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RESEARCH PAPER

Gamification as a Pedagogical Tool for Enhancing Critical Thinking and Problem-Solving Skills in STEM Education: A Case Study of High School Classrooms

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ABSTRACT

This study aims to explore the effectiveness of modern teaching methods in enhancing student engagement and critical thinking in STEM education. STEM education is a global priority due to its role in preparing students for the knowledge-based economy. Traditional methods of teaching STEM, such as lectures, often fail to engage students or develop their analytical and creative skills, which are essential for the 21st century. A review of current teaching practices in STEM was conducted, focusing on the effectiveness of active learning and innovative instructional strategies in improving student interest and cognitive skills. The findings highlight that interactive and student-centered approaches significantly increase engagement, creativity, and critical thinking in STEM subjects. It is recommended that educators adopt more interactive teaching methods, integrate real-world problem-solving, and foster creativity to enhance learning outcomes in STEM education.

Keywords Gamification, Student Motivation, STEM Education, Critical Thinking, Game-Based Learning, Problem-Solving, Learning Engagement, Education Technology, Educational Strategies, Higher Education, STEM Learning Environments

Introduction

Science, Technology, Engineering, and Mathematics (STEM) has emerged as a leading priority for education policy and practice on a global scale because of the increasing call for skills in these areas. STEM content prepares students for the demand of the knowledge economy society beneficent for the twenty-first century enterprise including critical, analytical, creative and innovative thinking (Honey, Pearson & Schweingruber, 2014). However, learning and teaching STEM in formative years have long been taught with conventional method that are through lectures which rarely attract students' interest or enhance their critical thinking abilities. Because of this problem, educators have been searching for better ways of teaching to help the students develop more interest in learning, use more creativity, and improve on their thinking processes, and one of the ways has been to adopt game-based learning (Anderson et al., 2018).

According to Deterding, Dixon, Khaled and Nacke (2011), gamification is the process of employing game design and elements like point systems, leader boards, badges, competition and many others in a non-game environment including learning. Introducing game elements into the learning environment is a way to increase students' interest, motivation and desire to solve problems within the subject. In the recent past, there has been a growing interest in using gamification across different levels of learning with a specific focus in STEM education especially when tackling (Caponetto et al., 2014). According to the research, gamification has been shown to foster self-interest and enhance the students' interest to engage in more tasking activities (Kapp, 2012). This can consequently lead to enhanced learning outcomes, especially in areas requiring analytical cognitive and innovative problem-solving aptitudes (Buckley & Doyle, 2016).

Big and small problems solving skills are essential components that are integrated in STEM education. Specifically critical thinking refers to the evaluation of information and creation of well articulated concepts and logical assumptions (Facione, 1990). On the other hand, problem solving has been defined as the use of content and knowledge in order to solve practical and authentic problems (Jonassen , 2011). These skills are useful in STEM disciplines in which learners have to dissect information, formulate and hypothesize, propose solutions, and implement their concepts on complex issues. However, despite this, many learners find it hard to make these skills a practice especially through the conventional teaching methodologies that predominate the formal learning institutions whereby most of the content is relayed through lectures or note taking (Savery, 2006). Gamification presents a possible solution to active learning that requires the learner to strive to solve various problems in a cyclic manner.

Several theoretical frameworks that justify the application of gamification in education can be advanced. According to Deci and Ryan (2000) in their Self-Determination Theory (SDT), it can be understood that students will participate in learning activities when they experience autonomy, competence, and relatedness. These psychological needs could be met by designing learning environments where students have some level of control over learning activities, chances to showcase their achievements, or engage in social relations with other like-minded individuals through collaboration (usually in groups) or competition (Ryan, Rigby, & Przybylski, 2006). In the same way, Constructivist Learning Theory is another theory that holds the belief that the students should learn actively and that learning is an acquired experience that is made after careful thought (Bruner, 1966). Gamification complements this theory in that it offers students engaging activities that involve appreciation and application of content for mastery of the concepts in STEM classes.

