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Effect of Game-Based Learning (GBL) and Gamification on Senior Secondary School Students Learning Outcomes in Physics

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Abstract

New trends in teaching and learning have shown game-based learning (GBL) and gamification as potential viable tools for enhancing students' learning experience and outcomes. The promise of using this strategy is that play, fun and learning would occur simultaneously in order to create a changed social environment that would stimulate and motivate learners into having a better learning experience. This study therefore developed a GBL package (using board game) and gamification instructional package that determined its effect on senior secondary school students' achievements, attitude and motivation towards physics. The self-determination and socio-constructivist theory of Vygotsky provided the framework, while the study employed the pretest-posttest control group quasi-experimental design. Participants in the study consisted of 94 senior secondary school one students that were drawn from three public secondary schools. Results from analysis of covariance, estimated marginal mean, and descriptive statistics show that game-based learning and gamification enhanced students' achievement ($F_{2,74}$= 2.484, $p >$ .05) and positively influenced their attitude ($F_{2,74}$ = 4.73, $p>.05$) and engagement ($F_{2,74}$ = 5.42, $p > .05$). Although the two treatments were effective in enhancing students' learning outcomes in physics, gamification was more effective than game-based learning in enhancing motivation towards physics while game-based learning was more effective than gamification in enhancing students' attitude and achievement in physics. Based on these findings, the study concluded that game-based learning and gamification enhanced senior secondary school students learning outcomes, motivation and attitude in physics and should therefore be adopted in teaching secondary school subjects.

Keywords: Game-Based Learning, Gamification, Achievement, Attitude and Motivation

Introduction

The importance of physics to the scientific and technological development of any nation cannot be over-emphasized especially in this digital age where information and communication technology is a vehicle with great potentials for national and economic development. It is in view of this that Ibeh, Onah, Umahi, Ugwuonah, Nnachi, and Ekpe (2013) argued strongly that the specific priority of physics in the scientific and technological development initiatives of a nation is so important that regression and dependence on other countries will be the reward of any nation with poor records in physics. Nonetheless, physics remains the least favoured science subject among senior secondary school students and is generally considered boring (Veloo, Nor, and Khalid, 2015). Learning physics has often proven to be a difficult endeavour for many students because of calculations and abstract concepts which are fundamental to understanding the intricacies of the relationships between the different constituent parts of the world we live in.

This must have caused students' poor attitude and lack of motivation in learning physics (Ozden, 2007 and Saleh, 2014), hence, physics has become a subject of least choice in schools (Alexander, Kuppam, Shaik Kadir, and See, 2010). These challenges have continued to result in poor learning outcomes in physics and fewer enrolment in physics and physics-based courses at higher levels of study.

Many factors have been highlighted as contributing factors to students' poor learning outcomes in physics among which was teaching strategy (Adeyemo and Babajide, 2014). Asikhai (2010) opined that mass failure of students in senior secondary school physics examinations is mainly due to the use of inappropriate or ineffective teaching strategies by physics teachers. According to Mari (2002) teaching strategy is a variable that can easily be manipulated by teachers to improve students' learning outcomes as well as reduce gender bias in performance in physics. The major function of pedagogy is to ensure that ideas and information are meaningfully and logically presented in a creative manner that allows students to retain and apply all that has been learnt over a long period of time. As such, the teaching of physics in the absence of appropriate teaching strategy may result in poor outcomes of learning on the part of students.

Physics is a practical and applied subject that should be taught in a manner that fosters the easy integration of current innovations, especially in this technology-driven era where teachers are now facilitators and students now play a central role and take responsibility for their learning. Physics lessons ought to be activity packed and situated within the context of students' experience and immediate environment. This may not be possible using the rote learning method of instruction where mere teaching occurs. According to Al-Azawi, Al-Faliti, and Al-Blushi (2016) many studies and systems that use "pleasure" and "fun" as inherent aspects of games to improve learner's motivation have been developed in the field of the learning environment. A game is a competitive physical or mental activity governed by rules, especially engaged in for the purpose of entertainment and directed towards an explicit goal (Kapp, 2012). It can also be defined as activity that must have the following features:-

i. Fun: the activity is chosen for its light-hearted character.

ii. Separation: it is circumscribed in time and place.

iii. Uncertainty: the outcome of the activity is unforeseeable.

iv. Non-productive: participation does not accomplish anything useful.

v. Governed by rules: the activity has rules that are different from everyday life.

vi. Fictitious: it is accompanied by the awareness of a different reality (Al-Azawi, *et. al* 2016)

Innovations like game-based learning and gamification which involves the use of real games and game elements played within and outside the classroom could improve the attitude, motivation and performance of students in physics.

