorporating game elements into the teaching of STEM concepts. It consists of two lessons, which are Heat Transfer and Heat Capacity. The Instructional guide was given to experienced lecturers in the department to determine its face and content validity. Operational Guide for Conventional Teaching Strategy: This guide consists of two lessons that were used to teach the control group. The guide was based on the normal routing in a STEM classroom. The Instructional guide was given to experienced lecturers in the department to determine its face and content validity. Pre-service Teachers’ Achievement Test in Integrated Science (Basic Science): This instrument tests the pre-service teachers’ intellectual achievement in Heat Transfer and Heat Capacity. The test contains forty multiple-choice objective test items in two sections. Section A contains demographic information about the student, while Section B contains the multiple-choice test items. The reliability of the test item was determined using Kuder-Richardson formula 20 (KR-20). The KR-20 value of 0.85 was obtained. Pre-service Teachers’ Attitudinal Questionnaires on the Use of Gamification in STEM Education. Data collected were analysed using descriptive statistics (Mean and Standard Deviation) and inferential statistics (ANOVA).

**RESULT AND DISCUSSION**

**Table 1: Distribution of respondents based on Group.**

|  |  |  |
| --- | --- | --- |
| **Group** | **Frequency** | **Percentage (%)** |
| Control | 20 | 54.1 |
| Experimental | 17 | 45.9 |
| Total | 37 | 100 |

Figure 1 Pie chart showing distribution of respondents based on Group

As shown in **Table 1**, the respondents were divided into two groups: the control group and the experimental group. The control group comprised 20 participants, accounting for 54.1% of the total sample, while the experimental group consisted of 17 participants, representing 45.9%. This distribution demonstrates a near-even allocation of participants between the groups, ensuring a balanced comparison for the study.

**Table 2: Distribution of respondents based on Gender.**

|  |  |  |
| --- | --- | --- |
| **Group** | **Frequency** | **Percentage (%)** |
| Male | 08 | 21.6 |
| Female | 29 | 78.4 |
| Total | 37 | 100 |

Figure 2 Pie chart showing distribution based on Gender

As illustrated in **Table 2**, the respondents were predominantly female, with 29 participants (78.4%), compared to only 8 male participants (21.6%). This significant gender disparity highlights the predominance of females in the study sample, reflecting either a general trend in enrollment in science education courses or specific demographic characteristics of the institutions sampled.

**Table 3: Distribution of respondents based on Mode of Entry.**

|  |  |  |
| --- | --- | --- |
| **Group** | **Frequency** | **Percentage (%)** |
| JAMB | 31 | 83.8 |
| Direct Entry | 06 | 16.2 |
| Total | 37 | 100 |

Figure 3 Pie chart showing distribution based on Mode of Entry

As shown in **Table 3**, the majority of respondents (83.8%) gained admission through the Joint Admissions and Matriculation Board (JAMB), while a smaller proportion (16.2%) entered via direct entry. This distribution suggests that JAMB remains the predominant mode of entry into the University included in the study.

**Research Questions**

**Research Question 1: What is the impact of gamification as a teaching strategy on pre-service teachers’ achievement in STEM concepts**

**Table 4: The impact of gamification as a teaching strategy on pre-service teachers’ achievement in STEM concepts**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | **Pre-test** | | **Post-test** | |  |
| **Treatment** | **N** | **Mean** | **SD** | **Mean** | **SD** | **Mean Gain** |
| Control | 20 | 57.65 | 4.26 | 77.94 | 4.44 | 20.29 |
| Experimental | 17 | 61.47 | 5.83 | 85.72 | 3.27 | 24.25 |

The experimental group outperformed the control group in terms of mean gain (24.25 vs. 20.29), suggesting that gamification had a positive impact on students' achievement in STEM concepts. The higher mean scores and lower post-test standard deviation (SD = 3.27) in the experimental group indicate a more consistent improvement compared to the control group. These findings support the effectiveness of gamification as a teaching strategy in enhancing pre-service teachers’ understanding of STEM concepts. The strategy not only improved their overall achievement but also led to a more uniform performance within the group.

