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Exploring Students' motivation and academic performance in learning ohm's law using PhET simulations

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Abstract

Science teachers face several challenges in creating and implementing inquiry-based learning in Physics education. Part of this problem can be attributed to the fact that Physics is an imaginative science, which limits the students' readiness to grasp the concepts and demotivates them to pursue further studies related to Physics. This only suggests the need to introduce strategies that promote easy visualization and cultivate students' interest in the subject. This study examined the effect of PhET simulation on the academic performance and motivation of Grade 10 students to learn Ohm's Law. Specifically, it aimed to a) compare the students' pretest and posttest scores; b) determine their level of motivation in the five motivational areas (i.e., intrinsic, self-efficacy, self-determination, grade, and career); and c) determine the relationship between students' motivation and post-test score. Using the Physics Motivation Questionnaire II (PMQ-II), 61 students were surveyed after a 2-week lecture in Ohms' law. A paired t-test revealed that the PhET simulation is valid for improving the performance of the students on Ohm's Law. Among the five constructs of motivation, grade motivation and intrinsic motivation were the highest after the intervention. Lastly, it was found that the posttest scores of the students correlate positively with their motivation to learn Ohm's Law. Based on these findings, it is recommended that teachers continue to utilize PhET simulation to its full potential by letting students manipulate and interact with the program.

Keywords: Academic performance; Motivation; PhET Simulation; Inquiry-based learning

1. Introduction

Science teachers face several challenges when planning and conducting inquiry-based activities in Physics education. Typical challenges include a lack of access to instructional materials deliberately constructed to aid the visualization of concepts and principles, considering the theoretical nature of Physics. Studies have confirmed that instructional materials are among the most influential factors in students' performance and motivation in the teaching-learning process, as it alleviate the cognitive burden of arduous imagination on the students' end. Kiptum [1] asserts that students have difficulty grasping specific topics since they involve a lot of mathematical computation and visualization. Experts have noted that the fields of electricity and magnetism contain the most abstract concepts in physics since they involve the movement and interaction of subatomic particles and non-contact forces Mbonyiryivuze et. al [2]. The Department of Education had already recognized the problem and selected the area of "electricity and magnetism" as one of its critical and challenging components in Science 10 [3]. In line with this perspective, it is noteworthy to recognize electricity as a challenging subject matter within the discipline of physics. This doesn't only apply to lecture

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rooms but also to science laboratories. Laboratory activities serve a variety of functions in science education, including the acquisition of science process skills such as inquiry, investigative, organizational, and communication skills.

The fields of electricity and magnetism encompass a wide range of subject matter. The curriculum consists of fundamental subjects, one of which involves Ohm's Law. This topic delves into the interactions between current, voltage, and resistance, allowing students to comprehend their interrelationships. Resistors serve the function of absorbing electrical energy and affecting the overall energy efficiency of a circuit, therefore underscoring their significance in electrical circuits. Hence, the study of Tomkelski [4], Ohm's law is an essential topic for students to comprehend the concept of energy efficiency, which holds significant relevance in their daily lives, including activities such as lighting, temperature regulation, and the usage of household devices like refrigerators and televisions. However, understanding Ohm's law requires the utilization of analytical and creative skills due to its intrinsically abstract characteristics. Making use of the formula is straightforward; however, comprehending its underlying concept requires the cultivation of patience and unwavering commitment.

Introducing inquiry activities to students can equip them with research capabilities. According to Banda & Nzabahimana [5] and Renken et. al, [6] interactive simulations enable teachers to facilitate the learning of complicated and abstract physics ideas and allow learners to acquire skills in virtual laboratory experiments. There have been several studies carried out to determine the effectiveness of simulations using computers in science education. Computer simulations have been shown to enhance the quality of instruction, students' understanding of physics phenomena, students' engagement, and students' experimentation in physics [7]. Additionally, Moore [8] states that simulation offers students access to different representations, facilitates visualization, organizes the inquiry process, and enables them to engage in several trials and feedback cycles.

Individuals' levels of motivation have an impact on how quickly they learn [9]. Although students may be equally motivated to accomplish their tasks, individual motivational sources might be different. It can be classified as intrinsic or extrinsic motivation. Intrinsic motivation is described as an individual's natural desire to participate in an activity solely for the enjoyment and perceived level of challenge it provides, whereas extrinsic motivation refers to the use of rewards as a means of driving behavior [10]. Students are more likely to be intrinsically motivated if they attribute their educational outcomes to internal elements over which they have control, like if they are interested in mastering the lessons rather than memorizing information. Extrinsic motivation, on the other hand, is referred to as the type of motivation that results from external factors that are independent of the learning context, such as winning an award or getting good grades [11].

