Physics Students' Academic Achievement and Motivation in a Gamified Formative Assessment

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Abstract   There is an emergence of various modern strategies for teaching physics, but there have been few investigations into gamification strategies. Consequently, this study investigated the effects of a gamified formative assessment on students' academic achievement and motivation while learning physics. This study employed a one-group pretest-posttest pre-experimental design. All participants were given a pretest and posttest to determine their academic achievement in physics and Physics Motivation Questionnaire (PMQ-II) to determine their motivation to learn physics. Physics lessons were delivered online for an entire grading period, with gamified formative assessment in the form of a slide presentation via Quizizz. Descriptive and inferential statistics were used to analyze the academic achievement and motivation tests scores. The results revealed that academic achievement increased from pretest to posttest scores, but there was a "low-g" learning gain. The level of motivation also increased from pre-gamification to post-gamification, shifting from moderately high to high motivation. The results also revealed a significant difference in academic achievement and motivation after exposure to a gamified formative assessment. It was concluded that gamifying formative assessment effectively improved junior high school students' academic achievement and motivation in learning physics. It was recommended that physics instructors be encouraged to use gamification strategies when teaching physics lessons to cater to the learning needs of the younger generations migrating to an online environment.

Keywords: *gamification, self-determination, self-efficacy, intrinsic and extrinsic motivation, learning gain, Quizizz*

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1. Introduction

Physics is an essential component of a modern educational system and society. Despite its importance, students regard it as an abstract and challenging subject, resulting in poor grades [1,2]. A lack of motivation and the medium of instruction used are two challenges high school students face when learning physics [3]. This means that teaching methods and techniques for physics must be improved to make it more interesting and appealing to students and motivate them to learn more.

Due to the unprecedented pandemic, one of the challenges in teaching-learning activities is conducting assessments remotely [4]. Assessment of student learning is a critical component in motivating students and improving instruction, and providing feedback is an important part of the assessment process. Unfortunately, the physical distance between the teacher and the students makes providing immediate feedback difficult, necessitating adaptations and technology to assess them. However, physics teachers struggle to find engaging and meaningful assessments other than paper-pencil tests.

There is a need for an instructional system and support technology that considers meaningful learning in physics to address these challenges and issues. Hence, this study investigated the gamification of formative assessment and its effects on students' academic achievement and motivation while learning physics.

Gamification uses game elements and game design techniques in non-game contexts [5]. Only a few studies have looked at gamification in formative assessment [6,7,8], and there are few classroom studies of gamification [1,9]. As a result, there was a gap in knowledge regarding the impact of gamification, particularly as a formative assessment.

A formative assessment is an important component of the learning process, and many gamification platforms can help with this. A gamification platform is any software or tool that uses game mechanics in non-game environments to boost academic achievement and motivation [6]. Quizizz is a well-known assessment gamification platform that enables teachers to conduct student-paced formative assessments that are fun and engaging for students of all ages.

Academic achievement and motivation were the variables measured in this study. Students' academic achievement in physics is influenced by motivation, and

teaching technique significantly impacts students' motivation to learn physics [10]. In addition, student academic achievement is typically attributed to student motivation and participation in science-related classes. Similarly, teaching and assessment are important factors in determining students' level of science literacy [11].

Gamification in physics classes is a promising and innovative tool for educators to use to engage students in creative learning skills and exciting competition [19], and improve students' academic achievement and motivation [9]. Gamification in education should be thoroughly researched in order to further investigate the significant factors that greatly influence students' learning in physics courses. Hence, this study aimed to investigate the effects of a gamified formative assessment on physics students' academic achievement and motivation. Specifically, it sought to answer the following questions:

1. What is the level of academic achievement in physics among students in a gamified formative assessment?
2. What is the level of motivation in physics among students in a gamified formative assessment?
3. Is there a significant difference in students' academic achievement before and after gamifying formative assessment in physics?
4. Is there a significant difference in students' motivation before and after gamifying formative assessment in physics?

1.1. Theoretical Framework

1.1.1. Self-Determination Theory

The self-determination theory (SDT) is a theoretical framework that defines gamification and motivation in this study because it emphasizes autonomous learning and students' self-directed learning. SDT, proposed by Edward Deci and Richard Ryan in 1985, has influenced many empirical studies in the education literature. In SDT, motivation is divided into intrinsic and extrinsic motivation, which are important in promoting students' academic achievement and motivation. Intrinsic motivation is defined as engaging in an activity for joy and satisfaction. Individuals who are intrinsically motivated participate in an activity freely, without being compelled to do so by external or internal forces, and without expecting to be rewarded. On the other hand, extrinsic motivation refers to engaging in an activity to receive rewards. Amotivation is the third dimension of motivation, and it states that unmotivated people simply do not want to participate in an activity [12]. However, only intrinsic and extrinsic motivation were investigated in this study due to questionnaire limitations.

