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Effectiveness of digital learning on students' higher order thinking skills

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ABSTRACT

In the realm of education, learning and instructional activities play a crucial role in cultivating lasting and meaningful comprehension among science students. This research aims to evaluate the effectiveness of the i-Genius module in enhancing students' performance in science. The i-Genius module's development adhered to the ADDIE model, and two specific research questions were formulated: i) is there a statistically significant difference in mean scores between the experimental and control groups? and ii) to what extent can i-Genius contribute to students' conceptual evolution compared to traditional methods? To address these questions, a sequential mixed-method approach involving interviews, pre-tests, and post-tests was implemented in two distinct schools in the Seremban District. The experimental group comprised 35 participants, and the control group also included 35 students with similar characteristics. Student performance, assessed through pre-test and post-test mean scores, revealed that students exposed to i-Genius achieved significantly higher scores than those exposed to traditional methods in the post-test ($t(68)=8.37$, $p<0.05$). This study's implications lie in its practical application within the school context, offering an alternative instructional tool for teaching science and presenting an instructional model to guide teachers in formulating strategies that encourage problem-posing within the science curriculum.

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1. INTRODUCTION

In response to the challenges of the fourth industrial revolution, countries like Malaysia are actively enhancing science education to equip youth with a competitive skill set, emphasizing technology use, critical thinking, communication, teamwork, and problem-solving. A shift toward a student-centered model, particularly in science, technology, engineering, and mathematics (STEM) fields, is crucial for fostering cooperation, creativity, and critical thinking [1]. Learning in the STEM fields will help the next generation become more competitive [2]. According to several studies, effective learning tools, such as modules, play a vital role in shaping education quality, guiding students from theory to practical application and fostering independent thinking [3]–[6]. Digital learning emerges as a pivotal strategy, capturing interest, uncovering potential, and balancing classroom and self-learning to improve efficiency through student-centered activities [7]–[10]. The study's research objectives focus on investigating mean score differences between experimental and control groups and exploring the i-Genius module's impact on students' conceptual evolution compared to traditional methods.

2. RESEARCH BACKGROUND

Malaysia’s educational system underwent significant transformations in preparation for the 21st century, with three primary school curriculum iterations before 1982: Old Primary School Curriculum (OPSC), New Primary School Curriculum (NPSC), and Standard Primary School Curriculum (SPSC) [11]. According to previous studies [12]–[14], the goal of this curriculum is to integrate Malaysians whose ancestry includes more than one race. NPSC, introduced in 1982, aimed to provide equal opportunities for students to learn essential societal skills, while SPSC in 2011 addressed the needs of 21st-century students.

Recent studies emphasize the importance of higher order thinking skills (HOTS) in developing critical and logical thinking, analytical abilities, problem-solving, and decision-making [15]–[20]. HOTS involves complex thinking modes, resembling Bloom’s taxonomy, contributing to skills like problem-solving and creative thinking [21]–[23]. Academic success is closely linked to HOTS, influencing performance in tests, midterms, finals, and standardized scores [24], [25].

Research on college physics classes reveals the impact of HOTS on students' physics performance, emphasizing the significance of strong HOTS [26]. Engaging in hands-on activities and mental simulations is crucial for comprehending electrical concepts [27]. Students with advanced conceptual knowledge demonstrate effective problem-solving in scientific scenarios [28]. The idea of qualities and measures can be found at the intersection of scientific inquiry and physical investigation [29].

The theory of uses and gratification (U&G), developed in 1974, explores the motivations behind media consumption, influencing recent efforts in expanding digital learning modules [30]–[32]. It does so by concentrating on the reasons why individuals pick one medium over other options to suit various requirements [33]. Multimedia cognitive learning theory's design principles guide effective information conveyance through audio and visual channels, preventing unnecessary repetition and lightening cognitive loads [34]–[36]. Advancements in information technology facilitate positive outcomes in digital learning, impacting test achievement, mental aspects, and HOTS [37].

3. METHOD

The analyze, design, development, implementation, and evaluation (ADDIE) model was employed in this study's based on its selection was measured, grounded in its organizational structure, systematic approach, ease of implementation, and alignment with the theoretical underpinnings of the study [38]. This study aimed to develop an integrated electrical science curriculum with HOTS using the ADDIE model. The structured approach ensured rigorous analysis, design, and evaluation, contributing to curriculum development, and offering an adaptable methodological framework for diverse educational initiatives. The data were collected in Malaysia which involved year 5 pupils from two primary schools in Seremban District. By employing a sampling technique recommended by several researchers [39], [40], a total of 70 out of 200 students were chosen with 35 assigned to both the treatment and control groups, due to the convenience of placing students in ordinary classrooms in Malaysia. The deliberate selection of a small sample size was intended to enhance control over extraneous variables [41]. Using a quasi-experimental approach, this study examines two dependent variables (HOTS accomplishment) simultaneously for both groups during the pre-test and post-test stages. The selection of the treatment and control groups was deliberate and based on pre-test results and other pertinent features, as advised by the school administration [42], [43]. In this context, the treatment group employed a module, whereas the control group adhered to traditional teaching and learning approaches. By creating a control group, it was possible to determine the average score for traditional learning, which could then be compared to the average score of the treatment group using the i-Genius module for learning assistance.

