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Abstract

Index terms—

1 INTRODUCTION

Concepts learned in physics significantly impact society because they are frequently used in several scientific and technological advancements ??MoE, 2010). For this reason, one of the objectives of the Senior High School physics programme in Ghana as stipulated in the 2010 Physics syllabus is to encourage and maintain students' enthusiasm in physics as a practical tool for societal change ??MoE, 2010, p. ii). Attainment of such an objective means physics concepts must be taught in ways that are able to sustain and maintain students' interest in the subject (Antwi & Sakyi-Hagan, 2015; Wieman et al., 2010). In the classroom, the use of relevant instructional resources to support the teaching learning process significantly impacts students' performance and maintain their interest in learning concepts taught (Adebayo & Adigun, 2018). An instructional resource that has been proven by research in the 21st century to help encourage and maintain students' enthusiasm towards learning is the use of interactive simulations such as the PhET simulation ?? animations, visualisations and interactive laboratory experiences that present theoretical or simplified models of real-world components, phenomena, or processes" (Bell & Smetana, 2008). Simulations have also been proven to give real life view of theoretical concepts, motivate and sustain learners' interest and makes students active participants during the teaching-learning process (Antwi & Sakyi-Hagan, 2015; Wieman et al., 2010). Simulating situations increases students' interest and encourages engagement through the use of role-play in the simulation environment and also develops in students critical thinking (Rahmawati et. al., 2022). This suggests that simulation has the potential to motivate learners towards learning concepts taught in the classroom.

Notwithstanding, students' performance in physics in the external examination organised by the West African Examination Council for Senior High School students in Ghana have been below average over the years (WAEC, 2015; ??016;2017;2018; ??019; ??020;2021). The report by the Physics Chief Examiner showed that students' continually show weaknesses on questions drawn from electricity concepts (WAEC, 2015;2017;2018; ??019; ??020;2021) which could account for their low performance as students who try to answer such questions are unable to provide the required answer expected by the examiner. The examiner highlighted incorrect explanation, lack of understanding and application of physics concepts as the causes of students' low performance. In addition to these factors, research has also indicated availability and adequacy of instructional materials (Fatoki et. al., 2021), lack of understanding and application of mathematical skills in solving physics problem (Tuminaro & Redish, 2004;Semela, 2010) as well as lack of reference materials, laboratory equipment, and interest in the subject (Mekonnen, 2014) as plausible causes of students' low performance in the physics. This suggests that the use of relevant teaching-learning resources influences students' motivation which will in turn improve their performance (Lalley et. al., 2010).

Interestingly, the National Curriculum Framework of Ghana (MoE, 2018) entreats the teacher to use relevant instructional materials that will help the learner in learning. The Education Strategic plan 2018 -2030 also highlights the application of technology as relevant teaching-learning tool ??MoE, 2018). The ICT Education policy has also recommended ICT to be used as a pedagogical tool (MoE, 2018). One of the technological tools that has the efficacy to influence learning of physics is the use of computer simulations (Wang et. al., 2010).

The study specifically sought to answer the research question; What are the motivational behaviours of students in learning electricity concepts when taught with the PhET simulations in a demonstrative classroom and in an exploratory classroom?

2 II. LITERATURE REVIEW

3 Theoretical Framework

The constructivist theory is one of the theories mostly used with regards to technology assisted lessons on students' learning outcomes ((Marshall, 2007;Mensah, 2019). The engagement theory like the constructivist also emphasised a teaching methodology which has students at the core of affairs and this makes the theory have similar features to the constructivist theory and for that reason, suitable to be employed as the study's theoretical underpinning.