1.1.2. Social Cognitive Theory

Another theory that describes this study, developed by Bandura in 1986, is the Social Cognitive Theory, which holds that students' learning is most effective when it is self-regulated, which occurs when students understand, monitor, and manage their motivation and behavior in desirable learning outcomes. Furthermore, the SCT was used as one of the frameworks in this study, with motivation and self-efficacy playing a significant role.

Motivation is defined in SCT as an internal state that arouses, drives, and sustains goal-oriented action [13]. On the other hand, self-efficacy, which evolved from SCT, is defined as a belief in one's ability to plan and execute the courses of action required to achieve specific goals [7].

1.1.3. Formative Assessment Theory

As defined by the influential Paul Black and Dylan Wiliam, the theory of formative assessment is a synthesis of socio-cultural and socio-cognitive theories. Formative assessment may be the only, or even the best, way to facilitate a broader range of desirable changes in classroom learning. It may be unusually effective in part because the quality of interactive feedback is a critical feature in determining the quality of learning activity and thus a central feature of pedagogy [14]. According to the theory of formative assessment, students' thinking and learning processes are aided when given information and feedback about the learning criteria and standards against which they are evaluated.

2. Methodology

2.1. Research Design

The study utilized a pre-experimental one-group pretest-posttest design to investigate the effects of gamified formative assessment on physics students' academic achievement and motivation. The design included a pretest measure, an intervention, and a posttest for a single group of students with no control group.

2.2. Population and Sample

The research was conducted at Central Mindanao University Laboratory High School in Musuan, Maramag, Bukidnon, Philippines. The school is a laboratory high school of the College of Education of Central Mindanao University. The study was entirely conducted online, with no face-to-face interactions. The study used a purposive sampling method, which is a non-probability sampling method. The third or last section in Grade 10 was studied with 36 students and was treated as a single group with no control group based on the design of this study. Participants in the study were officially enrolled in the Integrated Science Physics course during the third quarter of the school year 2021-2022.

2.3. Data Collection and Instruments

Before and after the intervention, a 60-item achievement test and a 25-item Likert-type Physics Motivation Questionnaire (PMQ-II) were given to the students. All PMQ-II elements were classified as intrinsic motivation (IM), self-determination (SD), self-efficacy (SE), career motivation (CM), or grade motivation (GM).

Descriptive statistics were used to determine the mean and standard deviation of students' academic achievement and motivation in learning physics using gamified formative assessment. A paired sample t-test at the 0.05 level of significance was used to determine the significant difference in academic achievement and motivation of

students before and after learning physics using gamified formative assessment.

The study also used qualitative interpretations for academic achievement, learning gain, and motivation to give meaning to the quantitative results.

Table 1. Range and qualitative interpretation for academic achievement

Range	Qualitative Interpretation (QI)
90-100	Very High (VH)
86-89	High (H)
80-85	Moderately High (MH)
75-79	Low (L)
65-74	Very Low (VL)

Table 2. Range and qualitative interpretation for learning gain

Range	Qualitative Interpretation (QI)
>=0.7	High-g
0.31-0.69	Medium-g
<=0.3	Low-g

Table 3. Range and qualitative interpretation for motivation

Range	Qualitative Description	Qualitative Interpretation
5.00-4.21	Usually	Very High (VH)
4.20-3.41	Sometimes	High (H)
3.40-2.61	Rarely	Moderately High (MH)
2.60-1.81	Never	Low (L)
1.80-1.00	Always	Very Low (VL)

2.4. Validity and Reliability

Three experts in the field content validated the 80-item test, and it was revised accordingly. The test items were pilot tested with Grade 11 students from the same school and subjected to item analysis, yielding a reliability coefficient of 0.716, indicating that the test was good with only a few items to improve. Based on this item analysis, a 60-item pretest and posttest were generated and administered to participants before and after the gamification. The 25-item PMQ-II was also pilot tested with the same students, obtaining a Cronbach's alpha of 0.848, indicating high internal consistency. The participants were then given the 25-item PMQ-II before and after the gamification.

2.5. Intervention

A pretest was administered before gamification to determine the initial level of students' physics learning competencies. A Physics Motivation Questionnaire-II (PMQ-II) was also administered to assess the students' motivation before exposure to gamification. The online Zip Grade was used to administer the 60-item pretest-posttest and the PMQ-II.