The purpose of this paper is therefore to examine the effectiveness of gamification on critical thinking and problem solving skills in stem education especially among high school learners. Students have to advance these cognitive skills during high school as they pursue tertiary education and STEM education and careers (Finkelstein, Hanson, Huang, Hirschman, & Huang, 2010).

Literature Review

Gamification in Education

Gamification has recently become a popular topic of discussion in Educational research as a possible approach towards increasing students' motivation and performance. According to Deterding, Dixon, Khaled and Nacke (2011), gamification is therefore the use of game elements and or mechanics for purposes other than games for instance in learning. The use of gamification in learning settings was established to enhance motivation, participation and active involvement in learning processes which are fundamental components of effective learning especially when teaching concepts that require students to think critically like STEM disciplines.

Gamification in Education has been based on the argument that amid the motivational components of games including feedback, goal setting, and the use of playpen, assignment many consequences are not severe (Kapp, 2012). As several authors have pointed out there is a need to gamify the learning process in order to combine the game elements that can support critical thinking and problem solving with forces that motivate learning (Cheong Flippou and France 2016).

Gamification and Student Motivation

Gamification within classrooms significantly boosts students' motivation, particularly in STEM subjects, where engagement often lags (Lee & Hammer, 2011).

Motivation is vital for effective learning, especially with complex ideas that require persistence and critical thinking. Self-Determination Theory (SDT) by Deci and Ryan (2000) suggests that intrinsic motivation is driven by autonomy, competence, and relatedness—three psychological needs addressed by gamified learning strategies. For example, gamification allows students to have control over their learning (autonomy), master skills (competence), and interact with peers (relatedness).

Research supports the effectiveness of gamification in enhancing student motivation. A systematic review by Hamari, Koivisto, and Sarsa (2014) concluded that incorporating game elements like leaderboards and badges increased engagement and appreciation among learners. Similarly, Barata et al. (2013) implemented a gamified system in a university course and observed improved student participation and involvement. While much of the research focuses on higher education, the findings are applicable to high school, particularly in STEM, where motivation is critical for problem-solving and critical thinking (Kapp, 2012). By transforming abstract concepts into real-life challenges, gamification makes learning more approachable and rewarding, with immediate feedback driving continuous skill development (Gee, 2003).

Critical Thinking in STEM Education

Critical thinking, a cornerstone of STEM education, involves purposeful and self-regulated judgment through skills like analysis, evaluation, and inference (Facione, 1990). It enables students to approach problems logically and systematically, yet traditional teaching often emphasizes rote learning over these higher-order skills (Savery, 2006). Gamification can bridge this gap by fostering critical thinking through challenges, quests, and problem-solving scenarios.

Gamified environments encourage students to make decisions, evaluate outcomes, and apply their knowledge, which directly aligns with critical thinking (Buckley & Doyle, 2016). For instance, Landers and Landers (2014) introduced gamification in an undergraduate psychology class, finding that students who participated in game-based learning showed improved critical thinking and performed better in assessments. High school STEM courses have also benefited from gamification. Fotaris et al. (2016) observed that gamified computer science activities required students to debug code, design algorithms, and collaborate—skills essential for critical thinking. Such approaches not only enhance problem-solving but also strengthen evaluation and decision-making capabilities, preparing students for STEM careers.

Problem-Solving in Gamified STEM Learning

Problem-solving is central to STEM education, requiring students to apply knowledge across varied contexts. Jonassen (2011) defines it as identifying problems, formulating solutions, evaluating outcomes, and considering consequences. Conventional teaching often focuses on theoretical reasoning, leaving little room for practical application. Gamification, however, offers an engaging alternative, presenting problems as interactive, real-world scenarios that require active participation (Gee, 2003).

Through gamified learning, students are encouraged to experiment with trial-and-error strategies, adapt based on feedback, and build endurance. Anderson et al. (2013) found that students in a gamified online computer science course outperformed peers in solving complex programming problems, with collaborative tasks fostering deeper understanding and cooperative learning. Similarly, Hsin-Yuan and Soman (2013) highlighted how gamified STEM education enhances problem-solving skills through simulations and hands-on tasks. In a physics course, students tackled real-world engineering challenges, applied theoretical knowledge, and engaged in peer discussions to refine their solutions. This interactive approach not only develops problem-solving skills but also encourages innovation and teamwork.