"The engagement theory is a framework for technology-based teaching, whose fundamental underlying principle is that students must be meaningfully engaged in learning activities through interaction with others and worthwhile activities" (Kearsley & Shneiderman, 1998). Also, proponents of this theory are of the view that learners' engagement can be facilitated using technology as a teaching tool. These theorists implore teachers to have lessons that are activity oriented in order to help students apply creative and innovative ideas to solve problems. Also, these activities should be motivating and interesting to students and they believe that The engagement theory also emphasises the integration of activities that promote meaningful students' learning such as students learning in groups to solve problems. This theory according to the proponents has three major parts which when put together, enhances meaningful learning by students. The components are "relate, create and donate" (Kearsley & Shneiderman, 1998). The first component which is "the relate component emphasises team efforts that involve communication, planning, management and social skills". By working in teams, students cooperate and collaborate to bring out ideas towards understanding concepts being taught since cooperativeness facilitates improvements in teaching and learning of physics (Agyei et. al., 2019).

The second component which is "the create component" involves making the teaching and learning activity creative and innovative. Under this component, the realisation of the real-life application of concepts that are taught are made known to the learner and this has the propensity of making learning more motivating and interesting to students. The PhET simulation has been proven to have the potential to offer such real-life scenarios to learners (Bell & Smetana, 2008).

The donate component of the engagement theory also emphasise the essence of making useful contributions while learning. This motivates students to learn due to their active involvement in the series of activities that go on in the classroom (Kearsley & Shneiderman, 1998).

The "engagement theory" served as the underlying theoretical underpinning of this study. Also, this theory was used since it emphasises students collaborative work as well as using technology as an instructional tool to actively engage students.

4 Impact of Computer Simulations on the Motivation of Students

According to Schunk et. al. (2014), "motivation is the process whereby goal-directed activity is instigated and sustained". This means that motivation provides the desire that encourages an individual to try and accomplish a task in order to become successful. Motivation serves as the basis for gaining understanding of scientific concepts due its significance in improving students' concept formation (Albalate et. al., 2018). Studies have shown that students' learning of science (physics) is highly influenced by their motivation. According to Albalate et. al. (2018), without motivation, students' learning will be basically by rote memorization which will in turn lead to inadequate understanding of scientific concepts. To Spandana et. al. (**??**020), motivation has the inherent effect of inspiring and increasing students' interest towards science (physics) learning. Also, students who are motivated to learn have better learning outcomes than their counterparts with low motivation (Zimmerman & Schunk, 2008).

Past studies have explored how the application of computer simulations influenced students' learning. A study done by Prima et. al. (2018) on the topic "Learning Solar System using PhET Simulation to Improve Students' Understanding and Motivation" explored how the use of the PhET simulation will enhance learner's understanding and motivate the learners to learn solar system concepts. According to the study's findings, students who learned about the solar system with simulation as a teaching tool improved on conceptual knowledge and motivation more than students who learned about the same thing without simulation. The study further revealed a moderate correlation between students' conceptual understanding and motivation towards learning solar system concepts. PhET Simulation Instruction and its Effects on Students' Motivation to Learn Physics enhance students' motivation and problemsolving skills. The study revealed that there was a significant gain in students' problem-solving skills and motivation with the use of the PhET interactive simulation as a teaching and learning resource. All these suggest that the use of the interactive PhET simulation in teaching physics concepts significantly improves students' motivation.

5 The Students Motivation Towards Science Learning (SMTSL)

Studies have been conducted using the SMTSL to determine students' motivation towards specific content areas in science (physics, biology, chemistry). A study conducted by Spandana et. al.

