The Influence of a Virtual Physics Experiment Learning Environment on Grade 9 Students' Motivation towards Physics Learning

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Abstract: Experiments are essential in physics to help students comprehend abstract concepts. Although studies had been conducted to explore whether virtual physics experiments could affect students' learning motivation, they showed inconclusive results. Therefore, this research aimed to investigate the influence of a virtual physics experiment learning environment on the physics learning motivation of Grade 9 students, combining quantitative (quasi-experimental design) and qualitative (student interviews) research methods. Participants of this research were from two different classes, divided into an experimental group (n=37) and a control group (n=37). The intervention lasted for three weeks, with one 45-min physics experiment class per week. Learning motivation was measured by the Physics Learning Motivation Test, which included dimensions like interest-enjoyment, tension-pressure, perceived choice, perceived competence, and perceived value. Based on the data analysis, we found that the virtual experiment learning environment could significantly increase students' learning motivation, especially for the perceived value dimension. Moreover, students who perceived a higher level of competence in the virtual environment were more likely to appreciate its value and utilize virtual experiments again. We expect that the implications of this study and intervention design can be a reference for teachers in incorporating virtual experiments in future physics education and provide a possible solution for conducting physics lessons during the COVID-19 pandemic. More in-depth teacher interviews are recommended to investigate the issues from different pedagogical perspectives.

Keywords: Virtual physics experiment, motivation, learning environment

1. Introduction

Physics could be abstract and complex, which could reduce learners' interest (Awan et al., 2011). Experiments are essential in physics because they are considered to be a useful tool to help students grasp abstract concepts and acquire hands-on skills (Hamed & Aljanazrah, 2020). However, the outdatedness and inadequacies of experimental equipment negatively impacted teaching and learning in traditional physics instruction (Huo, 2015), which dampened students' enthusiasm to learn physics because they didn't have enough opportunities to experience and study physics experiments. Research pointed out that the inadequacies of traditional physics experiments could be compensated by virtual physics experiments (Hamed & Aljanazrah, 2020). Virtual physics experiments could simulate real experiments by visualising some difficult-to-observe experiment phenomena and providing a flexible learning environment (Li, 2015), thus boosting student achievement (Al-Amri et al., 2020), learning interest and engagement (Ogbuanya & Onele, 2018). Although studies had been conducted to explore whether the virtual physics experiment learning environment could influence students' learning motivation, they showed inconclusive results, with an increase (Gunawan et al., 2018), a decrease (Aliane et al., 2010) and no significant effect (Aslan & Duruhan, 2021). Therefore, this study aimed to explore whether the virtual physics experiment learning environment could shape the motivation of Grade 9 students in a middle school in Mainland China. This study investigated two research questions as follows:

1) Does the virtual physics experiment learning environment affect Grade 9 students' motivation towards physics learning?
2) If so, how does the virtual physics experiment learning environment affect Grade 9 students' motivation towards physics learning?

2. Literature Review

2.1 Virtual Experiments to Create Physical Learning Environments

The virtual physics experiment is the product of virtual technology applied to physics education, allowing students to complete physics experiments online without considering time and space (Carnevale, 2003). The effectiveness of using virtual experiments to create learning environments has received considerable attention in research. For instance, Hamed and Aljanazrah (2020) found that flexible virtual experiment learning environments helped undergraduate students better prepared for real experiments. Although many studies had examined the impact of virtual experiments in teaching and learning, most of them focused on higher education and little research investigated the effectiveness in secondary education. Thus, this research aimed to investigate whether Grade 9 students' motivation would be influenced in the virtual physics learning environment and to see if the virtual physics learning environment could be exploited to promote secondary school students' physics learning.

2.2 Virtual Physics Experiment and Learning Motivation

Of the research that examined the impact of virtual physics experiments on students' learning motivation, many studies demonstrated that they could increase students' motivation, while other studies showed different results. For instance, Gunawan et al. (2018) found that students who utilised virtual experiments had higher levels of conceptual understanding because the enjoyment of using virtual experiments increased their motivation. However, Aliane et al. (2010) described the limitations of virtual labs, such as negatively affecting student motivation because of the lack of hands-on activities. Aslan and Duruhan (2021) found no significant difference in motivation between virtual and real learning environments. The above review of studies revealed different findings on the impact of virtual physics experiments on students' motivation. To better stimulate students' learning motivation in physics, it is necessary to conduct this research to explore how the virtual physics experiment learning environment may influence learning motivation.

