Effectiveness of Virtual Lab on Year 5 Students' Achievement and Motivation in the Topic of Electricity

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ABSTRACT

The integration of Information and Communication Technology (ICT), particularly through tools such as virtual labs, offers an innovative approach to enhance science education and overcome common learning challenges. Virtual labs can assist students in understanding abstract concepts, such as electricity, by providing an interactive and tangible learning experience. This study aimed to evaluate the effectiveness of virtual labs in improving Year 5 students' achievement and motivation in learning the topic of electricity. A quasi-experimental design with a quantitative approach was employed, involving pre- and post-tests and a motivation questionnaire. The study sample consisted of 40 Year 5 students from a school in Penang (Malaysia), divided equally into a control group (n = 20) and a treatment group (n = 20). Data were analysed using independent samples t-test. The results revealed a statistically significant difference in post-test scores between the treatment and control groups, indicating that the use of virtual labs had a positive impact on students' achievement. Furthermore, the findings from the motivation questionnaire showed that students in the treatment group had higher levels of motivation compared to those in the control group. These findings support the effectiveness of virtual labs in enhancing both students' academic performance and motivation in learning electricity.

Keywords: Virtual lab, achievement, motivation, electric circuits

INTRODUCTION

Malaysia aims to become a developed country by fostering a science-focused society, promoting innovation, cultivating critical thinking skills, enhancing problem-solving abilities, and adapting to global competition (Chongo et al. 2020) .The country's educational system places high value on achievements in science education; however, it continues to face significant challenges in nurturing students' critical, analytical, and creative thinking, particularly at the elementary and secondary levels, despite being recognized by other countries (Hin, 2015). Numerous global surveys have assessed educational performance across nations, emphasizing the urgent need for Malaysia to strengthen its education system by integrating critical thinking, problem-solving, and higher-order thinking skills to prepare students for future challenges and ensure sustained global competitiveness (Thien et al., 2015; Jia & Samri, 2024).

As students near the end of their mandatory education, countries can compare learning outcomes through the international assessment program PISA (Kastberg et al., 2015). In the Asean region, Malaysia has seen the biggest decline in Programme for International Student Assessment (PISA) scores, followed by Indonesia, Thailand, and Vietnam (Rajaendram & Dzulkifli, 2024). Singapore continued to lead, while Malaysia's overall score dropped by 6.26% from 431 in 2018 to 404 in 2022 (Nur Sahrizan et al., 2020). Brunei recorded the biggest increase, rising from 423 to 439 (3.78%). This demonstrates the difficulties Malaysian students encounter in raising their reading, science, and math proficiency. Malaysian students' performance has declined, according to the Trends in International Mathematics and Science Study (TIMSS), while Singapore and Japan have higher scores, indicating subpar science performance globally. Besides, Singaporean students show a higher interest in science than Malaysian students, with 41% enjoying learning science and 49% valuing it. A study found that Grade 8 students who enjoyed science coursework outperformed their peers on the TIMSS science exam. Students in Malaysia and Singapore who prioritized science education also outperformed those who gave it low importance (Lay & Chandrasegaran, 2016).

Given the declining student performance and waning interest in science among Malaysian students, it is crucial to explore innovative teaching strategies that can re-engage learners and improve learning outcomes. One such approach is the integration of virtual laboratories into science education. Research indicates that virtual labs can significantly improve student engagement and learning outcomes. Li and Liang conducted a meta-analysis revealing that virtual laboratories have a considerable positive impact on engineering education, particularly in enhancing student motivation and participation (Li & Liang, 2024). This finding aligns with Vries and May, who noted that virtual laboratory simulations create engaging environments that motivate students while accommodating various learning levels (Vries & May, 2019). Such interactive platforms foster an atmosphere where students can experiment, make predictions, and learn from their errors without the risks associated with physical labs (Lynch & Ghergulescu, 2017; Ghergulescu et al., 2018).

Furthermore, the specific application of virtual labs in subjects like electricity highlights their importance in teaching abstract concepts. For instance, Kollöffel and Jong emphasized the effectiveness of virtual laboratories in enhancing the understanding of electrical circuits, where students demonstrated improved skills not only in theoretical knowledge but also in procedural learning (Kollöffel & Jong, 2013). Supporting this, Nkwande et al. described virtual labs as crucial tools for mitigating challenges related to traditional physical labs, such as equipment availability and safety concerns, thereby providing students the opportunity to engage meaningfully with complex content (Nkwande et al., 2024).