Computer simulations, such as Physics Education Technology (PhET), are becoming a fundamental aspect of science teaching and learning. It can be utilized to support traditional instruction and encourage learning. PhET, an open-access program, is a product of the University of Colorado. Programmers designed these simulations to make initial interactions straightforward and intuitive, resulting in immediate, useful feedback for sense-making. The selection of interactive features focuses on concepts, and the simulation's intuitive layout ensures that students quickly understand how to interact with it Makransky et al. [12]. Students derive benefits from PhET simulations by having the opportunity to virtually experience fundamental physics concepts without having to purchase expensive real-life equipment. It has the potential to be effective in teaching science lessons in high school and college. The simulations have been developed so that students can investigate physical laws such as Ohm's law. Through visualization, demonstrations, and illustrations, PhET interactive simulation gives an alternative method to the traditional laboratory and can boost students' learning [12].

Batuyong & Antonio [13] tested the influence of PhET interactive simulations centered around the topic of electromagnetism on students' performance and learning experiences. The study recommended that using PhET can improve understanding of physics concepts. Similarly, Potane & Bayeta [14] discovered that the students achieved satisfactory academic achievement after being exposed to virtual learning. Furthermore, Dionson [15] claimed that when students participated in computer-based simulation activities, their performance improved. It was also revealed that after using the interactive simulations, students' attitudes toward physics lessons and experiments increased. There was a significant relationship between students' post-test achievement and their attitudes related to Physics lessons.

In the Philippines, little research has been done to explore the effect of PhET simulation on different aspects of students' motivation and its relation to academic performance in physics education. This study aims to determine the influence of PHET simulation on the student's motivation and performance in learning Ohm's Law.

Specifically, it sought to answer the following questions:

- Is there a significant difference between the pre-and post-test scores of students?
- What is the level of motivation of students in terms of:
  - Intrinsic motivation
  - Self-efficacy
  - Self-determination
  - Grade motivation
  - Career motivation
- What is the relationship between the level of a student's post-test and their level of motivation to learn Ohm's Law?

2. Material and methods

2.1. Participants

The study was implemented for 61 grade 10 students under a special science curriculum who are taking advanced physics classes at a private school in Laguna, Philippines.

2.2. Instrument

In the study, two instruments were used:

- A 25-item multiple-choice test about Ohm's Law, which was developed and administered to students as a pre-assessment and post-assessment. The assessment tool underwent content validation by four science teacher experts in the topic; and
- The Physics Motivation Questionnaire II (PMQ-II), was adopted from Glynn et al. [16] to determine the effect of the PhET simulation on the academic performance of the students. This Likert-type instrument probes the five motivational areas (i.e., intrinsic, self-efficacy, self-determination, grade, and career).
- The five-point Likert scale has arbitrary ratings of 0 to 4, which correspond to never, rarely, sometimes, often, and always. The calculated mean ranges are:
  - 0.00-0.80: Very Unmotivated
  - 0.81-1.60: Unmotivated
  - 1.61-2.40: Moderately Motivated
  - 2.41-3.20: Motivated
  - 3.21-4.00: Very Motivated

2.3. Data collection and analysis

After a two-week lecture on Ohm's Law, students were asked to perform an enrichment activity using the Ohm's Law PhET interactive simulation. They were given worksheets with guided questions. The Ohm's Law Quiz was implemented as a pre-test and post-test. Scores were tabulated and analyzed. Measures of central tendency were calculated. The effect of using PhET simulation on students' academic performance was determined by establishing a significant difference between the pre-test and post-test scores using a paired sample t-test.

After the implementation of the post-test, the students responded to the Physics Motivation Questionnaire II (PMQ-II). Data were tabulated and analyzed by getting the mean value of the students' ratings in each of the five motivational areas mentioned: intrinsic, self-efficacy, self-determination, grade, and career. It can be noted that each construct is composed of a 5-point Likert-type questionnaire. The author Glynn et al. [16] suggested that the overall mean of each construct must be calculated and treated as a ratio variable. This is the reason why, instead of starting with 1, the scale started with 0. Lastly, the relationship between the academic performance of the students after using the PhET simulation and their level of motivation was determined using Pearson's r correlation coefficient.