Game-based learning employs the use of games to enhance the learning experience and meet learning outcomes while gamification takes the entire learning process and turns it into a game. To do this, instructional designers use game design elements which are digital objects and elements that make an experience game like. Studies have shown that the incorporation of games into the teaching and learning process is usually more effective than the conventional teaching approach by actively engaging the learner, arousing learners' interests, and enhancing learning motivation (Kirikkaya, Iseri, and Vurkaya, 2010). Game-based learning can provide an effective way to offer engaging and motivating learning experiences that would increase students' interest in physics and improve students' academic performance (Musselman, 2014). In recent years, many researchers have investigated the effectiveness of digital and indigenous games in the promotion of learning of science-related school subjects. Liu and Chen (2013) used game-based learning in an energy course and discovered that students generally accepted the method and their achievement was significantly higher after playing the game.

Through game-based learning, motivation and efficiency can be improved. Students learn more actively and construct knowledge for themselves, enabling the learned content to have a deeper and lasting imprint that may not be possible under conventional teaching methods (Papastergiou, 2009). Gamification, on the other hand, is the application of game elements and digital design techniques to games to achieve educational objectives, attract the attention of learners, raise motivation and solve the problem of low academic achievement. It allows educators to encourage students to master a set of objectives, by empowering them to revise and try again in a positive, non-threatening and productive way (Elshemy, 2017).

In a study carried out by Smith, Herbert, Kavanagh and Reidsema (2013) on the effect of gamification (leaderboard and badges) on the participation and quality of an online technical course discussion, it was discovered that gamification was an effective means of motivating students through higher students' participation as well as feedback during instruction. In a similar study, Turan, Avinc, Kara and Goktas (2016) reported that the experimental group students who were taught using gamification had better achievement scores than those taught using the conventional approach. However, most studies on game-based learning and gamification have focused on digital game-based learning and gamified courses while neglecting the possible effect of students' self-regulation ability (Boticki, Baksa, Seow, and Looi, 2015; Mekler, Brühlmann, Tuch, and Opwis, 2017) . Fewer Nigerian studies have also explored game-based learning in the form of educational board games. It is hoped that the findings of this study will demonstrate the effectiveness of GBL and gamification in enhancing engagement and learning outcomes in the learning process. The study therefore, examined whether there is

- significant main effect of treatment in students' achievement in physics
- significant main effect of treatment on students' attitude to physics.
- no significant main effect of treatment on student motivation to learn physics.

Literature Review

Game-Based Learning (GBL) refers to the application of games to teaching and learning situations in order to enhance learning experience and meet learning outcomes (Poulsen, 2011) A GBL environment describes an approach to instruction where learners explore relevant aspects of games and gameplay in an organized learning context designed by the instructor (Chen, Yen and Chang, 2015). The purpose of adopting game for instructional purpose is to create a highly motivated and engaging learning experience (Ke, Xie, and Xie 2015). Games create a highly social, emotional and sometimes complex environment that helps learners think and reflect critically, take risks in a space with reduced consequences, assume multiple identities, receive reward, learn new skills, interact experimentally with the game environment, discover knowledge from experience and apply such knowledge to real life situations (Liu and Chen, 2013; Alfaifi, 2013).