(2020) used videos and quizzes to determine students' motivation towards science (physical science and biology concepts) using the SMTSL developed by Tuan et. al. (2005). The study revealed that significant changes were observed in learners' motivation on the concepts taught with active learning strategy having the highest mean and performance goal having the lowest mean. In another study done by Albalate et. al. (2018), the researchers investigated the motivation of STEM university students towards science learning using the SMTSL. It was observed that all students scored higher on all the domains of the SMTSL questionnaire except performance goal which attained a lower score. Achievement goal attained the highest mean score followed by active learning strategies with performance goal attaining the lowest mean score which suggest that students are motivated to learn for their own sake and not to compete with friends and also to impress the teacher during the teaching-learning process. Furthermore, Dermatsaki et. al. (2012) adapted the SMTSL in the "Greek language to determine students' motivation towards physics learning". The aim of the study was to test the factorial structure of the SMTSL in order to "provide information on the reliability and structural validity of the SMTSL in different cultural contexts" with emphasis on physics learning. The results of the study showed that the items on the SMTSL questionnaire were reliable and valid. The researchers further recommended that to use the "SMTSL in different cultural contexts, a rewording of some of the items might be needed". SMTSL is useful for determining motivation in subject-specific content areas, a predictor of attitude towards learning and performance with the items being reliable to determine students' motivation towards physics learning in different cultural contexts and grade levels. This makes the SMTSL questionnaire appropriate to be adapted for the current research which sought to determine students' motivation on learning electricity concepts in physics.

6 III. METHODOLOGY

7 Research Design

The study employed the explanatory sequential mixed methods design. In this approach, researchers collect quantitative data first, analyse the data and then use qualitative data to give a detailed explanation to the quantitative results obtained (Creswell & Creswell, 2018). This approach to research is considered to be explanatory since it uses qualitative data to explain quantitative results and its sequential nature is based on the fact that quantitative data is collected before a qualitative data (Creswell & Creswell, 2018). The collected data was analysed quantitatively. After this analysis, the researcher interviewed a sample of the students to help understand why there was a decrease in the mean score on performance goal.

8 Participants for the Study

The participants were first-year Senior High School science students selected from two Senior High Schools in the South Dayi district of the Volta region of Ghana. The two schools were identified as School A and School B for purposes of anonymity. The sample size consisted of sixty-three (**??**3

9 Data Collection Instruments and Procedure

The Students' Motivation Towards Science Learning (SMTSL) questionnaire was adapted for the study. The questionnaire was first developed by Tuan, Chin and Shieh, (2005). The questionnaire has thirty-five (35) items with six (6) subscales on a five point Likert scale. The subscales/dimensions are self-efficacy, active learning learning strategies, science learning value, performance goal, achievement goal and learning environment stimulation.

According to Tuan et. al. (2005), the questionnaire is useful when a researcher is interested in determining students' motivation in a particular content area of a subject since students show different motivational traits in different content areas. This makes the use of the SMTSL questionnaire relevant in this current study.

The six subscales on the SMTSL questionnaire measure students' motivation for learning science (Bawaneh & Moumene, 2020). The scales on the questionnaire are described below:

? Self-efficacy involves the learners' perceptions on their own capabilities to do well on classroom learning activities;

? Active learning strategies deals with the participatory position of the learner during classroom activities which requires the learner to apply comprehended knowledge to solve learning problems;

? Science learning value requires learners to comprehend the invaluable impact of science in daily life which will in turn lead to the arousal of students' interest in learning. This brings about the use of creative and innovative strategies such as inquiry, problem-solving and critical thinking which the student will apply to learning situations; ? Performance goal deals with the learner's rationale to take part in class activities. Among such rationale include being seen as an academically good student by the learner's peers and teachers and also to obtain higher marks on test activities in the classroom;

? Achievement goal deals with the learners' inherent characteristic to feel happy and fulfilled when able to solve a learning problem. This inherent characteristic has the tendency to arouse students' interest to learn; ? Learning environment stimulation deals with the use of activities capable of sustaining students' interest in learning. This includes the use of instructional resources such as interactive simulations which are able to create a lively classroom atmosphere for learning to occur (Tuan et. al., 2005, p. 643).

The original test items have an overall Cronbach alpha (?) reliabilty coefficient of 0.89. The Cronbach alpha (?) reliability coefficient of the questionnaire items in this study was 0.88 which implies that the items were reliable (Creswell & Creswell, 2018).