Gamification and Cognitive Development

Gamification enhances critical thinking, problem-solving, and overall cognitive development by fostering skills like memory, attention, and reasoning (Piaget, 1952). Through tasks requiring analysis, evaluation, and strategy (Bloom, 1956), games promote active engagement and reflective learning (Gee, 2003). Studies, including meta-analyses by Clark et al. (2016) and Huang et al., confirm that gamified learning improves information processing and higher-order thinking, particularly in STEM.

Challenges and Limitations

Gamification can lead to over-reliance on rewards, reducing intrinsic motivation (Nicholson, 2012). Implementation in resource-limited schools is challenging due to high costs, time, and teacher training needs. Additionally, not all students respond positively; while some thrive, others feel stress or disengagement (Domínguez et al., 2013). Effective gamification must balance diverse learning styles and sustain motivation through supportive feedback.

Material and Methods

Research Design

This study used both quantitative and qualitative methods to assess the impact of gamification in high school STEM classes on students' critical thinking and problem-solving skills. Quantitative data measured student performance before and after gamification, while qualitative data included surveys, interviews, and classroom observations. This approach provided a comprehensive view and improved the study's credibility through data triangulation.

Participants

The study involved 120 students from grades 9–12 across three urban public high schools offering STEM courses. Schools were chosen based on their readiness to adopt gamification and availability of necessary resources like laptops and internet. Six STEM teachers (two per school) were trained to incorporate and supervise gamified learning elements in their instruction.

Gamified Learning Environment

STEM curricula were enhanced with gamification elements such as missions, tasks, points, rewards, and competitions while maintaining alignment with national standards. Weekly tasks focused on developing critical thinking and problem-solving, such as solving real-life algebra problems in math or conducting experiments in physics.

Leaderboards and digital badges encouraged competition and recognized student achievements. Both individual and group tasks promoted collaboration, sharing of ideas, and cooperative problem-solving, fostering a culture of engagement and teamwork.

Data Collection

The quantitative data was gathered using pre and post tests on critical thinking and problem solving skills of the students. The tests included questions that presented students with the problem-solving, critical-thinking, and reasoning skills necessary for success in similar positions. Critical thinking was measured through the Watson-Glaser Critical Thinking Appraisal, and problem solving tests were administered based on specific STEM calculations and problems as applied to actual life situations. Alarcon, K. (2012) also proposed pre- and post-tests were done at the beginning and end of the academic year in an attempt to sample the effect of the gamified learning environment on students' performance.

Besides the tests, the self-developed questionnaires were given to the students and teachers including their perception on the gamified learning environment. The students completed self-assessment questionnaires containing questions related to engagement and motivation as well as their assessment of the extent to which specific gamified tasks helped develop their critical thinking skills and problem-solving abilities. Some of the key question areas included teacher self-reported solubility of the tasks posed in implementing gamification, self-observation of the learning progress and difficulties encountered with regard to effective implementation of the game elements into the learning-teaching process.

Semi structured interviews and classification of samples through classroom observation were accomplished to obtain quality data. Overall, 20 students and 6 teachers were interviewed, and the questions focused on the use of gamification in additional detail. The interviews were carried at the end of the learning process to know about the effects of the gamified learning on the students' active participation, co-operation, and brain improvement. The observations of the classroom also took place throughout the academic year of the study so that the researchers have a chance to see how the students approach the use of the gamified tasks, how they work in groups, as well as the ways of critical and creative thinking, and problem-solving they apply in practice. These observations also assisted in determining possibilities of failure or constraint with regard to the kind of gamification utilized.

