Journal of Science and Mathematics Education
Vol. 1 No. 3, September 2025, pp. 82-88
E-ISSN 3090-0336
JOSME Journal of Science and Mathematics Education

Effectiveness of Interactive Animation Media in Improving Conceptual Understanding Physics Education at National High School of Tengku Sulaiman Malaysia

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ARTICLE INFO

Article history
Received : July 21, 2025
Revised : August 26, 2025
Accepted : August 29, 2025
Published : September 16, 2025

Keywords
Interactive Animation
Conceptual Understanding
Physics Education
Instructional Media
Secondary School

ABSTRACT

This study aims to evaluate the effectiveness of interactive animation media in enhancing students' conceptual understanding in physics education at the National High School of Tengku Sulaiman, Malaysia. The research was conducted using a quasi-experimental method with a pre-test and post-test control group design. A total of 60 students from two equivalent classes were selected as the sample, with one class receiving instruction through interactive animation media and the other through conventional teaching methods. The instrument used was a validated conceptual understanding test consisting of multiple-choice and open-ended questions tailored to the physics topics covered. Quantitative data analysis was conducted using descriptive statistics and inferential tests, including paired and independent samples t-tests. The results showed that students in the experimental group demonstrated significantly higher improvement in conceptual understanding compared to the control group. The use of interactive animations allowed students to visualize abstract concepts, engage in self-paced learning, and foster deeper cognitive connections. Furthermore, the media stimulated curiosity and motivation, leading to more active participation during lessons. These findings suggest that integrating interactive animation media into physics instruction can be a powerful pedagogical strategy to address students' learning difficulties and enhance academic outcomes. The study recommends broader implementation of such media in science classrooms and further research on its long-term impact.

How to cite: Khualid, K., & Rohmah, S, N. (2025). Effectiveness of Interactive Animation Media in Improving Conceptual Understanding Physics Education at National High School of Tengku Sulaiman Malaysia. *Journal of Science and Mathematics Education*, *1*(3). 82-88. https://doi.org/10.70716/josme.v1i3.242

INTRODUCTION

Physics education is pivotal in cultivating critical thinking, problem-solving abilities, and scientific literacy among students. However, the abstract nature of many physics concepts often poses significant challenges to learners, leading to misconceptions and superficial understanding (Dancy & Beichner, 2006). Traditional instructional methods, predominantly lecture-based, may not sufficiently address these challenges, necessitating the exploration of innovative teaching strategies.

Interactive animation media has emerged as a promising tool to enhance conceptual understanding in physics education. By providing dynamic visualizations of complex phenomena, these media facilitate deeper cognitive engagement and aid in bridging the gap between theoretical concepts and real-world applications (Ploetzner, 2020). Animations can depict temporal and spatial changes effectively, which are often difficult to convey through static images or verbal explanations.

The integration of interactive animations into physics instruction aligns with the principles of active learning, which emphasize student engagement and participation. Studies have demonstrated that active learning strategies, including the use of interactive media, can significantly improve student performance and reduce failure rates in STEM courses (Freeman et al., 2014). In physics education, active engagement through interactive simulations has been linked to higher conceptual gains compared to traditional teaching methods (Hake, 1998).

One notable example of interactive animation in physics education is the PhET Interactive Simulations project, which offers a suite of research-based simulations designed to enhance learning in science and mathematics (PhET Interactive Simulations, n.d.). These simulations allow students to manipulate variables and observe outcomes, fostering inquiry-based learning and deeper understanding. Research indicates that such tools can effectively support the development of conceptual knowledge in physics (Perkins et al., 2006).

In the Malaysian educational context, the adoption of interactive animation media in physics instruction is gaining traction. The Ministry of Education has recognized the potential of digital tools to enhance teaching and learning, promoting initiatives that integrate technology into the curriculum (Ministry of Education Malaysia, 2013). However, empirical studies evaluating the effectiveness of these tools in Malaysian schools remain limited.

Previous research in Malaysia has explored the impact of interactive multimedia on students' understanding of scientific concepts. For instance, Ahmad et al. (2020) developed an interactive computer animation module for electrochemistry topics and found significant improvements in students' achievement and motivation. Similarly, Julia et al. (2022) reported that interactive physics learning videos based on the Science Environment Technology Society (SETS) approach enhanced students' comprehension of static fluid concepts.

Despite these positive findings, challenges persist in the effective implementation of interactive animation media. Issues such as limited access to technology, lack of teacher training, and insufficient infrastructure can hinder the integration of these tools into classroom instruction (Yunus et al., 2010). Addressing these barriers is crucial to maximizing the benefits of interactive animations in physics education.