To obtain qualitative information on students' motivation, the researcher used a semi-structured interview to obtain in-depth information on students' views of the PhET simulation assisted lessons on their motivation to learn electricity concepts.

10 IV. DATA ANALYSIS

The study employed both descriptive and inferential statistics to analyse quantitative data while content analysis was used to analyse the qualitative data obtained through the interview.

Means and standard deviations were used to ascertain students' motivation before and after they were taught electricity concepts with the PhET interactive simulation. Independent sample t-test and paired sample t-test at a confidence level of 95% were used to compare students' motivations before and after teaching with the PhET in both demonstrative and exploratory lessons.

The students' motivation mean scores were categorised based on a criterion adopted from Ofori and Dampson (2012) cited by Akoto-Baako (2020). A mean score of 1.00 -1.99 denotes low motivation, 2.00 -2.99 denotes a moderate motivation and 3.00 -3.99 denotes a high motivation.

© The overall motivation mean score for School A (M = 2.67, SD = 0.19) and that of School B (M = 2.52, SD = 0.13) showed that students in both schools have moderate motivation before the intervention. It could also be observed that performance goal had the highest score on students' motivation before the intervention (M = 2.87, SD = 0.67) while learning environment had minimal influence on students' motivation in School B (M = 2.16, SD = 0.16). All the constructs moderately influenced students' motivation to learn electricity concepts in physics. The higher mean score for performance goal could suggest that students' rationale for learning physics concepts could be to obtain higher scores on tests, to impress the teacher and also to be seen as smart students. The low mean score for learning environment (M = 2.16, SD = 0.13) could imply that students do not find the physics learning environment (classroom) to be interesting and interactive.

To ascertain students' level of motivation towards physics (electricity concepts) after being taught with the PhET interactive simulation, motivation means scores for both schools were computed.

Table 2 showed the mean scores of students on the various motivation constructs after the intervention for Schools A and B. The overall motivation means of 3.26 for School A and 3.38 for School B indicates a high motivation. This means that students' motivation on electricity concepts increased after being taught the concepts using the simulation in either a demonstrative classroom or in an exploratory laboratory.

To ascertain whether mean scores for the two schools differ significantly or not, an independent sample t-test was performed and the result presented in Table 3. The t-test results in Table 3 showed that there was no statistically significant difference in the mean scores of students in Schools A (M = 3.26, SD = 0.29) and B (M = 3.38, SD = 0.15), t (61) = 1.994, p = 0.051. This implies that when the PhET interactive simulation is used in teaching electricity concepts either in a demonstrative classroom or in an exploratory classroom, it has the potential to sustain students' interest and motivate them to learn the concepts taught.

Also, to ascertain whether there was significant difference in the mean scores between the pretest and posttest scores, a paired sample t-test was performed for all the two schools and the results shown in Table 4. The results showed that there was a statistically significant difference in the mean scores between the pretest (M = 2.67, SD = 0.19) and posttest scores (M = 3.26, SD = 0.29) for School A, t (31) = 10.399, p = 0.000. Again, there was a statistically significant difference in the mean scores between the pretest (M = 2.52, SD = 0.13) and posttest scores (M = 3.38, SD = 0.15) for school B, t (30) = 19.850, p = 0.000.

The effect size was computed to be 0.777 for School A and 0.933 for School B. This indicates a large variation between the pretest and posttest scores and suggests that students' motivation to learn electricity concepts increased when they