**Research Question 2: Does the mode of entry of pre-service teachers into the university have an impact on their achievement in STEM concepts**

**Table 5: The mode of entry of pre-service teachers into the university has an impact on their achievement in STEM concepts**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | **Pre-interest** | | **Post-interest** | |  |
| **Treatment** | **N** | **Mean** | **SD** | **Mean** | **SD** | **Mean Gain** |
| Jamb | 31 | 58.22 | 3.42 | 77.00 | 3.85 | 18.78 |
| Direct Entry | 06 | 58.47 | 3.51 | 87.15 | 3.57 | 28.68 |

The findings suggest that both groups improved significantly after the intervention. However, Direct Entry students achieved a higher mean gain (28.68) compared to JAMB students (18.78). This disparity might reflect differences in prior educational experiences or readiness for the STEM concepts covered in the study. The data indicate that pre-service teachers' mode of entry into the university may influence their performance in STEM concepts. Direct Entry students' higher mean gain could suggest that their advanced academic background or work experience better prepared them for the intervention.

**Research Question 3: Does the gender of pre-service teachers have an impact on their achievement in STEM concepts**

**Table 6: Gender of pre-service teachers’ impact on their achievement in STEM concepts**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | **Pre-test** | | **Post-test** | |  |
| **Treatment** | **N** | **Mean** | **SD** | **Mean** | **SD** | **Mean Gain** |
| Male | 08 | 59.61 | 5.95 | 76.61 | 3.72 | 17.00 |
| Female | 29 | 59.78 | 4.87 | 76.93 | 4.36 | 17.15 |

Both male and female pre-service teachers showed similar levels of improvement after the intervention, with mean gains of 17.00 for males and 17.15 for females. The negligible difference in mean gains suggests that gender had minimal impact on the effectiveness of the teaching strategy. This indicates that the intervention was equally effective for both genders in improving achievement in STEM concepts. The results highlight the gender-neutral nature of the teaching strategy, suggesting its broad applicability across diverse groups. This finding supports the idea that gamification or other interactive teaching strategies can bridge potential gender gaps in STEM education.

**Research Hypotheses**

**The table answered research hypotheses 1 to 3 using Analysis of Covariance (ANCOVA)**

H01: There is no significant main impact of treatment on pre-service teachers’ achievement in STEM concepts

H02: There is no significant main impact of the mode of entry on pre-service teachers’ achievement in STEM concepts

H03: There is no significant main impact of gender on pre-service teachers’ achievement in STEM concepts

**Table 7:** **Analysis of Covariance (ANCOVA) for the Test of Significance of Three Effects: Treatment, Gender, and Mode of Entry on Pre-Service Teachers' Achievement in STEM Concept**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Source | Type III Sum of Squares | Df | Mean Square | F | Sig. |
| Corrected Model | 518.805a | 6 | 86.468 | 9.607 | .000 |
| Intercept | 165.448 | 1 | 165.448 | 18.383 | .000 |
| Pre | 174.240 | 1 | 174.240 | 19.360 | .000 |
| Group | 38.897 | 1 | 38.897 | 4.322 | .046 |
| Gender | 12.926 | 1 | 12.926 | 1.436 | .240 |
| Mode | 43.413 | 1 | 43.413 | 4.824 | .036 |
| Error | 270.006 | 30 | 9.000 |  |  |
| Total | 12455.000 | 37 |  |  |  |
| Corrected Total | 788.811 | 36 |  |  |  |
|  |  |  |  |  |  |
| a. R Squared = .658 (Adjusted R Squared = .589) | | | | | |

Pre-test scores had a significant effect on post-test achievement (*F*(1, 30) = 19.360, *p* < .001). This indicates that students' prior knowledge significantly influenced their post-test performance. The effect of treatment (group) was statistically significant (*F*(1, 30) = 4.322, *p* = .046), suggesting that the intervention (gamification) had a measurable impact on post-test achievement. This finding supports the hypothesis that gamification is an effective teaching strategy for improving STEM concept achievement.

The effect of gender was not statistically significant (*F*(1, 30) = 1.436, *p* = .240). This suggests that gender did not significantly influence post-test achievement, aligning with earlier findings (Table 6) that both male and female students benefited similarly from the intervention.

The effect of mode of entry was statistically significant (*F*(1, 30) = 4.824, *p* = .036). This indicates that students’ mode of entry into the university (JAMB or direct entry) had a significant influence on their post-test achievement. Direct entry students, who had higher mean gains in earlier analyses (Table 5), may have contributed to this result.

The findings highlight the significant impact of the teaching strategy (gamification) and mode of entry on students' achievement, while gender did not play a significant role. The strong contribution of pre-test scores underscores the importance of prior knowledge in predicting academic success.