Moreover, the design and quality of interactive animations play a critical role in their educational effectiveness. Animations that are pedagogically sound, aligned with learning objectives, and user-friendly are more likely to facilitate meaningful learning experiences (Mayer & Moreno, 2002). Therefore, careful consideration must be given to the development and selection of animation media used in instruction.

The cognitive theory of multimedia learning posits that learners can better understand complex information when it is presented through both visual and auditory channels (Mayer, 2005). Interactive animations leverage this dual-channel processing by combining visual representations with interactive elements, enabling learners to construct mental models of physical phenomena more effectively.

Furthermore, interactive animations can cater to diverse learning styles and preferences, offering personalized learning experiences. Students can control the pace of learning, revisit challenging concepts, and engage with the content actively, which can lead to increased motivation and self-efficacy (Clark & Mayer, 2016). These factors contribute to a more student-centered learning environment conducive to deeper understanding.

In addition to enhancing conceptual understanding, interactive animations can support the development of higher-order thinking skills. By engaging in simulations that require analysis, evaluation, and synthesis of information, students can cultivate critical thinking and problem-solving abilities essential for success in physics and related fields (Chi et al., 1989).

The use of interactive animations also aligns with constructivist learning theories, which emphasize the active construction of knowledge through experience and reflection. By allowing students to manipulate variables and observe outcomes, animations provide opportunities for exploratory learning and hypothesis testing, fostering a deeper grasp of scientific principles (Jonassen, 1999).

Empirical evidence supports the efficacy of interactive animations in improving physics education outcomes. For example, a study by Suroso et al. (2019) found that high school students who engaged with interactive physics animation media demonstrated significant improvements in conceptual understanding. Similarly, Singh (2016) reported that interactive video tutorials enhanced problem-solving and metacognitive skills among introductory physics students.

Despite these promising results, more research is needed to understand the specific conditions under which interactive animations are most effective. Factors such as the complexity of the content, students' prior knowledge, and the level of interactivity may influence learning outcomes (Ploetzner, 2020). Investigating these variables can inform the design and implementation of more effective instructional animations.

This study aims to evaluate the effectiveness of interactive animation media in enhancing students' conceptual understanding in physics education at the National High School of Tengku Sulaiman, Malaysia. By employing a quasi-experimental design with pre-test and post-test assessments, the research seeks to determine the impact of interactive animations compared to traditional teaching methods.

The findings of this study are expected to contribute to the growing body of literature on technology-enhanced learning in physics education. Insights gained can inform educators, curriculum developers, and policymakers on best practices for integrating interactive animations into physics instruction, ultimately aiming to improve student learning outcomes and engagement.

RESEARCH METHODOLOGY

The present study employed a quantitative research approach using a quasi-experimental design with a non-equivalent control group to investigate the effectiveness of interactive animation media in improving students' conceptual understanding of physics. This design was considered appropriate since random assignment of students into experimental and control groups was not feasible in the school setting. Instead, two intact classes with relatively similar academic performance were selected. Both groups underwent pre-test and post-test assessments, enabling the comparison of learning gains between students taught with interactive animation media and those taught with traditional lecture-based methods. To ensure internal validity, the same teacher handled both groups, and the instructional content was aligned with the Malaysian national physics curriculum.

The population of the study consisted of Form 4 students enrolled in physics courses at the National High School of Tengku Sulaiman, Malaysia, during the academic year. Using purposive sampling, two classes with approximately equal levels of prior achievement, as indicated by their midterm examination results, were chosen. The experimental group comprised 30 students and received instruction using interactive animation media, while the control group, also consisting of 30 students, was taught using conventional approaches. The sample was deemed representative of the school's general student population in terms of gender, age, and academic ability, thereby increasing the generalizability of the findings within the school context.

The instructional treatment was implemented over a period of two weeks, consisting of five 80-minute lessons covering the topics of force and motion, which are widely recognized as conceptually challenging for high school students. In the experimental group, the lessons incorporated interactive animations that allowed students to manipulate variables, observe dynamic visualizations, and engage in peer discussion. The animations were carefully designed to be consistent with the cognitive theory of multimedia learning, combining verbal explanations with visual representations to enhance dual-channel processing. The control group, on the other hand, followed a traditional approach where the teacher explained the concepts through lectures, static diagrams, and textbook exercises. This contrast was intended to isolate the effect of interactive animation media as the independent variable.