3. Methodology

3.1 Research Design

This research was conducted in physics experiment classes in a middle school in southern China. Using mixed methods with quantitative (embedded quasi-experimental design) and qualitative (student interviews) approaches, this research investigated the influence of the virtual physics experiment learning environment on Grade 9 students' motivation toward physics learning. Figure 1 shows the overview of the research design. The two groups came from two classes with a similar academic background and were divided into an experimental group (n=37) and a control group (n=37). They were taught by the same teacher, ensuring that their learning processes did not differ significantly. Figure 1 provides an overview of the research design.

Questionnaires and student interviews were applied to collect data. Students' learning motivation was measured by the Physics Learning Motivation Test (PLMT), adapted from the Intrinsic Motivation Inventory (McAuley et al., 1989; Yin et al., 2020). The PLMT includes five areas: interest-enjoyment (IE), tension-pressure (TP), perceived choice (PCh), perceived competence (PCo), and perceived value (PV). Both groups finished the same pre-test and post-test questionnaires. Additionally, six students of the experimental group were randomly selected for interviews.

The intervention lasted for three weeks, with one 45-min physics experiment class per week. Students in the experimental group completed the intervention in the virtual environment, while the control group in the real laboratory. The virtual experimental platform created the virtual experimental environment provided in this study. An experienced physics teacher who joined this study designed the experimental content. The entire intervention consisted of three physics experiment sessions on electrical experiments.

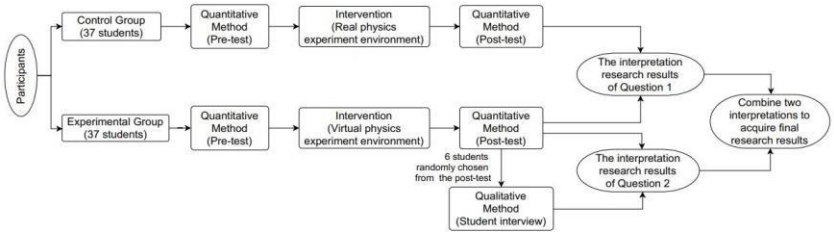

Figure 1. Overview of the Research Design

3.2 Virtual Physics Experiment Platform: Guangdong Virtual Learning Platform

The Guangdong Virtual Learning Platform (*Guangdong Virtual Learning Platform*, 2018) is an innovative digital learning platform widely used by secondary schools in Guangdong Province, a province of southern China. It provides high-quality virtual physics experiments for students and teachers to learn and simulate online, avoiding wasting time restarting experiments due to errors in the real lab. Users can also conduct virtual experiments at any time, which is not feasible in a real lab. Figure 2 shows the translated screenshot of the virtual physics experiment platform.

In this study, the virtual environment could help students learn knowledge and skills by allowing them to complete online experiments related to circuits through interaction with the virtual physics experiment platform. For instance, one of the experiments for Ohm's Law was to investigate the relationship between current and voltage. Students were required to select the appropriate range of ammeter, voltmeter, and other experimental instruments, measure the current through the resistor several times by changing the voltage, record and analyse the current law in the virtual platform, and draw conclusions.