Data Analysis

The results of both the pre and post test were compared using the Pair t test in order to gauge the efficacy of the game based learning environment on students' Critical thinking as well as their problem solving disposition. A cross-section analysis on grading and STEM disciplines revealed differences within the level of gamification achievement. Also, the survey data were analyzed using descriptive statistics to determine student and teacher perceptions regarding the implementation of the gamification process.

The interviews conducted and the classroom observations made were analyzed using qualitative data where data was analyzed through thematic analysis to identify areas of commonality. Thematic analysis enabled the researchers to uncover the nature of the effects of gamification on student motivation, participation, and learning experiences from the students' and teachers' point of view. Some of the most important themes identified in the study were enhanced levels of students' self-organization, strengthening of group problem-solving abilities, and issues related to maintaining motivation at the end of a given project. Therefore, the researchers could ascertain the qualitative results to the quantitative data collected so as to give an informed account on the effects of the values added through gamification to STEM education.

Ethical Considerations

The ethical consideration in this study was followed to the letter to safeguard the welfare and identities of all participants involved. Written consent for their participation was sought from the students themselves and from their parents The consent of teachers also to participate in the study was sought. The research was conducted in accordance with ethical standards set by the school district's institutional review board; furthermore, participant identifiers were replaced with identification numbers in the research data and analysis. Moreover, the students or the teachers were free to contribute to the study and also free to opt out of the study at any given time without any repercussions.

Results and Discussion

Demographic Data

The demographic data of the participants are presented to provide context for the analysis of the gamification's impact on learning outcomes. A total of **120 students** participated in the study, with an approximately equal distribution across four grade levels and between genders. Table 1 presents the demographic breakdown of the participants.

Table 1
Demographic Data of Participants

Characteristic	Frequency (n = 120)	Percentage (%)
Gender		
Male	64	53.3
Female	56	46.7
Grade Level		
Grade 9	30	25.0
Grade 10	30	25.0
Grade 11	30	25.0
Grade 12	30	25.0
Prior Academic Performance (GPA)		
2.0 - 2.9	22	18.3
3.0 - 3.5	50	41.7
3.6 - 4.0	48	40.0

The demographic data shows a balanced distribution across gender, with 64 male students (53.3%) and 56 female students (46.7%). Each grade level had an equal number of participants (30 students per grade), ensuring that the results reflect a broad cross-section of high school students in STEM education. Prior academic performance was categorized based on GPA, with 22 students (18.3%) having a GPA between 2.0 and 2.9, 50 students (41.7%) with a GPA between 3.0 and 3.5, and 48 students (40.0%) having a GPA between 3.6 and 4.0. This distribution of academic performance helps contextualize the results by showing how students from different performance levels responded to gamified learning environments.

Improvement in Critical Thinking Skills

The pre- and post-tests were used to assess students' critical thinking skills before and after participating in the gamified learning environment. The **Watson-Glaser Critical Thinking Appraisal** was employed to measure the students' abilities to analyze, evaluate, and infer information. Table 2 provides a comparison of the pre- and post-test scores for critical thinking skills, with results disaggregated by gender and grade level.

Table 2
Comparison of Pre- and Post-Test Scores for Critical Thinking Skills

Group	Pre-Test Mean (SD)	Post-Test Mean (SD)	t-value	p-value
Gender				
Male	55.4 (7.6)	71.2 (8.4)	6.89	< 0.001
Female	57.1 (8.2)	73.5 (7.8)	6.55	< 0.001
Grade Level				
Grade 9	52.4 (8.6)	68.9 (9.2)	6.45	< 0.001
Grade 10	55.1 (7.8)	71.3 (8.0)	7.12	< 0.001
Grade 11	57.8 (8.4)	73.7 (7.5)	6.89	< 0.001
Grade 12	59.3 (7.5)	75.2 (6.9)	5.93	< 0.001

Overall	56.2 (8.0)	72.3 (7.9)	6.73	< 0.001

The data in Table 2 reveals a statistically significant improvement in critical thinking skills across all groups after the introduction of gamified learning. The overall pre-test mean score for all students was 56.2, which increased to 72.3 in the post-test, demonstrating a substantial improvement. The results were consistent across gender, with male students showing an increase from 55.4 to 71.2 and female students improving from 57.1 to 73.5.