The research instruments consisted of a conceptual understanding test and a student perception questionnaire. The conceptual test was adapted from the widely recognized Force Concept Inventory (FCI) and included 20 items in the form of multiple-choice and short-answer questions. Three experts in physics education evaluated the instrument to establish content validity, focusing on the accuracy of the concepts, clarity of the wording, and alignment with the curriculum objectives. A pilot study was conducted with a group of 25 students from another school, and the test produced a Cronbach's alpha reliability coefficient of 0.81, indicating high internal consistency. The questionnaire, administered only to the experimental group, explored students' perceptions of the usefulness, clarity, and motivational aspects of the interactive animations.

Data collection was carried out in three stages. First, a pre-test was administered to both groups to determine baseline equivalence. Next, the instructional intervention was delivered over the five lessons according to the designated instructional strategies for each group. Finally, a post-test identical in structure to the pre-test was administered to measure learning gains. The questionnaire was distributed immediately after the post-test to the experimental group to gather qualitative insights into their experiences. To minimize researcher bias, the test administration was supervised by the same teacher under standardized conditions, and students were not informed beforehand of the study's focus to avoid expectancy effects.

The data analysis employed both descriptive and inferential statistics. Descriptive statistics, including means and standard deviations, were used to summarize the pre-test and post-test scores. Inferential statistics were then conducted to test the hypotheses. Paired sample t-tests were used to determine within-group differences between pre-test and post-test scores, while independent sample t-tests assessed differences between the experimental and control groups. Additionally, ANCOVA was employed, with pre-test scores as the covariate, to control for initial group differences and ensure a more accurate estimation of treatment effects. The significance level was set at $p < 0.05$. Through this rigorous methodological approach, the study aimed to provide valid and reliable evidence on the effectiveness of interactive animation media in enhancing students' conceptual understanding of physics.

RESULTS AND DISCUSSION

The study aimed to evaluate the impact of interactive animation media on students' conceptual understanding in physics. A total of 60 Form 4 students from the National High School of Tengku Sulaiman, Malaysia, participated in the study, divided equally into experimental and control groups. Both groups underwent a pre-test and post-test using a validated conceptual understanding assessment.

The pre-test results indicated no significant difference between the experimental group ($M = 45.3$, $SD = 5.2$) and the control group ($M = 44.8$, $SD = 5.5$), confirming the groups' equivalence before the intervention. However, the post-test results revealed a significant improvement in the experimental group's performance ($M = 78.6$, $SD = 6.1$) compared to the control group ($M = 62.4$, $SD = 5.9$). An independent samples t-test confirmed this difference was statistically significant ($t(58) = 10.23$, $p < 0.001$).

The gain scores, calculated by subtracting pre-test scores from post-test scores, further emphasized the effectiveness of the interactive animation media. The experimental group achieved a mean gain of 33.3 points, while the control group's mean gain was 17.6 points. This substantial difference underscores the positive impact of interactive animations on students' conceptual understanding.

Effect size analysis using Cohen's d yielded a value of 2.0, indicating a large effect size and confirming the practical significance of the findings. This aligns with previous studies that have reported large effect sizes when utilizing interactive simulations in physics education (Freeman et al., 2014).

Additionally, a student perception questionnaire administered to the experimental group revealed high levels of engagement and satisfaction with the interactive animation media. Students reported that the animations made complex concepts more accessible and enhanced their interest in physics.

The significant improvement in the experimental group's conceptual understanding can be attributed to the dynamic and interactive nature of the animation media. Interactive animations provide visual representations of abstract physics concepts, facilitating better comprehension and retention (Mayer & Moreno, 2002).

The findings align with the cognitive theory of multimedia learning, which posits that learners understand complex information more effectively when it is presented through both visual and auditory channels (Mayer, 2005). The interactive animations leveraged this dual-channel processing, enabling students to construct mental models of physical phenomena more efficiently.

Moreover, the use of interactive animations supports active learning strategies, which have been shown to enhance student performance in STEM subjects (Freeman et al., 2014). By engaging with the animations, students actively participated in the learning process, leading to deeper understanding and improved academic outcomes.

The positive student perceptions further corroborate the effectiveness of interactive animations. Students reported increased motivation and interest in physics, which are critical factors in promoting sustained engagement and learning (Clark & Mayer, 2016).

These findings are consistent with previous research conducted in Malaysia, where interactive multimedia tools have been shown to enhance students' understanding of scientific concepts (Ahmad & Ahmad, 2020). The current study adds to this body of evidence by demonstrating the effectiveness of interactive animations in a Malaysian high school physics context.