This approach is designed to balance instructional content or knowledge with gameplay and foster the retention and application of such knowledge to the real world by the learners. The instructor and students also collaborate in order to construct ideas and add depth and perspective to the experience of playing the game. In recent years various studies relating to the use of GBL have reported the potentials of using this approach for instruction. Alfaifi (2013) found that GBL using board games was effective in enhancing college students' intrinsic motivation in learning physics. A study by Divjak and Tomic (2011) also reported that students' achievement and attitude towards learning was greatly improved with GBL approach. Liu and Chen (2013) also reported the positive effect of GBL on students' achievement and motivation in science learning. In a similar study by Yien, Hung, Hwang and Lin (2011) it was reported that a properly designed GBL environment has a positive effect on students' achievement and attitude. Meanwhile, few studies have also reported that GBL has no significant effect on students' learning outcomes (Giannakos, 2013; Chen, Yeh and Chang, 2015).

Gamification, on the other hand refers to the use of elements common in game plays in the design of learning processes for the purpose of motivating learners (Kapp, 2012; Huang and Soman, 2013). According to Kapp (2012) gamification involves the use of game-based aesthetics to promote learning or to engage and motivate individuals to solve a given problem. In using gamification, researchers attempt to integrate the engagement and motivation that exist in games to enhance participation, motivation and achievements in various activities other than game (Richter, Raban and Rafaeli, 2015).

The rationality for the gamification of learning is that the incorporation of elements that are found in games to learning activities will foster engagement and immersions such as is experienced in games and ultimately change learners' behaviour in a desirable way (Codish and Ravid, 2015; Holman, Aguilar and Fishman, 2013). In recent years, gamification has gained popularity among researchers

and its use in educational programmes is enabling instructors to find the balance between achieving instructional objectives and meeting evolving student needs (Huang and Soman, 2013). A study conducted by Elshemy (2017) in an elementary school showed that gamification was effective in enhancing elementary school students' achievement and motivation to learn. Reichelt (2015) also reported that gamification using points and levels could be effective in improving students' academic achievement and motivation.

Methodology

This study adopted a pre-test and post-test quasi-experimental control group design. The independent variables were the different teaching strategies. The experimental groups were taught using GBL and gamification, while the control group received instruction with the conventional lecture method. The dependent variables were learning achievement, attitude towards physics and physics motivation.

Participants

The participants in this study included 94 senior secondary one students in three classes that were purposively selected from three public senior secondary schools. One class consisting of 30 students (16 males and 14 females) was experimental Group A, another class with 32 students (19 males and 11 females) was the experimental Group B and the last class with 30 students (12 males and 18 females) was the control group. To prevent the influence of different instructors on the experimental results, the experimental classes were taught by the same instructor. The students in experimental group A learned with the GBL, experimental group B learned with gamification while those in the control group learned with the conventional instruction method.

Measuring Tools

Three research instruments were used for data collection. These were the Physics Achievement Test (PAT), Students' Attitude to Physics Questionnaire (SATPQ) and Students' Motivation to Learning Physics Questionnaire (SMTLPQ). To evaluate the learning achievement of the students, the physics achievement test was developed by the researcher based on purposively selected contents on the concept of "motion" in the senior secondary school physics curriculum. The test items were designed to measure the first four levels of the cognitive domain according to Bloom's taxonomy of cognitive skills. The test consists of 15 multiple response items which were validated by seasoned physics teachers. Respondents were required to choose a correct answer among four possible choices, A to D. Each item was awarded 4 marks if the student gave the correct answer. The reliability index was 0.78.

To measure the students' learning attitude towards physics, the questionnaire that was developed by Barmby, Kind and Jones (2008) on science attitude was adapted. It consisted of 37 items on a 4-point Likert scale. The Cronbach's test of internal consistency had a value of 0.73 showing good reliability.

To evaluate the motivation of the students in learning physics, the questionnaire developed by Tuan, Chin, and Shieh (2005) was adopted. The instrument was modified by the researcher to collect information about respondents' level of motivation in the physics class. It consisted of 22 items that were based on five constructs of motivation which are self-efficacy, active learning strategies, performance goal, achievement goal and learning environment stimulation. The respondents were required to give their sincere opinions on a 4 point Likert scale. The questionnaire has a Cronbach's alpha value of 0.80.