11 VI. DISCUSSION OF RESULTS

Findings from the study revealed that before the use of the interactive simulation in teaching electricity concepts, students' motivation to learn electricity concepts was moderate for both schools. On the motivation subscales, students in school A had a higher mean score on performance goal (M = 2.87, SD =0.67) and students in school B had a higher score on self-efficacy (M = 2.89, SD =0. 19) followed by performance goal (M = 2.79, SD = 0.34) before the intervention. However, after teaching electricity concepts using the PhET interactive simulation, students' motivation significantly increased for School A (M = 3.26, SD = 0.29) and School B (M = 3.38, SD = 0.15). This finding corroborates with previous studies (Prima et. al., 2018; **??**anao et. al., 2022;Susilawati et. al., 2022) who found that the use of the interactive PhET simulation in teaching physics concepts led to an increase in students' motivation from a lower level to a higher level. It was also found that the mean scores of students on all the motivation scales increased significantly except performance goal which recorded a lower mean for both School A (M = 2.46, SD = 0.45) and School B (M = 2.27, SD = 0.36) after using the PhET simulation to teach. This finding was in line with the studies conducted by Spandana et. al. (2020) and Albalate et. al. (2018) who also observed that performance goal recorded the lowest mean score after students have been taught with

PhET simulation which implies that students now feel motivated to learn not just to impress the teacher but for their own personal gains. However, there was no significant difference in students' motivation towards electricity concepts taught with the PhET simulation in a demonstrative classroom and in an exploratory classroom as revealed by the independent sample t-test analysis. This suggests that teachers can use the PhET simulation to motivate students to learn electricity concepts in a demonstrative classroom if a computer laboratory is not available for use. Again, it was found that learning environment stimulation recorded the highest mean score for both schools after the intervention. However, School B recorded a higher mean score on this scale than School A. This finding corroborates with the findings of Agyei (2019), Agyei and Agyei (2021) who indicated that students in the exploratory classroom had access to computers with the simulations installed on them which made their lessons livelier than those who had it in the demonstrative classroom. Also, in order to find out why students' mean score on performance goal dropped after being taught electricity concepts with the PhET simulation, three students were randomly selected from each school and interviewed to gain more understanding concerning the results obtained. All the students interviewed mentioned that they participated in the lesson from the beginning to the end. When the students were asked why they participated in all the lessons taught with the PhET simulation, they gave the following responses: S1: I participated in the lesson because this was the first time I have seen physics being taught in a computer laboratory or doing physics on a computer. I always think the computers are meant for ICT lessons.

12 S2: I joined the lesson every time because I became curious on the first day that we had the lesson with the thing (referring to PhET simulation) and so I wanted to learn more from it. S3: I was very happy we were learning physics with a projector and also how I could just visualise circuit symbols. I don't think I will forget these circuit symbols because you click on the component and it changes to its symbol and a click brings it back to the original component.

Students' reasons for participating in the study were reasons personal to them and not because they have to attend the physics class. Students were also asked whether their reason for participating in the lesson was hinged on impressing the teacher or having higher scores than their friends. Below are some of the responses given by students. PhET Simulation Instruction and its Effects on Students' Motivation to Learn Physics S4: Sir, you can find out from my friends, they will tell you I am a punctual student and I attend all classes. We have always been told when resistors are in parallel, the current is shared among them and I have been thinking about how it is shared. But from this lesson I saw with my own eyes how the moving current divided when it got to the junction. I was more curious about seeing this because I know when I understand I can do well in class. S5: I know I perform better than some of my friends and some also do well than me. What I was more concerned with was trying to build different circuits to see which of the bulbs will give a brighter light. S6: As for me, I always want to understand things so that I can explain in my own way. Sir, I know you are not going to be here with us all the time so I want to understand the thing well.

Students did not particularly join the lesson to impress the teacher or have better marks than their friends. Students were more concerned with their achievement goal more than their performance goal. The researcher further finds out from students whether they enjoyed the lesson taught with the PhET simulation and would also like to have more physics lessons. Below are some of the responses given by the students.

13 S7: The lesson was very interesting and l really enjoyed it. I wish we always learn with this tool (referring to the PhET simulation).

S8: I really enjoyed the lesson because I was able to create my own circuits. To me, I would like to have more lessons with the PhET.