Participants were required to attend a three-hour synchronous class once a week where the lessons were taught using a Quizizz Instructor-paced Live Session with embedded 10-item multiple-choice questions per lesson in the presentation, resulting in more interactive lessons and just-in-time assessment and feedback. The three chapters covered in the five lessons for the third quarter of the integrated science physics course were electromagnetic waves, geometric optics, and electricity and magnetism.

For a total of five lessons, participants must complete a 10-item formative assessment via Quizizz for each topic covered in the lesson during the synchronous discussion. The 10-item multiple-choice quiz was created using the set competencies for each lesson and the lesson guide. Each lesson question has a time limit based on its complexity. Following each question, the leaderboard was displayed so that participants could see their current ranking as the lesson progressed, followed by feedback on correct and incorrect answers, as well as any misconceptions. At the end of the lesson, a final point ranking was updated and displayed, along with the total number of points earned by the participants, with the top three high scorers recognized. Participants also see their updated ranking in Google Classroom at the end of each lesson, which helped them get motivated to strive for the top spot in the next lesson.

A validated pretest given before the gamification served as the posttest given to participants after they had been exposed to the gamification. The PMQ-II was then administered to assess the students' motivation following their exposure to gamification.

3. Results and Discussion

3.1. Level of Academic Achievement

The data collected were analyzed using the frequency, percentage distribution, mean, and standard deviation for the level of academic achievement, and Hake's normalized gain for the learning gain to determine the level of students' academic achievement and gain in learning physics in a gamified formative assessment.

Table 4. Level of academic achievement in pre and post gamification

Level of Academic Achievement	Pretest (pre-gamification)		Posttest (post-gamification)	
	f	%	f	%
Very High (VH)	-	-	1	2.8
High (H)	-	-	2	5.5
Moderately High (MH)	-	-	9	25.0
Low (L)	-	-	14	38.9
Very Low (VL)	36	100.0	10	27.8
Total	**36**	**100.0**	**36**	**100.0**

Table 4 shows that all students received a "Very Low" rating in the pretest prior to being exposed to gamification. However, there is a wider distribution of scores ranging from "Very Low" to "Very High" in the posttest after exposure to gamification. This indicates that students' exposure to gamification resulted in a wide range of posttest scores.

Table 5. Academic achievement and learning gain

Academic Achievement	Mean	SD	Qualitative Interpretation
Pretest	71.80	1.41	Very Low
Posttest	79.00	5.08	Low
Learning Gain	**0.25**	**0.17**	**Low-g**

Table 5 shows the overall mean and standard deviation of transmuted pretest scores, transmuted posttest scores, and learning gain of physics students before and after

exposure to a gamified formative assessment. There was a shift from "Very Low" to "Low" rating of students' academic achievement before and after exposure to gamification, with the transmuted posttest scores having a higher mean value compared to the transmuted pretest scores, indicating that the students achieved higher posttest scores after exposure to gamification. Furthermore, students' overall learning gain is labeled as "Low-g", indicating that they have a lower level of understanding of the lesson than what they could have learned.

In terms of academic achievement, the findings of the present study revealed that students' academic achievement increased after being exposed to a gamified formative assessment. This means that most students who had low pretest scores received high posttest scores, indicating that gamifying formative assessment was effective. This finding is consistent with the study of Rahim, Ziden and Yap [15] who investigated the effects of gamified online quizzes using Quizizz and found that gamified quizzes improved students' achievement because they learned from instant feedback, mistakes, and post-quiz discussion.

In addition, the findings of the present study revealed a Low-g or Low normalize gain based on Hake's increment in learning gain. This finding is consistent with the results of Tolentino and Roleda [1] who investigated gamified physics instruction in a reformatory classroom setting and found a low normalized gain of students based on Hake's operational definition.

Despite the increase in the level of students' academic achievement, the majority of students had a small difference in the posttest and pretest scores, resulting in a low-g; however, this does not imply that the students did not learn about the lesson; instead, they could have learned more if they were continuously exposed to this method of assessing them.

3.2. Level of Motivation

The data collected were analyzed using frequency, percentage, mean and standard deviation to determine the level of students' motivation in learning physics in a gamified formative assessment.

Table 6. Level of motivation in pre and post gamification

Level of Motivation	Pre-Gamification		Post-Gamification	
	f	%	f	%
Very High (VH)	2	5.6	11	30.6
High (H)	14	38.9	10	27.8
Moderately High (MH)	12	33.3	10	27.8
Low (L)	7	19.4	3	8.3
Very Low (VL)	1	2.8	2	5.5
Total	**36**	**100.0**	**36**	**100.0**

Table 6 shows students' level of motivation before and after exposure to a gamified formative assessment. It shows that some students who were "Low" to "High" motivated before gamification shifted to a "Very High" level of motivation after exposure to gamification. Furthermore, the percentage of students with a "Very High" level of motivation before gamification increased to 30.6 percent after gamification from 5.6 percent prior to gamification, indicating that the majority of students were

very highly motivated resulting from exposure to a gamified formative assessment.