The game-based learning system

The framework used in designing the game-based learning system was based on the ADDIE instructional design model. The model involved five processes - analysis, design, development, implementation, and evaluation. Analysis was to the process of determining the instructional goals and objectives, including the learners' characteristics, preferences and environment. Design consisted of the specific knowledge and skills the learners ought to attain at the end of the study while development involved the integration of game-based learning strategy with the identified learners' characteristics, need and other environmental logistics. The board game package that was employed for this study was also developed based on Bates, Brown, Cranton and Lewis' (2010) six steps requirement for the design of a board game. These are content analysis, incubation, chunking, aligning, drafting, and incubating.

Figure 1: Board game six steps model according to Bates, Brown, Cranton and Lewis (2010)

The board game was designed to teach learners the concept of motion in senior secondary school one physics course. The activities involved included the awareness of motion, identification of different types of motion, explanation of position, displacement and velocity, awareness of force, identification and description of friction, and exercise unit. In achieving these objectives, the board game divided numbered and coloured squared paths from start to finish using the principle of traditional monopoly and snake/ladder game. The game also had chance squares, problem squares and knowledge squares for giving learners more opportunity to learn about the concept of motion

Figure 2 shows the interface of the board game. The game required more than one player. Each player chooses a character (car, airplane, power bike and ship toys), and moves on the board based on the number that he or she gets of the dice. At problem squares, players can answer the questions based on the topic taught to collect a colour piece and the attached prize from the banker. Players who land on a property can either purchase it (if not yet purchased by other players) or pay the accompanying rent fee. Chance squares were designed to give players wild cards during the game play. Knowledge cards give players the opportunity to learn more during the instructional process. The player(s) who was able to collect all or most colour pieces of question card, as well as own the highest number of properties becomes the winner.