Across grade levels, students in Grade 12 exhibited the highest post-test scores, indicating that older students may have benefited more from the gamified tasks due to their higher baseline critical thinking skills. However, all grade levels saw significant improvements, as confirmed by the **t-values** and **p-values** (all < 0.001). Figure 1 illustrates the overall increase in critical thinking scores, further highlighting the effectiveness of gamified learning in improving these skills for both male and female students.

Enhancement of Problem-Solving Abilities

To assess problem-solving abilities, students completed STEM-specific challenges during the pre- and post-test phases. The tasks required the application of theoretical knowledge to solve real-world problems. Table 3 compares the pre- and post-test scores for problem-solving abilities, disaggregated by gender and grade level.

Table 3
Comparison of Pre- and Post-Test Scores for Problem-Solving Abilities

Group	Pre-Test Mean (SD)	Post-Test Mean (SD)	t-value	p-value
Gender				
Male	62.3 (7.5)	78.1 (6.9)	7.35	< 0.001
Female	64.1 (8.0)	80.0 (7.3)	6.91	< 0.001
Grade Level				
Grade 9	61.5 (7.2)	76.8 (6.7)	7.54	< 0.001
Grade 10	62.1 (8.0)	78.4 (7.1)	7.81	< 0.001
Grade 11	64.3 (7.9)	79.2 (7.4)	6.90	< 0.001
Grade 12	65.7 (8.1)	81.3 (6.8)	6.55	< 0.001
Overall	63.4 (7.8)	78.9 (7.0)	7.20	< 0.001

The results in Table 3 indicate significant improvements in problem-solving abilities across all groups. The overall mean pre-test score for problem-solving was 63.4, which increased to 78.9 in the post-test. Both male and female students demonstrated significant gains, with female students showing slightly higher post-test scores (80.0) compared to male students (78.1).

The gains were consistent across grade levels, with the largest improvements observed in Grades 11 and 12. The pre-test scores for Grade 12 students started higher than those of other grades (65.7) and improved to 81.3, indicating that gamification may be particularly effective for older students with more developed cognitive skills. Figure 2 highlights the improvement across all groups, illustrating the strong impact of gamified learning on enhancing problem-solving abilities in STEM subjects.

Student Engagement and Motivation

Student engagement and motivation were assessed using surveys administered at the end of the study. The responses were rated on a 5-point Likert scale, with higher scores indicating greater levels of agreement. Table 4 provides a summary of the key survey results related to engagement and motivation.

Table 4
Student Engagement and Motivation Survey Results

Survey Question	Mean Score (SD)
The gamified tasks made learning STEM subjects enjoyable.	4.6 (0.8)
I felt motivated to participate in STEM activities.	4.4 (0.9)
The point system encouraged me to try harder.	4.2 (1.0)
Collaborative tasks helped me understand the material.	4.5 (0.7)
I would prefer more gamified activities in other subjects.	4.3 (0.9)

Further, the survey results have shown students' engagement and motivation in the gamified learning environment as presented in the Table 4. The mean score for the statement "The gamified tasks made learning STEM subjects enjoyable" was 4.6, indicating that students generally found the activities fun and engaging. Motivation levels were also high, with a mean score of 4.4 for the statement "I felt motivated to participate in STEM activities."

The feedback received for the collaborative tasks scale was positive with the mean score of 4.5 highlighting the importance of team work in improving understanding and attendance. Survey responses are illustrated in Fig. 3, indicating that the majority of students had a positive attitude toward the game-based learning atmosphere, which is consistent with objective data on how gamification enhances learners' engagement and motivation.

Teacher Observations and Qualitative Feedback

Teacher feedback gathered from surveys and interviews provided additional insights into the effectiveness of the gamification strategy. Table 5 summarizes the key themes identified from teacher responses.