4. RESULTS AND DISCUSSION

Students face various challenges in acquiring knowledge in science, as identified by six teachers who shared diverse perspectives on pupils' instructional difficulties. These challenges include complex terminology, insufficient cognitive abilities, misunderstandings, methodologies, subject matter characteristics, and students' perspectives. The analysis emphasizes the recurring theme of the significance of HOTS and the challenges associated with instructing and acquiring HOTS in electrical subjects. According to the teachers, students struggle with envisioning the operation of an electrical circuit and comprehending terminology related to electrical subjects. The deficiency of HOTS proves to be a major obstacle, as students often struggle to apply acquired knowledge to HOTS assignments. Many students’ memories information without offering additional explanations or demonstrating comprehension, hindering their ability to analyze material and generate suitable outcomes. Challenges in differentiating between circuits, especially series and parallel circuits, were highlighted by the teachers.

The study's data analysis, conducted on pre-test and post-test performance in electrical topics, follows recommended values for skewness and kurtosis, Table 1 indicating an acceptable univariate normal distribution for further analysis [44]. The statistical analysis reveals that the scores obtained in this study adhere closely to a normal distribution pattern, a characteristic commonly assessed through the Kolmogorov-Smirnov statistic. The hypothesis regarding the normal distribution is articulated as null hypothesis (H0): the dataset follows a normal distribution. Alternative hypothesis (HA): the dataset deviates from a normal distribution. This framework allows for rigorous examination of the data's distributional properties, enabling researchers to make informed interpretations about the underlying characteristics of the dataset.

The Kolmogorov-Smirnov test for normality in Table 2 has shown several p's less than 0.05, which is a violation of the normality assumption. However, due to the sensitivity of the Kolmogorov-Smirnov test, scores can be referred to other tests as discussed; then the normality hypothesis is accepted. Tabachnick and Fidell [45] suggest using histograms and frequency curves to further assess the normality of the score distribution. The histograms for both tests indicate a reasonably normal distribution. The normal probability plot and detrended normal Q-Q plot in Figures 1 and 2 support the normality of the variables. In these plots, observed values for each score are compared against the expected values of a normal distribution, with most scores accumulating around the zero line.

Table 1. Skewness and Kurtosis tests for pre-test and post-test

Test	Skewness	Kurtosis
Pre	0.786	0.022
Post	0.153	-0.752

Table 2. Normality test for pre-test and post-test

Test	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	Df	sig	Statistic	Df	sig
Pre	0.215	66	0.000	0.911	66	0.000
Post	0.960	66	0.200	0.973	66	0.157

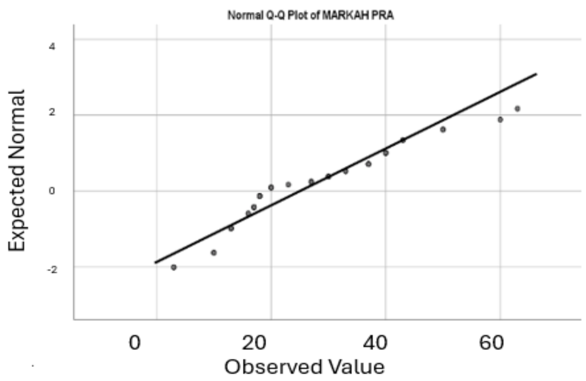

Figure 1. Plot Q-Q normal pre test

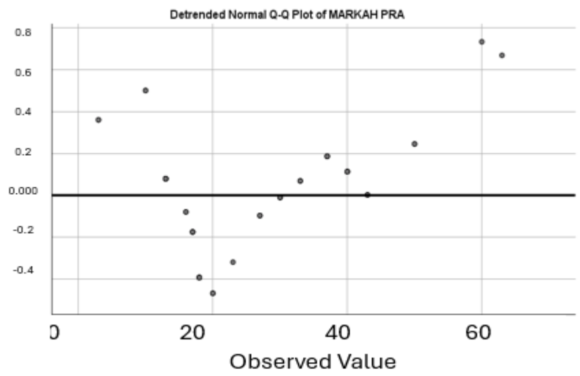

Figure 2. Plot Q-Q normal detrended pre test

Figure 3 displays the expected quantiles from a normal distribution on the x-axis and the actual quantiles from the dataset on the y-axis. Each point represents a value in the dataset, and its position relative to the line indicates how much it deviates from the expected distribution. Most points lie close to the reference line, suggesting an approximately normal distribution. However, a few points at the ends may indicate potential outliers or variations in tail heaviness, indicating possible skewness or kurtosis. In conclusion, the dataset appears to be roughly normally distributed, with potential deviations in the tails. While these deviations are common in real-world data and might not invalidate a normality assumption, further investigation may be warranted, especially if applying statistical tests or models assuming normality.