In terms of motivation, the present study found that students' motivation increased after being exposed to a gamified formative assessment. This means that after gamification, the majority of the students were very highly motivated. The motivation spectrum was divided into five categories: intrinsic motivation, self-determination, self-efficacy, extrinsic motivation – career, and extrinsic motivation – grade.

Table 7 depicts the motivation of physics students before and after exposure to gamified formative assessment. The sub-mean interpretation of intrinsic motivation increased from "Moderately High" to "High". Based on significant shifts in motivation levels before and after gamification, the findings revealed that students are intrinsically motivated because they find their physics learning relevant to their lives. This is consistent with the study of Tinedi, Yohandri and Djamas [2] who stated that relevance to daily life is the motivation needed by students to learn physics.

It is also evident that the mean score of students' self-determination increased, indicating that students study hard to learn physics. Students' self-determination increased as a result of their belief that they are working hard to learn physics. This is consistent with the self-determination theory of Ryan and Deci [12] which emphasizes autonomous and self-directed learning.

In addition, students' self-efficacy mean score increased, indicating that they are confident in their ability to understand physics. This is also consistent with the social cognitive theory, which defines self-efficacy as the belief in one's ability to plan and execute courses of action to achieve specific goals [16].

Furthermore, the table shows that students are more extrinsically motivated in their careers. It is revealed that there was an increase in the mean score of students' extrinsic motivation-career before gamification and after gamification, indicating that they believe learning physics will help them get a good job and understanding physics will help them in their career. It is also evident that there was a major shift from "Low" to "Moderately High" on students' extrinsic motivation-career, indicating that their career will involve physics. These findings for extrinsic motivation in terms of career are consistent with the study of Torio [17] who concluded that students' motivation to learn physics is an important factor in determining the career path they will pursue at the collegiate level

Students' extrinsic motivation in terms of grade, on the other hand, remains "High" both before and after gamification. This is consistent with the findings of the study of Chumbley, Haynes and Stofer [18] who concluded that grade motivation and self-efficacy were the most important motivational constructs for students. Furthermore, a direct relationship between motivational components, specifically self-efficacy and grades was discovered in the study of Glynn, Brickman, Armstrong and Taasoobshirazi [13], after validating and testing the reliability of the science motivation questionnaire

As a result, the overall mean score of motivation before and after gamification, increased from "Moderately High" to "High," indicating that students' motivation increased after exposure to a gamified formative assessment.

Table 7. Motivation categories in pre and post gamification

Motivation Categories	Pre-Gamification			Post-Gamification		
	Mean	SD	QI	Mean	SD	QI
The physics I learn is relevant to my life.	3.22	0.93	MH	3.64	0.96	H
Learning physics is interesting.	3.50	0.94	H	3.89	0.89	H
Learning physics makes my life more meaningful.	3.03	1.06	MH	3.19	0.89	MH
I am curious about discoveries in physics.	3.72	1.11	H	3.89	1.12	H
I enjoy learning physics.	3.42	1.08	H	3.53	1.13	H
Sub Mean – Intrinsic Motivation	3.38	0.82	MH	3.63	0.80	H
I put enough effort into learning physics.	3.44	0.88	H	3.53	1.03	H
I use strategies to learn physics well.	3.03	1.11	MH	3.39	1.18	MH
I spend a lot of time learning physics.	2.72	1.06	MH	3.11	1.12	MH
I prepare well for physics tests.	3.06	0.98	MH	3.39	1.10	MH
I study hard to learn physics.	3.08	1.05	MH	3.44	1.11	H
Sub Mean – Self-Determination	3.07	0.85	MH	3.37	0.97	MH
I am confident I will do well on physics tests.	2.61	1.10	MH	2.94	1.01	MH
I am confident I will do well on physics labs and projects.	2.69	1.17	MH	2.92	1.05	MH
I believe I can master physics knowledge and skills.	3.33	1.20	MH	3.17	1.03	MH
I believe I can earn a grade of "A" in physics.	2.92	1.32	MH	3.25	1.18	MH
I am sure I can understand physics.	3.19	0.89	MH	3.47	1.06	H
Sub Mean – Self-Efficacy	2.95	0.93	MH	3.15	0.90	MH
Learning physics will help me get a good job.	3.36	1.15	MH	3.56	1.11	H
Knowing physics will give me a career advantage.	3.44	1.00	H	3.44	1.18	H
Understanding physics will benefit me in my career.	3.31	1.17	MH	3.42	1.25	H
My career will involve physics.	2.50	1.38	L	2.74	1.46	MH
I will use physics problem-solving skills in my career.	2.97	1.30	MH	3.22	1.44	MH
Sub Mean – Extrinsic Motivation – Career	3.12	0.99	MH	3.28	1.10	MH
I like to do better than other students on physics tests.	3.08	1.08	MH	3.31	1.01	MH
Getting a good physics grade is important to me.	4.08	1.08	H	4.06	0.98	H
It is important that I get an "A" in physics.	3.81	1.17	H	3.92	1.16	H
I think about the grade I will get in physics.	3.97	1.06	H	4.06	0.98	H
Scoring high on physics tests and labs matters to me.	3.81	1.26	H	3.69	1.17	H
Sub Mean – Extrinsic Motivation – Grade	3.75	0.93	H	3.81	0.90	H
Overall Mean	**3.25**	**0.78**	**MH**	**3.45**	**0.81**	**H**