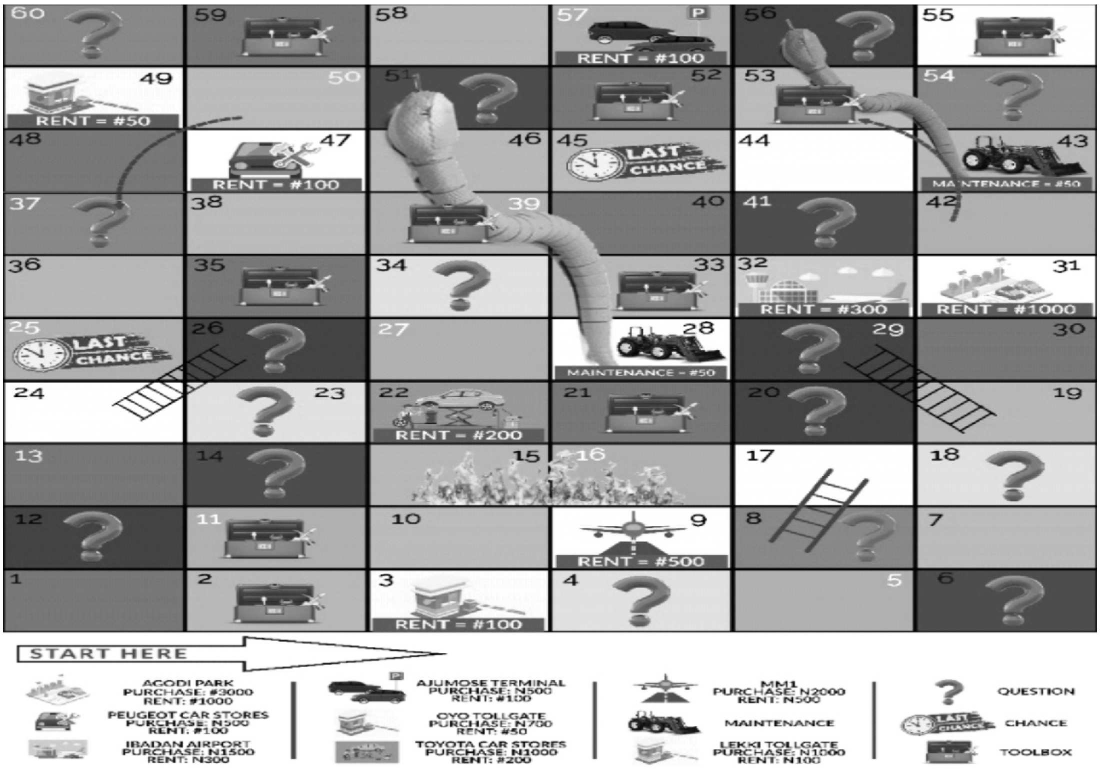

Figure 2: *The board game interface*

The gamified learning system

1. The game-play learning system was designed using the ADDIE model to teach the concept of motion. The elements of gamification that were employed were points, badges and leader boards as shown in Figure 3. Regular physics classes were broken into short frames, with each frame adopting activities that allowed individual students and group of students to earn points. Class activities were in two modes - individual and group activities. Individual activities were the activities set for each student while the group activities were the activities that involved groups of learners working together. Individual activities were rewarded with points and badges while the group activities were awarded points and leader board. The researcher also implemented a class-wide reward system where everyone celebrated individual and collaborative accomplishments.

Figure 3: Sample point and badges used in the study

Experimental Procedure

The experimental procedure consists of stages: the pre-test, the implementation of the packages and learning tasks, and the administration of post-test.

During the pre-test, all students in the three groups took the physics achievement pre-test, and completed both the motivation and the attitudinal questionnaires. This lasted for a period of one-week. After the pre-test the students were exposed to the instruction and learning activities which lasted six (6) weeks. During this period, the students in the experimental group A learned with the game-based learning approach. Those in experimental group B learned with the gamification approach while the students in the control group learned with the traditional teacher-centred method.

At the end of the administration of treatments, all the students took the post-test and completed the motivation and attitude questionnaire and achievement test. This lasted one-week.

Results

Hypothesis 1: There is no significant main effect of treatment on students' achievement in Physics

Table 1*:* ANCOVA result of the post -achievement scores of the three groups

Variable	Group		N	Mean	SD	Adjusted Mean	Std. Error	F
Post-test	**(EA)**	**Experimental group A**	**29**	**5.78**	**2.23**	**7.738**	**.320**	**18.53***
	(EB)	**Experimental group B**	**32**	**6.84**	**3.07**	**7.096**	**.300**	
	(C)	**Control group**	**32**	**5.41**	**1.64**	**4.795**	**.384**	

This study adopted the pre-test scores of the physics achievement test as the covariate for the analysis of covariance (ANCOVA) to avoid the possible influence of the pre-test on physics achievement. It was found that there was no significant interaction between the independent variable and the covariate of the physics achievement test ($F = 18.53$, $p > .05$; this implies that the three groups possessed equivalent physics knowledge before the experiment. Further ANCOVA analysis was subsequently conducted.

Hypothesis 2: There is no significant main effect of treatment on students' attitude to physics.

Table 2 : *ANCOVA result of the ratings of the attitudinal post -questionnaire rating of the three groups*

Variable	**Group**		**N**	**Mean**	**SD**	**Adjusted Mean**	**Std. Error**	F
Post-test	(EA)	Experimental group A	32	79.28	12.95	89.05	1.45	11.26*
	(EB)	Experimental group B	32	85.09	13.57	85.56	1.37	
	(C)	Control group	29	79.28	8.04	78.31	1.76	

After the experiment, ANCOVA was used to compare the post-attitudinal scores of the students by excluding the impact of the pre-attitudinal scores. Table 2 shows the descriptive data and ANCOVA result. The adjusted means of the experimental group A, experimental group B and the control group were 89.05, 85.56, and 78.31 respectively. Results also showed that the three groups had significant differences on their post-attitudinal ratings, with $F = 11.26$, $p < .05$. Pair comparison further showed that both experimental groups A and B outperformed the control group with the experimental group having the highest adjusted mean. This implies that both GBL and gamification approach in teaching physics could significantly enhance students' attitude towards physics.

Hypothesis 3: There is no significant main effect of treatment on student motivation to learn physics.