The elevation of student motivation through virtual labs is echoed in numerous studies. Penn and Ramnarain's comparative analysis indicated that students exposed to virtual labs achieved conceptual understanding that surpassed those in traditional hands-on laboratory settings (Penn & Ramnarain, 2019). Moreover, according to Zhou and Feng, virtual experiments encourage student curiosity and persistence, leading to deeper learning outcomes (Peechapol, 2021). This motivation is critical, especially for younger students, as it correlates with enhanced academic achievement; students like those in Year 5 require both cognitive engagement and emotional encouragement to excel in challenging subjects such as electricity.

Research Objective

The primary objective of this research is to identify the effectiveness of using a virtual lab in enhancing Year 5 students' learning outcomes in science, specifically in the topic of electricity. The specific objectives are as follows:

1. To determine the effectiveness of using a virtual lab in improving students' achievement in learning the topic of electricity.
2. To determine the effectiveness of using a virtual lab in improving students' motivation in learning the topic of electricity.

Research Questions

The overall and specific research questions addressed in this study are:

1. Can the virtual lab improve Year 5 students' achievement in learning the topic of electricity?
2. Can the virtual lab enhance Year 5 students' motivation in learning the topic of electricity?

Hypothesis

H_{01}: There is no significant difference in students' achievement between the virtual lab group (treatment group) and the non-virtual lab group (control group) in learning the topic of electricity.

H_{02}: There is no significant difference in students' motivation between the virtual lab group (treatment group) and the non-virtual lab group (control group) in learning the topic of electricity.

LITERATURE REVIEW

The integration of virtual laboratories into science education has garnered increasing attention for its potential to improve students' understanding and engagement, particularly in abstract scientific topics such as electricity. This study explores the effectiveness of virtual labs in enhancing Year 5 students' academic achievement and motivation in learning the topic of electricity. Digital simulations have been widely acknowledged as effective tools for making abstract scientific concepts more tangible, promoting interactive learning, and supporting differentiated instruction in primary education.

The theoretical foundation for this study is Self-Determination Theory (SDT), a psychological framework developed by Deci and Ryan (2000), which emphasizes the importance of intrinsic and extrinsic motivation. According to SDT, individuals are most motivated when their basic psychological needs for autonomy, competence, and relatedness are fulfilled. Autonomy refers to the sense of volition and self-direction; competence involves the need to feel effective and capable in one's activities; and relatedness pertains to the need to feel connected to others and supported in a social context. These three components are critical in fostering sustained engagement and motivation among learners. Intrinsic motivation, which stems from personal interest or enjoyment in the task itself, can be enhanced through virtual labs that provide interactive, visual, and experiential learning opportunities (Ryan & Deci, 2020). For example, primary school students may find the concept of electricity more engaging and easier to grasp when allowed to manipulate virtual circuits and observe outcomes in real time. Extrinsic motivation, driven by external rewards or recognition, may also be stimulated through features commonly embedded in virtual labs, such as progress tracking, feedback, and gamified elements (Legault, 2020).

Kolil and Achuthan (2024) assert that virtual labs, as a form of information and communication technology (ICT), offer a learning environment that supports both intrinsic and extrinsic motivational drivers. These platforms can provide instant feedback and adaptive challenges that promote mastery and build student confidence. By allowing repeated trials and low-risk experimentation, virtual labs help students build both theoretical knowledge and practical skills in scientific inquiry, particularly in topics that are typically difficult to simulate physically, such as electrical circuits. Empirical studies support the efficacy of virtual labs in enhancing science education. Ghavifekr and Rosdy (2015) reported that ICT-based instruction leads to more effective and engaging classroom environments. Their findings indicate that students are generally more attentive and better behaved when lessons incorporate digital tools, contributing to improved classroom management and learning outcomes. Similarly, Ghavifekr et al. (2016) found that teachers held moderate perceptions of ICT use in classrooms but noted improvements in student learning efficiency and attitudes. These findings suggest that the integration of ICT, including virtual labs, can positively influence both teaching and learning experiences.