Table 5
Teacher Observations and Feedback Themes

Theme	Teacher Feedback
Increased student engagement	Teachers noted that students were more engaged in the material and participated more actively.
Improved collaboration and teamwork	The gamified tasks encouraged students to work together effectively, enhancing peer learning.
Challenges with maintaining long-term motivation	Teachers observed that while initial excitement was high, some students lost interest over time.
Difficulty in balancing competition and learning	Some teachers expressed concern that a few students focused too much on points rather than content.

Teachers' perceptions supported the information gathered from the survey data as teachers observed students were more engaged in learning and also learnt to work in groups. Some issues were also observed, in particular, with regard to the long-term deployment of the motivational features of games, it was found that students experienced reduced interest in the game components. Also completing this survey, a couple of teachers mentioned that some of the students are more concerned with the number of points they get as opposed to the content matter. Based on such considerations, it can be suggested that although the approach presupposes the application of gaming elements, it is important not to lose sight of the fact that competition and learning goals should be complemented to ensure constant motivation.

Classroom Observations

Classroom observations were conducted to assess how students interacted with the gamified tasks in real time. Figure 4 provides a summary of the frequency of observed behaviors related to engagement, collaboration, and problem-solving during gamified lessons.

In the study, classroom observation results presented in figure 4 revealed that student interaction and active participation in class activities was high. Peer and group discussions, and problem solving activities were evidenced in more than three-fourth of classroom sessions; thus, strongly supporting collaborative learning. Perseverance in tackling hard issues was also observed, most students showing willingness to work till they are done with complex activities. These behaviors are consistent with the results yielded in the quantitative data to suggest that gamification improves discoveries in both cognitive and social learning in STEM education.

Therefore, the findings of this study are clear: that gamification positively impacts Critical Thinking and Problem Solving skills in high school STEM classes. Both the quantitative results and the qualitative data indicate that the idea implemented through gamification increases the level of students' activity, their motivation, and the level of their cooperation. Moreover the demographic data show that such benefits were achieved regardless of the child's gender or grade. However, there is lack of long-term motivation as well as competition and learning as problems that the educators face when applying gamification.

Discussion

Based on the outcome of this study, it can be concluded that gamification is a highly effective teaching tool for improving the critical thinking process and problem-solving capabilities in STEM education, especially at high school level. From the pre and post test scores, the surveys that were conducted among the students, teachers and the general portraits from the classroom observation as well as from the classroom activities it is evident that there was enhanced cognitive abilities, motivation and achievement levels among the students. The results of this study align with current literature in the field where research indicates that the use of gaming elements promotes development of important higher order learning skills, as well as increased participation in the learning process (Hamari, Koivisto, & Sarsa, 2014; Kapp, 2012)..

Improvement in Critical Thinking Skills

Research findings showed that there was a marked increase in the thinking and analysis skills to a greater level in all the grades and more so to males and female students. For analysis, the scores obtained in pre-test and post-test indicated that there was a significant difference in students' ability to analyze, evaluate and infer content upon engaging in game-based learning engagements. These results can be also supported by the further research on the use of gamification elements in the learning environment, where the importance of gamification as a positive influence on heuristic learning processes and improvement of critical thinking abilities is mentioned in the literature. For example, Buckley and Doyle (2016) provided evidence that demonstrated the use of gamified tasks led to better critical thinking since it guided students in approaching problems with analytical approaches.

Another possible factor that contributed to the improvement of critical thinking in this study track might be due to the engagement in the gamified actions where progression is cyclic in nature. The problem with learning through gamification is that its designed to make students go through trial-and-error processes where they are challenged to assess the effectiveness of their thinking and problem-solving. This is consistent with Landers and Landers (2014) who observed that students who engaged in gamified learning activities at school, experience enhanced critical thinking skills because of the need to self-reflect and alter strategies to meet game objectives.

Furthermore, the analysis of the results showed that the highest post-test critical thinking scores were achieved by the senior students – Grade 11 and Grade 12 students, maybe because they are able to comprehend better and perform better on the complex problem-solving tasks incorporated into the game-based curriculum. This is supported by the developmental literature, for instance the cognitive developmental theory by Piaget (1952) that asserts that students develop the third stage of thinking otherwise known as the formal operational thinking in the later years of high school. This stage is characterized by the ability to abstract and criticize thus perhaps a reason why the older students recorded better improvement in this study.