3. Results and discussion

3.1. Difference Between the Pre- and Posttests of Students

Prior to the intervention, students were given a 25-item multiple-choice quiz about Ohm's Law to explore their initial understanding of the topic. The scores ranged from 0 to 23, with a mean value of 16.7 (SD = 2.91). After the intervention, a parallel summative quiz was administered to test if there had been a change in their performance on the topic. This time, they got a maximum score of 24/25 with an average of 18.0 (SD = 3.19). A paired-sample t-test reveals that this

1.3 mean difference is significant, *t* (60) = -3.85, p < .001. It only implies that PhET simulation is a valid tool for improving students' performance in learning Electromagnetism (Ohm's Law). This elaborates on the growing literature showing that PhET simulation has a positive impact on student's academic achievement as it promotes conceptual understanding of abstract concepts in science subjects Banda & Nzabahimana [5], Mirana [9], Renken et.al [6], Salame & Makki [17].

Table 1 The T-Test Between Pretest and Posted of Students

	n	**max**	**min**	**mean**	**|dif|**	**Statistics**	***p***
Pretest	61	11	24	16.7	1.3	-3.85*	<.001
Posttest	61	11	24	18.0			

**Significant at p < .05*

3.2. Student's Motivation

The tables below present the results of the survey on students' motivation in learning Ohm's Law in the five areas of motivation: Intrinsic motivation, Self-efficacy, Self-determination, Grade motivation, and Career motivation.

3.2.1. Intrinsic Motivation

In terms of students' intrinsic motivation, most of them demonstrated the highest agreement in statement number 3 "Learning Ohm's Law is Interesting" (*M* = 3.02), and the lowest in item number 1 "The topic I learn is relevant to my life" *(M* = 2.89). Although students demonstrate an overall intrinsic motivation for learning the topic, which supports Mirana [9], it doesn't necessarily mean that they 'often' find it relevant to their lives. According to Tinedi [18], the motivation required by students to learn physics consists of relevance to daily life, making the activity interesting, and elevating the importance of achieving the desired outcome.

Table 2 The Intrinsic Motivation

	Mode	**Mean**	**SD**	**Description**
01. The topic I learned about is relevant to my life.	2	2.89	0.877	Motivated
03. Learning Ohm's Law is interesting.	3	3.02	0.741	Motivated
12. Learning Ohm's Law makes my life more meaningful.	3	2.44	0.866	Motivated
17. I am curious about discoveries in Ohm's Law.	3	2.75	0.767	Motivated
19. I enjoy learning Ohm's Law.	3	2.87	0.785	Motivated
Total		2.79	0.588	Motivated

3.2.2. Self-Efficacy

Compared to the other 4 constructs, students show the lowest level of motivation in their self-efficacy, with an overall mean of 2.49 (*SD = 0.782*). The majority of them often believe that they are confident in doing well in the lab and projects and in understanding the topic, but it is only sometimes do they feel confident in doing well on the test, mastering the knowledge and skills, and attaining a grade of "A" in the topic.

Table 3 The Self-Efficacy

	Mode	**Mean**	***SD***	**Description**
09. I am confident I will do well on Ohm's Law tests.	2	2.38	0.934	Moderate
14. I am confident I will do well in science labs and projects.	3	2.69	0.941	Motivated
15. I believe I can master Ohm's Law knowledge and skills.	2	2.26	0.964	Moderate
18. I believe I can earn an "A" in Ohm's Law.	2	2.31	0.975	Moderate

21. I am sure I can understand Ohm's Law.	3	2.80	0.853	Motivated
Total		2.49	0.782	Motivated

3.2.3. Self-Determination

Most of them agree that they 'often' put enough effort into learning Ohm's law, prepare well for the tests and labs, and study hard to learn Ohm's law; however, the majority admit that it is only sometimes that they use strategies to learn the topic or spend a lot of time learning. Overall, students still showed that they were motivated (*M* = 2.65) or had self-determination to learn the topic.

Table 4 The Self-Determination

	Mode	**Mean**	***SD***	**Description**
05. I put enough effort into learning Ohm's Law.	3323	3.00	0.796	Motivated
06. I use strategies to learn Ohm's Law well.	2222	2.51	1.059	Motivated
11. I spend a lot of time learning Ohm's Law.	2222	2.39	0.842	Moderate
16. I prepare well for Ohm's Law tests and labs.	3333	2.57	0.784	Motivated
22. I study hard to learn Ohm's Law	3333	2.77	0.844	Motivated
Total		**2.65**	**0.681**	**Motivated**

3.2.4. Grade Motivation

As shown in the table below, students are most concerned about their grades when they are studying Ohm's law, as the majority of students rated all statements on a scale of '5'. This indicates that most students 'always' like doing better than their peers in Ohm's law, 'always' consider getting good grades or an 'A' mark as an important goal, and 'always' think about the grade that they will get in the topic. Among the five constructs, only in grade motivation did the students attain the verbal description of *very motivated* in some of the statements, which means that grades—a form of extrinsic motivation—are still the most important goal of students when it comes to learning Ohm's law. The results are congruent with Mirana's [9] findings, where student's grade motivation is the highest and self-efficacy is the lowest of the five constructs of motivation.