14 S9: The lesson was fun and interesting because I could see what was happening when you either change the voltage or current in the circuit. I would like to have more physics lessons everyday only when it will be taught with the PhET.

From students' responses, the interactive PhET simulation was interesting and fun learning with it. They further highlighted that they will enjoy other physics lessons when those lessons are also taught with the PhET simulation. The responses given by respondents suggest why there was a drop in students' performance goal after the intervention and the rest of the motivation constructs attaining a higher mean score.

15 VII. CONCLUSION

It was revealed by the study that the PhET interactive simulation improved students' motivation towards studying electricity concepts. There was a statistically significant difference between students' motivation before the intervention and after they were taught the concepts with the PhET for both schools. Particularly, no significant difference was observed between the motivation of learners towards studying electricity concepts for students taught in a demonstrative classroom and those taught in an exploratory classroom. Also, performance goal scale of motivation recorded a higher mean score before the intervention than after the intervention. Interview data revealed that students' motivation towards learning electricity concepts was hinged on their achievement goal. This suggests that the PhET interactive simulation offers the affordances of increasing students' motivation towards physics learning (Prima et. al., 2018; **??**anao et. al., 2022;Susilawati et. al., 2022).

16 VIII. RECOMMENDATION

It is therefore recommended that stakeholders in education should include the PhET simulation in the physics curriculum as an instructional resource for teaching electricity concepts since it has the potential to increase students' motivation towards learning physics concepts. Again, the government and other stakeholders must make efforts to provide projectors to schools so that physics teachers who want to teach electricity concepts can use the PhET simulation in a demonstrative manner to teach since using the PhET interactive simulation in the demonstrative classroom also improved students' motivation.

17 Competing Interest

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Figure 2: 15 |

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Figure 3: 15 |

"Interactive simulations" are "computer-generated dynamic models which include

Figure 4:

1

Motivation Construct	Intervention School A N = 32		School B N = 31	
	M	SD	M	SD
Self-efficacy	2.66	0.40	2.89	0.19
Active Learning Strategy	2.60	0.30	2.65	0.26
Physics Learning Value	2.77	0.75	2.34	0.30
Performance Goal	2.87	0.67	2.79	0.34
Achievement Goal	2.38	0.35	2.27	0.41
Learning Environment Stimulation	2.71	0.60	2.16	0.16
Overall motivation	2.67	0.19	2.52	0.13

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Figure 5: Table 1 :

2

Motivation Construct	Intervention School A N = 32		School B N = 31	
	M	SD	M	SD
Self-efficacy	3.44	0.35	3.58	0.17
Active Learning Strategy	3.37	0.37	3.52	0.26

PhET Simulation Instruction and its Effects on Students' Motivation to Learn Physics

Figure 6: Table 2 :

3

School	N	M	SD	t	df	P
A	32	3.26	0.29	1.994	61	0.051
B	31	3.38	0.15			

Figure 7: Table 3 :

17 COMPETING INTEREST

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School	N	Post-Questionnaire M	SD	T	df	P	2 ?
	Pretest	2.67	0.19	10.399	31		
A	32					0.000	0.777
	Posttest	3.26	0.29				
	Pretest	2.52	0.13	19.850	30		
B	31					0.000	0.933
	Posttest	3.38	0.15				

Figure 8: Table 4 :

Physics Learning Value	3.47	0.35	3.50	0.34
Performance Goal	2.46	0.45	2.27	0.36
Achievement Goal	3.28	0.43	3.58	0.25
Learning Environment Stimulation	3.55	0.45	3.83	0.19
Overall motivation	3.26	0.29	3.38	0.15
| Volume 23 Issue ?"? Compilation 1.0 15 |			© 2023 Great] Britain Journals Press	

Figure 9:

The authors received no funding for this research work.

[PhET Simulation Instruction and its Effects on Students' Motivation to Learn Physics] , *PhET Simulation Instruction and its Effects on Students' Motivation to Learn Physics*

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