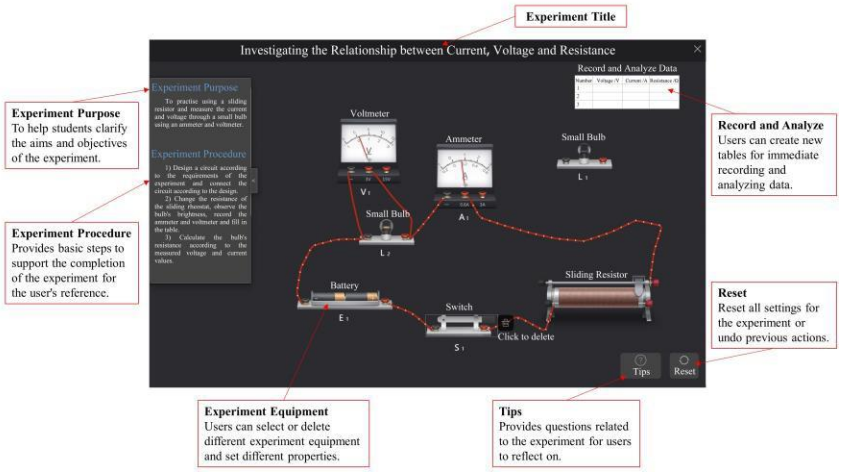

Figure 2. The Translated Screenshot of the Virtual Physics Experiment Platform

4. Results and Findings

The internal reliability of the PLMT was investigated based on Cronbach's alpha. The overall α for the questionnaire was .908, indicating that the questionnaire's data was high quality and reliable enough to evaluate the learning motivation. An independent t-test of pre-test motivation revealed no significant difference between the two groups ($p=.292>0.05$), indicating that these two groups had the same level of motivation before the intervention.

4.1 Impact of the Virtual Experiment Environment on Students' Physics Learning Motivation

The ANOVA was conducted to examine whether there were significant differences in learning motivation in the two learning environments after the intervention. The learning environments were set as independent variables, and the five dimensions of the PLMT were set as the dependent variables. Table 1 shows the result.

Statistical analysis showed that there was no significant difference in IE ($F=1.653$, $p=.203>.05$), TP ($F=.060$, $p=.807>.05$), PCh ($F=3.023$, $p=.086>.05$) and PCo ($F=1.816$, $p=.182>.05$), indicating that the virtual experimental environment could produce the same learning effect (e.g., learning interest, learning pressure) in these four dimensions as the real experimental environment. Moreover, the mean of IE ($M_E=4.927>M_C=4.517$), PCh ($M_E=4.439>M_C=3.946$) and PCo ($M_E=4.378>M_C=3.930$) in the experimental group were higher than in the control group, suggesting that after the intervention, students reported higher motivation in these three dimensions in the physics learning. This meant that students enjoyed the virtual environment more, were more likely to choose the virtual experiment environment if possible and believed that the virtual experiment was more capable of helping them improve their competence in learning physics. The mean of TP ($M_C=2.773>M_E=2.692$) in the control group was higher than in the experimental group, which indicated that students were slightly less stressed and nervous in the virtual environment. However, there was a significant difference in PV ($F=6.543$, $p=.013<.05$), suggesting that the intervention significantly impacted students' perceived value. In addition, based on the mean of PV post-test scores ($M_C=4.345<M_E=5.196$), students perceived a higher value in using the virtual physics experiment.

Table 1. *ANOVA of the Pre-test and Post-Test Learning Motivation*

Test	Dependent Variables	Groups	M	SD	F-value	P-value
Post-test	Interest-enjoyment (IE)	Control	4.517	1.509	1.653	.203
		Experimental	4.927	1.213		
	Tension-pressure (TP)	Control	2.773	1.309	.060	.807
		Experimental	2.692	1.525		
	Perceived Choice (PCh)	Control	3.946	1.403	3.023	.086
		Experimental	4.439	1.004		
	Perceived Competence (PCo)	Control	3.930	1.452	1.816	.182
		Experimental	4.378	1.411		
	Perceived Value (PV)	Control	4.345	1.500	6.543	.013
		Experimental	5.196	1.359		

The first research question can be answered based on the previous findings: the virtual physics experiment environment can increase students' physics learning motivation. Furthermore, the ANOVA results showed that the perceived value dimension presented the most significant changes, suggesting that the students in the experimental group perceived the value of using the virtual physics experiment, which boosted their motivation.

4.2 Students' Perceptions of Virtual Physics Learning Environment

Student interviews were conducted to investigate how the virtual physics experiment learning environment affects Grade 9 Students' motivation toward physics. Six participants from the experimental group were randomly invited. To protect privacy, we coded participants from ST1 to ST6. For example, ST1 is the first participant to participate in the interview.