Table 5 The Grade Motivation

	Mode	**Mean**	**SD**	**Description**
02. I like to do better than other students on Ohm's Law tests.	4	2.77	1.086	Motivated
04. Getting a good Ohm's Law grade is important to me.	4	3.48	0.788	Very Motivated
08. It is important that I get an "A" in Ohm's Law.	4	3.11	0.985	Motivated
20. I think about the grade I will get in Ohm's Law.	4	3.39	0.802	Very Motivated
24. Scoring high on the tests and labs matters to me.	4	3.25	0.888	Very Motivated
Total		3.20	0.730	Motivated

3.2.5. Career Motivation

When it comes to career motivation, students indicated a relatively high standard deviation (*SD* = 0.869), which means that their responses to the 5th group of questions are more dispersed. Most of them often think that learning Ohm's law will help them get a good job. This response is not always consistent, since in questions 12 and 23, it is only sometimes that they think understanding Ohm's law will benefit their career or that their career will involve the said topic.

Table 6 The Career Motivation

	Mode	Mean	*SD*	Description
07. Learning Ohm's Law will help me get a good job.	3	2.84	0.934	Motivated
10. Knowing Ohm's Law will give me a career advantage.	3	2.57	1.132	Motivated
13. Understanding Ohm's Law will benefit me in my career.	2	2.51	1.105	Motivated
23. My career will involve Ohm's Law.	2	2.03	1.183	Moderate
25. I will use Ohm's Law problem-solving skills in my career.	3	2.74	1.153	Motivated
Total		2.54	0.869	Motivated

All in all, like in all other areas of motivation, students exhibited career-related motivation toward learning Ohm's law. This is parallel to the findings of Banda & Nzabahimana [5] and Gani et. al [19] who discovered a positive impact of PhET simulation on students' motivation.

3.3. Correlation Between Students' Motivation and Performance

Table 7 The Correlation Between Students' Motivation and Performance

		Motivation	Post-test
Motivation	Pearson's r	—	
	df	—	
	p-value	—	
Post-test	Pearson's r	0.310*	—
	df	59	—
	p-value	0.015	—

Note: * p < .05, ** p < .01

The overall mean of students' motivation is 2.73, with a standard deviation of 0.58. The Shapiro-Wilk test (p =.212) shows that although the general distribution is slightly to the right of the normally distributed theoretical sample, this shape does not deviate significantly from it. The table above presents the relationship between the learners' motivation and post-test scores in Ohm's Law. Pearson r indicates a positive medium correlation between the two variables, r (59) = 0.31, $p < .05$. This only means that students who are more motivated to learn Ohm's law will more likely perform better on the topic. This result supports the findings in various studies, such as Adamma et al. [20], Banda & Nzabahimana [5], and Steinmayr et. al [21], where motivation and its different constructs are predictors of students' academic achievement.

4. Conclusion

Drawing from the results of statistical analysis done to address the research questions, this study concludes that the use of PhET simulation in science laboratories is a valid strategy for improving learners' performance in Ohm's Law. Moreover, students are generally motivated to learn the topic, and they perceive grades as the strongest motivating factor among the predictors of motivation. Thus, teachers must make good of the grading system to sustain student's motivation. Lastly, it is found that motivation is positively correlated with students' performance in Ohm's Law.

Recommendations

Based on the findings mentioned above, it is recommended that teachers utilize the PhET simulation in discussing Ohm's law to improve the students' acquisition of the concepts and principles. Since grades are the strongest predictor of student's motivation to learn the subject, teachers should plan for the effective and creative use of their grading system so that they can utilize the grades to motivate students. It is evident that if teachers make an effort to approach their lessons in a way that motivates their students, there is a greater tendency that students will perform better. It only implies that if you spoon-feed learners with information and deliver the lesson dryly, as in traditional lectures, students will lose their motivation to learn the topic of Physics. Therefore, teachers should consider how to motivate students if they want to have better learning outcomes.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest.

Statement of informed consent

Informed consent was obtained from all the individual participants of this research study.

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