3.3. Significant Difference in the Level of Academic Achievement

Preliminary assumption testing was conducted. Shapiro Wilk test for normality showed that at α = .05, there is no significant departure of the distribution of the paired differences from normality, p > .121. Thus, paired sample t-test was conducted.

Table 8. Paired samples t-test for the level of academic achievement before and after gamification

Academic Achievement	Mean	SD	SE mean	t	df	p
Pretest-Posttest	-7.19	4.83	.80	-8.93	35	.000*

*significant at p < .05 level.

Using an alpha level of .05, a paired sample t-test shows that the mean difference, 7.19, is statistically significant t (35) = 8.93, p = .000, which means that the transmuted posttest score is significantly higher than the transmuted pretest score, as shown in Table 8.

As a result of this finding, the null hypothesis was rejected. This demonstrated a statistically significant difference in physics students' pretest and posttest scores before and after exposure to gamified formative assessment. This also revealed that the intervention of gamifying formative assessment through Quizizz was highly effective, resulting in a significant difference in the students' academic achievement.

This finding is related to the study of Zainuddin, Shujahat, Haruna and Chu [6] who investigated the role of gamified e-quizzes as a formative assessment system on student learning in a science class and discovered the use of gamified e-quizzes was effective in evaluating students' learning achievement, particularly as a formative assessment tool. However, this finding contradicted the findings of Orhan Goksun and Gursoy [7] who compared academic achievement in gamified learning experiences and discovered that students in the Quizizz application had lower academic achievement when compared to the instruction method.

3.4. Significant Difference in the Level of Motivation

Preliminary assumption testing was conducted. Shapiro Wilk test for normality showed that at α = .05, there is no significant departure of the distribution of the paired differences from normality, p > .452. Thus, paired sample t-test was conducted.

Table 9. Paired samples t-test for the level of motivation before and after gamification

Motivation	Mean	SD	SE mean	t	df	p
PreGamification-PostGamification	-.19	.45	.07	-2.60	35	.013*

*significant at $p < .05$ level.

Using an alpha level of .05, a paired sample *t*-test shows that the mean difference, .19, is statistically significant $t(35) = 2.60$, $p = .013$, which means that the post-gamification is significantly higher than the pre-gamification motivation, as shown in Table 9.

As a result of this finding, the null hypothesis was rejected. This proved a statistically significant difference in student motivation before and after exposure to gamified formative assessment. This also revealed that the intervention of gamifying formative assessment through Quizizz was highly effective, resulting in a significant difference in student motivation. This finding is consistent with the study of Rose, O'Meara, Gerhardt and Williams [9] who investigated the use of gamification to improve students' motivation in physics and found that gamifying quizzes was significantly associated with increased motivation. This finding is also consistent with the findings of Mohamad, Arif, Alias and Yunus [19] who investigated online game-based formative assessment using Quizizz and concluded that the platform promoted student motivation.

4. Conclusion and Recommendations

The findings of this study revealed that gamifying formative assessment can effectively increase students' academic achievement and motivation in learning physics. Extrinsic motivation in terms of career was evidently increased by gamifying formative assessment; thus, introducing physics in an engaging manner influences students' motivation to learn physics. As a result, gamification appears to be a viable approach for assisting students in learning physics concepts, thereby increasing academic achievement and motivation. Hence, physics instructors are encouraged to adopt this instructional strategy for teaching physics and school administrators should consider introducing this instructional strategy to physics instructors for synchronous class discussions to supplement the existing strategies with the aid of current technologies.

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