**Discussion**

The demographic distribution of respondents, as presented in Tables 1–3, provides a foundational understanding of the study sample. Most of the participants (54.1%) were in the control group, and 45.9% were in the experimental group (Table 1). Regarding gender, the sample was predominantly female (78.4%) (Table 2), which aligns with studies such as Mouna(2021), Kazeem and Adetunji (2022), who observed that game elements and feedback often attract more female students. Additionally, the mode of entry was dominated by JAMB entrants (83.8%) compared to direct entry students (16.2%) (Table 3). This reflects broader trends in tertiary education access, as highlighted by Okebukola (2021), who noted that JAMB remains the most common pathway for students entering university.

Gamification significantly improved pre-service teachers’ achievement in STEM concepts, as evidenced by the greater mean gain in the experimental group (24.25) compared to the control group (20.29). This finding corroborates the results of Rahimi et al (2021), who emphasized that gamification enhances engagement and learning outcomes by fostering intrinsic motivation. Furthermore, Deci’s and Ryan's (2020) self-determination theory explains these results by suggesting that gamified environments fulfill learners' psychological needs for competence and autonomy, thereby boosting performance. This finding aligns with Salami (2021), Aina and Olaniyan (2023), who argued that direct entry students often bring prior academic or professional experiences that enhance their learning outcomes. Additionally, Obielodan et al. (2022) posited that diverse educational backgrounds provide direct entry students with broader perspectives, enabling them to excel in complex STEM concepts.

Minimal differences in mean gains between male (17.00) and female (17.15) respondents, indicating that gender had little impact on achievement. This result aligns with UNESCO (2023), which highlights those well-designed instructional strategies, such as gamification, tend to neutralize gender disparities in STEM education. Similarly, Jones and Okon (2020), Oguru and Amie-Ogan (2024) argued that interactive and inclusive teaching approaches can eliminate traditional gender biases in STEM performance.

The ANCOVA results in Table 7 provide a detailed understanding of the significance of various factors on pre-service teachers’ achievement in STEM concepts. The significant effect of treatment (*p* = .046) supports the effectiveness of gamification as a teaching strategy. This aligns with Cheng et al. (2023), who found that gamification positively influences cognitive and affective learning outcomes. The non-significant effect of gender (*p* = .240) further reinforces the inclusivity of gamification, consistent with findings from Zhao et al (2021), and the significant effect of mode of entry (*p* = .036) echoes earlier discussions, underscoring the role of prior academic preparation, as suggested by Cheng et al. (2023), Afolabi and Ajayi (2023). The overall model explained 65.8% of the variance in achievement, demonstrating the robustness of the predictors. This aligns with Alyahyan and Düştegör (2020), Bada and Oladipo (2022), who emphasized the importance of instructional methods and student background in predicting academic success

**CONCLUSION**

The findings revealed that gamification significantly improved learning outcomes, with the experimental group achieving higher mean gains compared to the control group. Gender had no significant effect, demonstrating the inclusivity of gamification, while mode of entry significantly influenced achievement, favoring direct entry students. These results underscore the effectiveness of gamified learning environments in enhancing engagement and performance across diverse student groups. The study highlights the potential of gamification to bridge educational gaps and foster equitable learning outcomes in STEM education. By leveraging this technologically inclined innovative teaching strategy, STEM Teachers can create a dynamic, student-friendly learning environment that caters for the needs of all students and create a long-lasting interest in the STEM discipline in them.

Based on the above findings, the following recommendations were made to the students, STEM teachers, Schools, Policy makers, and all stakeholders in the teaching and learning process:

Gamification and a Gamified learning environment should be incorporated into STEM teaching to foster an active and innovative teaching and learning process.

STEM teachers should design their lessons in such a way that the lesson objectives are spelled out to link gamified elements directly to the desired learning outcomes.

Gamification as a teaching and learning strategy should be included in the pre-service teachers’ curriculum so that they can be familiar with the strategy and find it convenient and comfortable to use when practicing as a teacher.

Gamification and gamified activities should be included in the in-service program activities for the In-service STEM teachers. Such activities should also include the use of digital tools to enhance STEM teaching.

STEM students should be encouraged to use gamification in the learning of STEM concepts to promote teamwork as well as improve their social and communication skills.

Government, School owners, and administrators should provide students’ student-friendly gamified environment for STEM teaching with adequate technological resources, tools, and devices, teaching and learning to cater for students from diverse backgrounds and skill levels.

With all these, the power of gamification can be used to turn around and revolutionize STEM education by producing a new generation of critical thinkers, problem solvers, and creators of innovative ideas.

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