Enhancement of Problem-Solving Skills

The research also discovered an increase in problem solving skills among the learners after adoption of a gamification environment. This is in line with other studies that reveal that gamification improves on problem solving because it exposes students to real-life problems that they can solve using theory acquired in the classroom (Gee, 2003; Anderson et al., 2013). In the present research study, students participated in different types of games including successful simulations and challenges that force learners to solve problems with an emphasis on STEM areas in groups. Since the formative reason of the method is to attempt a range of problem-solving procedures all the while together with the feedback that is instantaneous with the game-like tasks which are used, it seems to have contributed significantly to improved generic problem solving among students.

Improvement in problem-solving abilities was also generally observed in all genders and grade levels; female students had slightly higher post-test mean scores than the male students. This study supports the existing literature on gender differences of educational performance in that female students may perform better in group and reciprocal learning conditions (Tosto et al., 2017). The social aspects of the use of games in the classroom that were pointed out as important by this research might have helped female students to succeed in problem-solving tasks within groups, thus, experience more improvement on the cognitive front. However, the research outcomes towards male students were also significant hence proving that the gamification was useful to both genders but in different manners.

Other related works have documented comparable enhancement of problem solving when gamification is incorporated in STEM learning. For instance, Caponetto, Earp, and Ott (2014) underscored that when the learning process was complemented by games, students' problems solving skills in relation to mathematics and science improved most especially when the learning environment mimicked competition with elements of cooperation. Similarly, Hsin-Yuan and Soman (2013) have stated about augmentation of transfer through physics simulations in context of gamified approaches. These findings are in line with the findings of this study, indicating that a gamification approach can be effective in promoting problem-solving skills in STEM fields.

Student Engagement and Motivation

According to the survey the students were actively interested and motivated by the gamified aspects of the tasks; the majority of the students stated that incorporating a point system and awarding badges and introducing leader boards increased their motivity and interest. This is in line with prior studies that noted that when gamification elements are applied in learning, motivation, and engagement improve as a direct result of the intense focus achieved from game elements provision (Deterding et al., 2011; Hamari et al., 2014).

According to SDT by Deci and Ryan (2000), these motivational effects can be explained satisfactorily. According to SDT, people are more inclined to get motivated if they are granted autonomy, competence, and relatedness. On this basis, the learned environment in this study seemed to meet the above psychological needs by helping students to experience control in their learning process (autonomy), and by providing them with chances to achieve competent performance (competence), besides the chance to relate with peers. These motivational drivers most probably had an influence on the high level of engagement and participation identified in the construction of the gamified tasks.

The conclusions of this study are also comparable with the previous research done by Barata, Gama, Jorge, and Gonçalves, (2013) who have reported positive results on the engagement, motivation, and participation of students in a university course inculcated with a gamified approach. The extrinsic incentives of gamification like the point and leader board were found to increase student participation and completion of difficult tasks. In this study, the integration of the collaborative tasks added an extra motivation for the students as they were able to learn in groups and this group work is fundamental in the development of problem solving as well as critical thinking skills.

Nevertheless, some challenges were highlighted by the teachers concerning the longevity of motivating learning among the learners. There was also research finding suggesting that while carrying out the game-related tasks the students were highly motivated due to the game-based incentives, a number of the participants gradually grew less interested as the relative aspect of the game motifs started deteriorating. This is in line with Nicholson's (2012) observation whereby he notes that use of merit such as points and badges creates short-term motivation, but the tasks have to be ones that create long-term motivation to ensure learners are motivated to complete the tasks assigned to them. As a result, educators have to think about the structure of the games, as well as the type of rewards to offer and their integration with the content of the curriculum.