Figure 4 shows that most points in the plot align along a straight line, indicating similarity to a normal distribution. Some slight deviations, particularly at the ends, are common in many datasets and may suggest minor skewness or the presence of outliers. The central portion closely follows the line, suggesting consistent mean and variance with normality. Points at the extremes may represent outliers, potentially affecting the normality assessment, although this impact is more significant in smaller datasets.

In summary, the normal Q-Q plot of the post-test suggests the data is approximately normally distributed with minor deviations at the tails, generally acceptable for statistical analyses, especially with large sample sizes. An alternative analysis using boxplots as shown in Figures 5 and 6 reveals no extreme points between test scores, marked with an asterisk (*), but identifies slight outliers represented as small circles (°) in both tests. According to Pallant [46], extreme outliers () should be removed, while small outliers (°) can be retained, and they will be stored in the data file. The visual display suggests the study's data follows a normal distribution, supporting the testing of proposed hypotheses.

The pre-test descriptive data for the study sample are shown in Table 3. A t-test comparing pre-test scores of the treatment and control groups revealed no statistically significant difference (t-value=1.65, df=68, p>0.05). The mean pre-test scores for the treatment group (M=26.86) and control group (M=21.66) showed only a slight difference. Additionally, kurtosis values for both groups fell within the acceptable range for psychometric purposes [47] (-1.0 to +1.0), indicating an acceptable distribution for research. Descriptive data for post-test scores are presented in Table 4.