Most students (n=5) thought they were more motivated to learn physics because they perceived improved competence in the virtual learning environment. ST1 and ST3 believed that the virtual platform had improved their problem-solving ability. ST2 improved experimental ability by repeatedly performing experimental procedures in the virtual platform. ST4 and ST5 believed that their concept-understanding ability had improved because the virtual platform helped them understand the knowledge better and made physics less complicated and abstract. Those who felt their competence had improved in the virtual environment also recognised its value. The students perceived

the increased competence as the most significant value that the virtual environment brought them (ST1, ST2, ST4, and ST6), which motivated them to be choose the virtual environment again. For example, ST2 said, "*after using the virtual experiment, I felt my experimental ability and knowledge improved. This made me more courageous to challenge difficult physics problems because I can use virtual experiments to simulate the scenes and help me understand the problems.*" This indicated that once the students perceived good experimental competence in the virtual environment, they would choose the virtual environment again to challenge difficult problems.

In general, the flexible virtual experimental environment could provide students with a good learning experience, help them improve their abilities and solve physics challenges, and therefore have a high potential to increase their motivation. Especially those students with high perceptual competence could feel a higher value in using virtual experiments to learn physics and thus be more motivated.

5. Discussion: Virtual Physics Experiment Environment Could Increase Motivation

Although the results demonstrated that students' motivation rose in both learning environments, students in the experimental group showed significant changes after the intervention, suggesting that students perceived higher motivation in the virtual environment. It was consistent with the findings of Maksoud (2018) and de Vries and May (2019). As a novel teaching tool, virtual experiments have considerable potential to motivate students to learn physics. Based on the student interviews, this is mainly attributed to the flexibility of the virtual environment. It respected students' autonomy and provided opportunities for repetitive practice, significantly increasing participants' motivation in the experimental group. When students were given choices to do what they wanted, it positively affected their intrinsic motivation (Deci & Ryan, 1987). In addition, student interviews also confirmed that those who perceived increased experimental ability in the virtual environment were more self-motivated, which explained why the experimental group witnessed a higher level of interest-enjoyment, perceived choice, and perceived competence than the traditional group. Such qualities are of immense significance to students' academic development. Therefore, the numerous potentials of virtual physics experiments as a more effective and efficient teaching aid to motivate students remains to be tapped to a greater extent.

As shown in this research, the virtual experimental environment significantly increased perceived value. Further research found that students with high perceived competence had higher perceived value, and thus were more motivated to learn physics. One possible interpretation was that students perceived increased competency in the flexible virtual learning environment, thus recognising the value of virtual learning and gaining confidence to challenge difficulties (Rodriguez et al., 2021), so they may choose to use it again as a learning tool. This is because the flexible virtual learning environment allowed students to repeat the experiment at any time, which was restricted in the real lab. Therefore, if learning designers want to increase students' motivation to learn physics, they are recommended to design instructional strategies that would enhance students' perceived competence to increase their recognition of the value of the virtual physics experiment environment.

6. Conclusion

This study used a mixed methods design with a quantitative (quasi-experimental design) and qualitative approach (student interviews) to explore whether virtual physics experiments could affect Grade 9 students' learning motivation. The results showed that the virtual physics experiment learning environment could significantly increase participants' motivation, especially in the perceived value dimension. The student interviews also aligned with the results of the quantitative analysis that students with a high perceived competence were more likely to increase their motivation through the virtual physical experiment environment. This research has contributed to filling the gap left by current findings on using virtual physics experiments to motivate students. Furthermore, the intervention in this study created a virtual physics experiment-based instructional design, which can be a reference for learning designers and teachers in incorporating virtual experiments in future physics education and provide a possible solution for conducting physics lessons during the COVID-19 pandemic. The limitation of this study is that the intervention lasted only three weeks due to the course content. If the duration could be extended, it might deepen the impact and thus increase the

potential for motivational change. In addition, teacher perspectives could be considered to investigate the issues from different pedagogical perspectives.

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