Further evidence from science education research affirms the effectiveness of virtual labs. Asiksoy (2023) found that students who participated in physics experiments using simulation-based virtual labs exhibited significantly greater conceptual understanding compared to their peers in traditional lab settings. The dynamic and iterative nature of virtual lab activities appeared to foster deeper comprehension and longer retention of key scientific principles. Durkaya (2023) also highlighted that students using virtual labs demonstrated improved confidence in conducting experiments, alongside enhanced understanding of complex scientific procedures. These students developed stronger experimental self-efficacy, which translated into better academic performance and increased motivation to engage in science learning.

Despite the many benefits, some studies point to the nuanced role of ICT in education depending on usage context. Global assessments such as those based on the Programme for International Student Assessment (PISA) suggest mixed outcomes. For instance, Alderete et al. (2017) reported that while the use of ICT at home was positively associated with academic performance in reading, mathematics, and science, its use in schools showed a negative relationship. Similarly, Petko et al. (2017) found that frequent school-based ICT use correlated with lower academic outcomes, whereas home-based ICT use for educational purposes was generally beneficial across multiple countries. These findings highlight the importance of structured, purposeful ICT implementation to ensure positive educational outcomes.

METHODOLOGY

Research Design

Studies that aim to assess interventions without employing randomization are known as quasi-experiments (Anthony et al., 2006). In line with this definition, the researcher selected a quasi-experimental design to investigate the effectiveness of a virtual lab in enhancing Year 5 students' achievement and motivation in the topic of electricity. This study adopts a quantitative research approach and applies a quasi-experimental research design **t**o achieve the research objectives.

Sampling

This study employed a purposive sampling method targeting Year 5 student. Two intact classes were selected to form the sample, with one class assigned as the treatment group and the other as the control group. This sampling strategy ensured that the participants were suitable for achieving the study's objectives, which centered on investigating the impact of a virtual lab on students' understanding of electricity and their motivation in science learning. A total of 40 students participated, with 20 students in each group. Selection was based on the similarity of their academic performance in science, as indicated by their previous test results. This approach helped ensure that any observed differences in outcomes could be attributed more reliably to the intervention rather than to pre-existing disparities in achievement levels.

Instrument

Data collection involved two instruments: the Science Achievement Test (SAT) and the Motivation Level Questionnaire (MLQ). The SAT was designed to assess students' conceptual understanding of the electricity topic and comprised ten objective questions aligned with the Curriculum and Assessment Standard Document (DSKP) and modeled after the Final Examination of the Academic Session (UASA) format. The same test was administered as both a pre-test and a post-test, with a 30-minute completion time. The purpose was to measure the cognitive gains made by students in each group after the instructional intervention.

The MLQ was used to evaluate students' motivation levels. It contained two sections: one focusing on general learning motivation (12 items) and the other on science-specific motivation (11 items). The questionnaire combined various motivational dimensions, including interest, engagement, and confidence, and was administered before and after the intervention. The items were randomized to reduce response bias and increase the reliability of results. This instrument helped capture whether the virtual lab approach positively influenced students' enthusiasm and motivation towards learning electricity.

Data Collection

The study was conducted over several phases. Initially, all participants completed the SAT and MLQ to establish baseline data. The treatment group then received instruction through a virtual lab platform during a 60-minute after-school session, where students explored and constructed electric circuits using laptops in a guided but student-centered environment. Meanwhile, the control group was taught the same content through conventional methods, including PowerPoint presentations and direct teacher instruction. Following the intervention, all participants completed the post-test and post-questionnaire in the classroom under the supervision of the researcher. The instruments were administered in a consistent and structured manner to ensure standardization across both groups. To ensure the reliability of the research tools, a pilot study involving two Year 5 students from the same school (but not from the selected classes) was conducted prior to the main study. Feedback obtained from this pilot was used to refine the SAT and MLQ items for clarity, suitability, and alignment with the learning level of the students.

Data Analysis

Quantitative data will be collected through the motivation level questionnaire, pre- and post-tests. These tools will assess how using the virtual lab to study the topic of electricity has impacted students' motivation and achievement. Descriptive statistics will be used to summarize and describe the data, while inferential statistics, such as the t-test, will be employed to determine if there are statistically significant differences in motivation and achievement between the treatment and control groups.