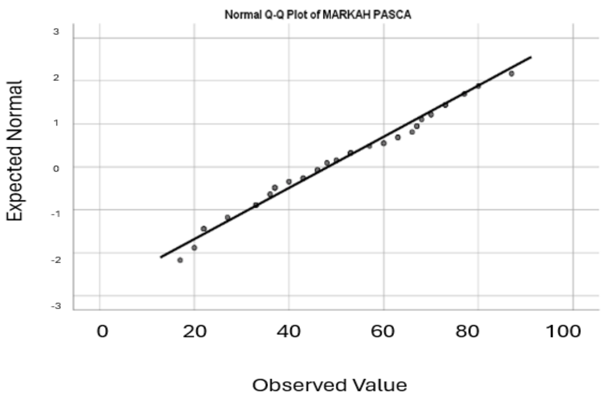

Figure 3. Plot Q-Q normal post test

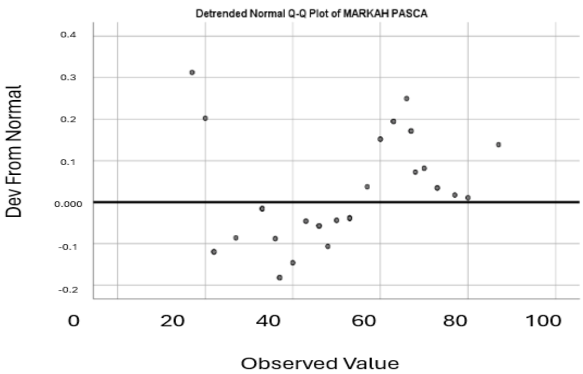

Figure 4. Plot Q-Q normal detrended post test

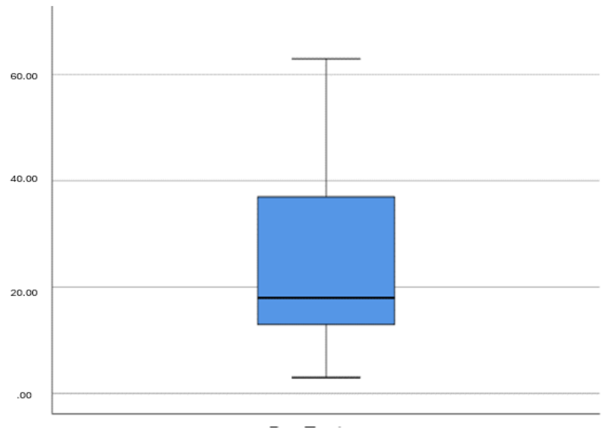

Figure 5. Boxplot pre-test

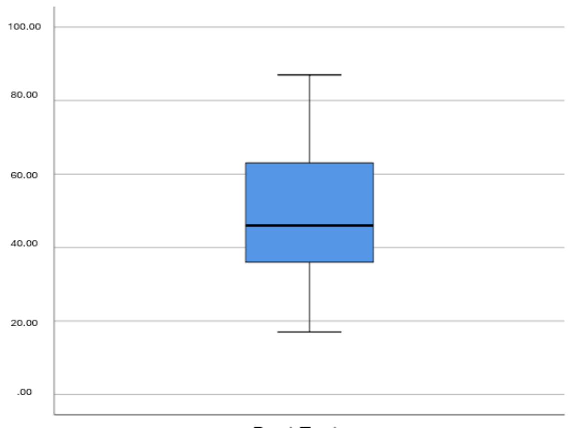

Figure 6. Boxplot post-test

Table 3. Independent t-test analysis result

Variables	N	M	SD	t	df	Sig.
Treatment	35	26.86	14.09	1.65	68	0.104
Control	35	21.66	12.24			

Table 4. Independent t-test analysis result

Variables	N	M	SD	t	df	Sig.
Treatment	35	59.03	12.94	8.37	68	0.000
Control	35	34.66	11.37			

An independent t-test revealed a significant difference in post-test scores between the treatment and control groups (t(68)=8.37, p>0.05). The treatment group (M=59.03) significantly outperformed the control group (M=34.66) on the HOTS variable, as indicated in Table 4, demonstrating a meaningful difference in HOTS between the two groups. This study provides valuable insights for teachers to diversify strategies and teaching methods in electricity topics. The i-Genius module's development enhances the teaching and learning process, particularly benefiting weaker students who can understand and master electrical topics more effectively through interactive tasks. Drawing on cognitive apprenticeship principles [48], the emphasis is on guided experiences of cognitive and metacognitive learning. Engagement with the i-Genius module involves active participation across four phases. Classroom setups are designed to facilitate collaborative learning, aligning with the principles of 21st-century learning. According to Wahyuddin *et al*. [49], collaborative learning enhances student interest and fosters critical thinking through active idea exchange in small groups. The study's findings indicate that students using the i-Genius module demonstrate improved understanding of problem-solving strategies, concepts, and information, leading to enhanced decision-making skills. Developed in alignment with the standard and curriculum document (SCD), the i-Genius module is structured to ensure students seamlessly utilize it, enjoy learning about electrical subjects, and feel motivated to tackle HOTS challenges. Results from post-intervention focus group discussions indicate that the well-organized i-Genius module, employing diverse pedagogical approaches, motivates Year 5 students to pursue knowledge. Shifting from traditional instruction to modular classrooms empowers students to collaborate, solve problems independently, and participate in group discussions [50]. In phase II of the teaching process outlined in the i-Genius module, students practice metacognition by verbalizing their thought processes, transforming implicit knowledge into explicit knowledge [51]. This allows teachers to identify misconceptions, and students evaluate their problem-solving approach [52], aligning with the active engagement strategy suggested in the Malaysian Education Development Plan 2013-2025 [52].

The study's results reveal that integrating the i-Genius module effectively enhances students' HOTS and deepens their understanding of electricity concepts [53], [54]. The hybrid approach, combining project-based and virtual learning, significantly impacts students' problem-solving abilities. The collaborative learning approach in the i-Genius module actively engages students in small groups, promoting cooperation to achieve objectives in problem-solving tasks, aligned with the education system's goal of nurturing students with problem-solving abilities [55]. Adopting the cognitive apprenticeship approach, teachers encourage students to explore unanswered questions post-module, fostering a role shift where the expert becomes the student [56]–[58]. The study provides insights into incorporating HOTS modules in scientific classes but acknowledges limitations, emphasizing the need for ongoing and improved research efforts. The study suggests rigorous approaches like controlled experiments, quantitative analysis, and cross-cultural studies to gain a thorough understanding of teaching HOTS in various educational settings [59].

5. CONCLUSION

In summary, this research offers valuable insights into students' perceptions of HOTS promotion in 21st-century education. The study, conducted over five years, demonstrates a generally positive attitude toward HOTS incorporation but reveals challenges in applying these skills in scientific classrooms. The temporal dimension adds practical insights into HOTS module implementation in Malaysian classrooms. A key finding points to a potential misalignment between prescribed curriculum and actual implementation, highlighting the necessity for closer examination of teaching methodologies. The research emphasizes the challenges students face in applying HOTS in scientific contexts, underscoring the importance of refining instructional strategies and tailoring the curriculum to practical realities. Confirmation that students benefit from well-designed modules underscores the significance of targeted curriculum development.

In conclusion, this research significantly contributes to understanding HOTS promotion in the Malaysian educational system. It underscores the practical challenges students face and advocates for a more cohesive and effective implementation of the HOTS module. The findings provide a foundation for future educational reforms, aiming to enhance the development of higher-order thinking skills among students in scientific classrooms.

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