Teacher Observations and Qualitative Feedback

Interpretation of other qualitative tools was supported by the feedback of teachers about the children's learning progress due to the use of gamification approaches. The teachers reported higher interaction and co-operational levels in the students during the gamified lessons, which again corroborates the quantitative method results on students' motivation levels. The greatest benefit of the use of the gamified tasks was seen in the area of peer learning and communication due to the fact that students had to work in groups and solve problems and complete the challenges as a team. The authors of this study are in agreement with Fotaris et al. (2016) whose study revealed that the incorporation of gamified tasks in a computer science course enhanced the collaborative and team spirit among students.

Nevertheless, teachers also reported on some of the possible pitfalls of competition for achieving learning outcomes. In particular, a few learners seemed more interested in earning points and badges than gaining knowledge on the contents being taught, a drawback discussed in the literature on gamification (Domínguez et al., 2013). This implies that though the theory if applied successfully in the classroom increases the level of students' participation as well as their motivation the educators must be very selective in developing the game mechanics so that students do not look for the game incentives but rather the learning content. Furthermore, based on teacher feedback, major issues affecting the long-term motivation were raised whereby students lost interest in the game elements after some time had elapsed. This result consolidates the worries proposed by Anderson et al. (2013), who revealed that the novelty of gamification may change if not rejuvenated by new problems and rewards periodically.

Comparison with Other Studies

The findings of this study align with research on the impact of gamification on teaching and learning. For instance, Hamari and colleagues, in their systematic review of gamification, revealed that the majority of the work done showed; positive impacts of gamification on students' engagement, motivation and learning achievement. In a similar way, Kapp (2012 stated that the best area to apply a gamified learning environment is where there is an element of problem solving or critical thinking since such concepts can be applied in real practical field through simulation.

The conclusion of this study also agrees with Gee(2003) that games are designed in such a way that they facilitate learning, played out as experimentation, failure and trial in the new procedure. This cycle resembles the scientific method, which is the core of STEM curricula, and may show why gamification fosters critical and rational thinking and problem-solving skills most effectively in STEM disciplines.

However, other studies have given more ambiguous results about the duration impact of gamification on customer engagement. For instance, Domínguez et al. . (2013) observed that where gamification was applied to enhance students' engagement, its positive effects were short-lived as students shifted more towards external reward than the learning goals. This underscores the necessity of developing appropriate gamification models that focus both on extrinsic motivating factors and intrinsically motivating factors with which teachers in this study also expressed concerns.

Implications for Educational Practice

The findings outlined in this paper have several practical implications for educational practice. First, based on the information and research findings, it can be concluded that using gamification methodology may be effective to improve critical thinking and problem solving skills in the context of high school STEM classes. The incorporation of game elements such as the challenges, points, and working together can enhance the learning process and make it fun so that students can apply what they have learnt in real life.

Second, educators ought to consider the pros and cons of gamification where one possible disadvantage is that learning goals can easily be overshadowed by the use of incentives. Particular attention should be paid to the development of the tasks that will be based on the most common motivations and that will support meaningful gameplay.

Lastly, implications of the study revealed that enhancing the social aspect of learning through collaborative learning strategies should be pursued alongside gamification efforts. The use of gamification in learning can promote not only conceptual learning but also collaborative learning, and the latter is critical for skills acquired during STEM education.

Conclusion

Thus, the results of this research indicate that gamification could be a suitable approach to positively impact the development of situational learning, critical thinking, and problem-solving abilities in STEM learning domains. These elements of games that were applied in this study include points, badges, and collaborative tasks which enhanced students' engagement and motivated them to participate in learning activities hence proved to improve the students 'cognitive abilities significantly. Thus, despite the tendency of interest in the gamification methodology to decrease over time, the results obtained from the use of gamification – deseo-oriented thinking and active learning – remain undeniable. The findings point to the usefulness of a well-designed gamification system as a useful tool for academics concerned with developing students' valuable higher order thinking abilities that would be beneficial in STEM-related professions. It is imperative that stakeholders conduct further research to establish the impact of gamification on learning outcomes both in the short term and the long term with emphasis on the durability of the appeal for students.

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