FINDINGS AND DISCUSSION

This study employed both descriptive and inferential statistics to address its two primary research questions.

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Descriptive statistics (mean and standard deviation) were used to summarize student achievement and motivation scores, while inferential statistics (independent samples t-test) were used to examine differences between control and treatment groups.

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Independent t-test have been used to analyse and determine whether there is a significant difference between the means of two independent groups.

Table 1: Independent samples t-test for Post-Test

T-test for Equality of Means			
	t	df	Sig.(2-tailed)
Equal Variances Assumed	-2.896	38	0.006

The independent samples t-test analysis, as presented in Table 1 revealed a statistically significant difference in the post-test mean scores between the control and treatment groups. The t-test result was $t(38) = -2.896$ with a p-value of 0.006. Given that the p-value is less than the significance threshold of 0.05, the null hypothesis was rejected. This finding indicates that there was a significant difference in students' achievement between those who utilized the virtual lab in learning the topic of electricity (treatment group) and those who did not (control group). The descriptive and inferential statistical analyses consistently supported the conclusion that the virtual lab was effective in enhancing Year 5 students' achievement in the topic of electricity. Although both groups exhibited improvement from pre-test to post-test, the treatment group demonstrated a substantially greater increase in achievement scores, suggesting that the virtual lab contributed to deeper learning and better conceptual mastery.

These findings align with the study conducted by Asiksoy (2023), which reported that students who participated in virtual physics laboratories achieved significant gains in conceptual understanding when compared to their peers in conventional laboratory settings. Similarly, prior research by Heradio et al. (2016) emphasized that virtual labs provide interactive, engaging, and flexible learning environments that support the development of scientific concepts, particularly for abstract topics like electricity. The virtual lab likely facilitated student achievement by enabling repeated exploration and experimentation, which are often limited in traditional lab environments due to time, cost, and safety constraints (De Jong et al., 2013) as shown in Figure 1. Virtual labs also offer instant feedback and visualization tools that can bridge the gap between theory and practice, making scientific principles more accessible to young learners (Makransky et al., 2019).

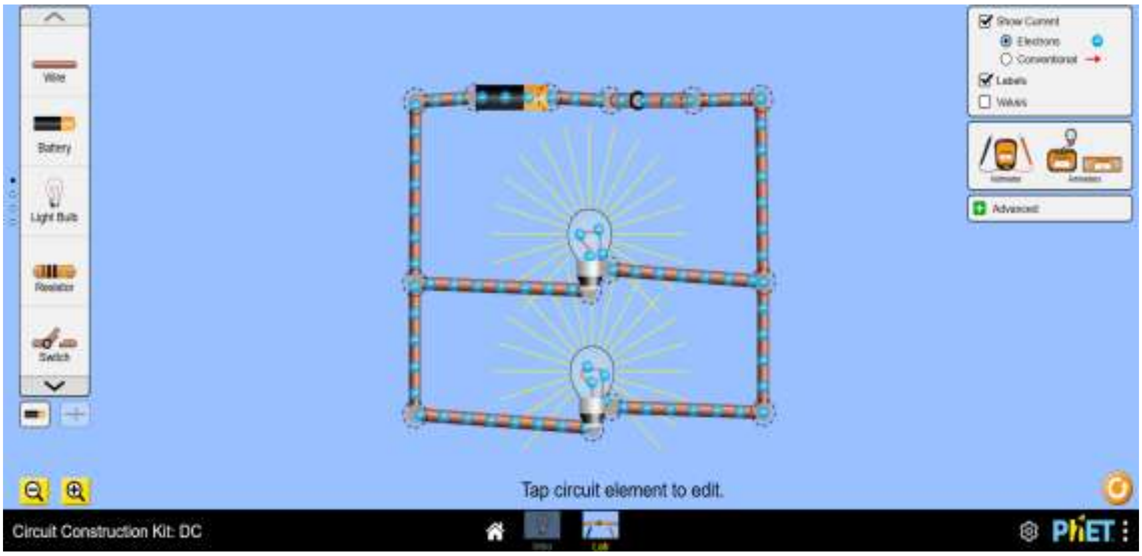

Figure 1: Virtual Lab

From a pedagogical perspective, this study provides empirical evidence supporting the integration of virtual labs in primary science education to supplement and enrich traditional teaching approaches. The virtual lab's interactive features not only improved students' test performance but potentially fostered higher-order thinking skills such as problem-solving, analysis, and application of knowledge, as supported by constructivist learning theories (Vygotsky, 1978; Piaget, 1977).