Table 3: **ANCOVA result of the motivation post -questionnaire scores of the three groups**

Variable	Group		N	Mean	SD	Adjusted Mean	Std. Error	F
Post-test	**(EA)**	**Experimental group A**	32	77.19	8.13	75.93	.788	14.41*
	(EB)	**Experimental group B**	32	76.97	10.39	78.76	.759	
	(C)	**Control group**	29	73.00	7.15	72.21	.956	

The pre-test scores of the questionnaire on students' motivation towards physics were used as covariates for the ANCOVA. There was no significant interaction effect between the independent variable and the pre-test scores on motivation with F=14.41, p > .05. Table 3 shows the ANCOVA result of the post-motivation scores after the influence of the motivation pre-test scores were excluded. The adjusted mean of students in experimental group B was the highest (78.76), followed by experimental group A (75.93), while the control group had the least adjusted mean (72.21).

This implies that both GBL and gamification could significantly enhance the students' motivation compared to the traditional lecture method. Further comparison between the experimental groups showed that gamification could be more effective in enhancing motivation in physics than GBL.

Discussion

This study was borne out of the need to empirically investigate effective strategies for teaching and learning physics as possible solutions to the problems identified in the current strategy for learning physics. A game-based learning package that involved students playing a board game and a gamified learning environment where students could earn points and badges were developed. In other to evaluate the effectiveness of this approach, a learning activity on motion in the senior secondary school one physics was conducted to compare the learning achievements, attitude and motivation of the students who learned with the GBL approach, gamification approach and conventional instruction.

The experimental results showed that both GBL and gamification were more viable tools for enhancing learning achievements of students than the conventional lecture method. The estimated marginal mean score also showed that students in the game-based group had the highest mean score, followed by those in the gamification group while students in the conventional group had the least mean score. This finding agrees with Olaiya, Akinyemi and Aremu (2017) that GBL using board games significantly enhanced students' achievement. This may be due to the fact that students in a game-based group have more opportunities and time to work collaboratively. The strategic roles of collaboration and teamwork in promoting enhanced engagement and improved performance of students at all levels of education in classroom settings has been emphasized . The high level of achievement attained by the students in the game-based group could therefore be due to the power of collaboration and interaction that energized the exchange of ideas among participants of the group. Moreover, the level of competition in the game-based group was more established than experienced in the other groups forcing the participants to give all it takes to succeed in the game play and become the “winner”. This also could have accounted for their significantly high post-achievement scores.

In terms of attitude the result shows that there was a significant difference in the attitude of students towards physics in the three groups. This significant effect on attitude was found to be solely due to the post-test mean score of the students exposed to GBL and gamification. This corroborates Papastergious (2009); Cózar-Gutiérrez and Sáez-López's (2016) finding that students learn more actively with greater interest when the learned contents leave a deeper impression than would be possible using conventional methods. Pairwise comparison between the three groups also showed that the attitude of students in the GBL group was significantly higher than those taught using gamification and conventional approach. It therefore implies that GBL is more effective in enhancing students' attitude towards physics compared to gamification. This may be due to the fact that the students in the game-based group had the opportunity to take charge of their own instruction having gotten familiar with the rules and mechanics of the game.

On the other hand, it was found that the gamification group outperformed the other two groups in terms of motivation, while there was a significant difference in the motivation of the GBL group and conventional group. This finding agrees with various studies on gamification that reported favourable effects of gamification on students' motivation to learn (Elshemy, 2017; Reichelt, 2015). Kapp (2012) observed that games provide more engagement for the learner, more personalized learning opportunities, an environment for authentic and relevant assessment and teaches 21st century skills. These could have been responsible for the higher motivation towards physics. The gamified environment allowed students to earn individual and group points thereby fostering healthy competition within and between groups. On the other hand, participants in the game-based group had no opportunity to compete with each other within groups. This finding however negates that of Meyer (2008) who reported that the use of points had no effect on students' motivation to post in an online discussion forum.

Conclusion and Recommendations

Although the findings in this study have been able to show game-based learning and gamification as effective approaches to enhancing students' achievement, attitude and motivation towards physics, there is still a need to conduct longer experiments with larger samples of heterogeneous groups to further investigate the effectiveness of GBL and gamification. GBL and gamification can be applied to lower levels of education such as pre-schoolers and primary school pupils to better understand possible interaction effect between pupils' age levels and abilities.

Furthermore, some improvement can be made to the current gaming model by making use of indigenous games that appeal to the students.

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