To determine the effectiveness of using a virtual lab in improving students' motivation in learning the topic of electricity.

To assess the effect of the virtual lab on student motivation, a 23-item motivation questionnaire using a 3-point Likert scale was administered pre- and post-intervention. Pre-test mean scores for both control ($M = 1.86$) and treatment ($M = 1.81$) groups indicated moderate motivation. Post-test results (control: $M = 2.07$; treatment: 2.61) were analyzed using a t-test to determine significant differences.

Table 2 **:** Independent samples t-test

T-test for Equality of Means			
	t	df	Sig.(2-tailed)
Equal Variances Assumed	-13.051	38	<.001

The results of Levene's test for equality of variances in the Post-Motivation Level Questionnaires indicated that the variances between the control and treatment groups were approximately equal, $F(1, 38) = 0.126$, $p > .05$, fulfilling the assumption of homogeneity of variances (Field, 2013). Based on this, an independent samples t-test was conducted to compare the post-motivation scores of the two groups. The analysis revealed a statistically significant difference in the mean motivation scores between the treatment group (students who used the virtual lab) and the control group (students who did not use the virtual lab), $t(38) = -13.051$, $p < .001$ as shown in Table 2. This result provides strong evidence to reject the null hypothesis, indicating that the virtual lab had a significant positive effect on students' motivation in learning the topic of electricity. The treatment group demonstrated substantially higher motivation levels compared to the control group. These findings are consistent with prior studies which reported that the integration of virtual labs in science education significantly enhances students' engagement, curiosity, and intrinsic motivation (Heradio et al., 2016; Sari et al., 2020; Makransky et al., 2019).

The increased motivation observed in the treatment group can be attributed to the interactive and exploratory nature of virtual labs, which provide a dynamic learning environment where students can actively manipulate variables and observe immediate outcomes (Kurtz et al., 2016). Such experiences are aligned with the constructivist learning theory, which emphasizes that learners construct knowledge more effectively through active participation and meaningful interactions (Piaget, 1977; Vygotsky, 1978). Furthermore, virtual labs offer a safe, repeatable, and cost-effective learning platform that mitigates the limitations of traditional laboratories, especially in schools with restricted access to physical resources (De Jong et al., 2013). This accessibility may contribute to increased student confidence and willingness to engage with complex scientific concepts.

The findings of this study suggest that the use of virtual labs had a significant positive impact on both students' achievement and motivation in learning the topic of electricity. Students who engaged with the virtual lab not only demonstrated higher post-test scores but also reported increased levels of interest, enjoyment, and engagement throughout the learning process. This positive impact can be attributed to the interactive nature of virtual labs, which allow students to visualize abstract scientific concepts, conduct experiments safely, and receive immediate feedback, all of which contribute to deeper conceptual understanding and sustained motivation. The result of this study is consistent with previous research, such as Asiksoy (2023), who also found that the integration of virtual laboratories in science learning environments significantly improved students' conceptual mastery and enthusiasm for the subject. Collectively, these findings highlight the potential of virtual labs as an effective educational tool that can address common learning difficulties in science and support meaningful, student-centered learning experiences.

CONCLUSION

The positive impact of virtual labs on students' achievement and motivation suggests that educators and policymakers should consider embedding virtual lab experiences within the science curriculum, particularly for topics that are conceptually challenging and resource-dependent. The use of virtual labs may be especially beneficial in schools with limited laboratory facilities or in remote learning contexts where physical lab access is restricted future researchers who wish to investigate the effects of virtual labs in education.

While this study demonstrated the short-term effectiveness of virtual labs, future research should investigate the long-term retention of knowledge gained through virtual lab experiences and explore their impact on students' problem-solving and critical thinking abilities. Further studies could also examine the influence of student demographics, digital literacy, and learning styles on the effectiveness of virtual labs to provide a more nuanced understanding of their educational potential.

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