However, it is important to acknowledge potential limitations. The study's sample size was relatively small, and the intervention period was limited to two weeks. Future research should consider larger sample sizes and extended intervention periods to validate and expand upon these findings.

Additionally, while the study focused on conceptual understanding, future studies could explore the impact of interactive animations on other learning outcomes, such as problem-solving skills and long-term retention. This would provide a more comprehensive understanding of the benefits of interactive animation media in physics education.

The successful implementation of interactive animations also depends on factors such as teacher training and access to technological resources. Ensuring that educators are equipped with the necessary skills and tools is essential for the effective integration of interactive media into the curriculum (Yunus et al., 2010).

Moreover, the design quality of the animations plays a crucial role in their educational effectiveness. Animations that are pedagogically sound, aligned with learning objectives, and user-friendly are more likely to facilitate meaningful learning experiences (Mayer & Moreno, 2002).

In conclusion, the study provides compelling evidence that interactive animation media can significantly enhance students' conceptual understanding in physics education. The integration of such media into instructional practices offers a promising avenue for improving science education outcomes.

CONCLUSION

The use of interactive animation media has demonstrably and significantly enhanced students' conceptual understanding of physics at Tengku Sulaiman National High School, Malaysia. Statistical findings revealed a notable improvement in post-test scores among students exposed to the interactive animations compared to those in the control group. The high effect size and substantial gain scores further reinforce the value of integrating dynamic visual learning tools into science classrooms. By translating abstract physics concepts into animated visualizations, students were able to internalize and retain information more effectively. These findings align with the cognitive theory of multimedia learning, which supports the use of multiple representations to aid comprehension. The research thus validates the integration of technology as a pedagogical tool, offering strong empirical support for its effectiveness in improving physics education outcomes.

Furthermore, the positive impact of this interactive animation media can be attributed to its ability to bridge the gap between abstract theory and real-world applications in physics. Animations allow students to visualize complex phenomena such as particle motion, force fields, or waves, which are often difficult to grasp through textual or static explanations alone. The interactivity within the animations, such as the ability to manipulate variables or observe changes in real-time, fosters active student engagement and promotes self-exploration. This approach not only deepens conceptual understanding but also cultivates students' interest and motivation towards learning physics. Consequently, the findings of this study are not only relevant to the context of Tengku Sulaiman National High School but also have significant implications for curriculum developers and educators worldwide to consider integrating interactive visual media as a core component in science teaching strategies.

Student feedback consistently indicates that interactive animations are not only pedagogically effective but also highly engaging. Learners expressed increased motivation, improved focus, and deeper interest in physics topics, particularly those typically considered difficult or abstract. This highlights the crucial role of multimedia in addressing common physics learning challenges, such as misconceptions and a lack of visualization. Animations offer opportunities for self-paced exploration, immediate visual feedback, and contextualized learning—elements often missing from traditional methods. Therefore, interactive animations serve as both cognitive scaffolds and motivational tools that enrich the learning environment, contributing to both improved academic performance and learner satisfaction. This heightened engagement is vital as it helps students stay focused on the subject matter, allowing them to build a stronger, more lasting understanding of complex physics concepts.

The benefits of interactive animations extend beyond simply making physics more enjoyable; they fundamentally change how students interact with the material. By providing dynamic visual representations, these animations help bridge the gap between abstract theory and real-world applications, enabling students to "see" what's happening at both microscopic and macroscopic levels. This is particularly helpful in resolving common misconceptions that often arise from misinterpretations of physical phenomena. Furthermore, features like the ability to manipulate variables, replay scenarios, or receive instant feedback encourage active learning and experimentation. Students aren't just passively receiving information; they are actively involved in the discovery process, which solidifies their understanding. This also fosters a sense of curiosity and confidence, empowering students to take ownership of their own learning journey in physics.

In summary, this study concludes that the use of interactive animation media should be seriously considered as an integral part of physics instruction in Malaysian secondary schools. Policymakers, educators, and curriculum developers are encouraged to embrace such innovations to align with 21st-century learning demands. Adopting these tools can help prepare students for future challenges and careers in science and technology. By systematically integrating interactive animations into the curriculum, the Malaysian education system can foster a generation of more skilled and motivated learners capable of tackling real-world problems. This also aligns with national efforts to enhance the quality of STEM (Science, Technology, Engineering, and Mathematics) education and promote critical thinking among young people.

However, successful implementation of interactive animation media requires careful attention to several key factors. Adequate teacher training is crucial to ensure educators can effectively utilize these tools and seamlessly integrate them into their teaching practices. Additionally, sufficient technological infrastructure, including access to hardware and reliable internet connectivity, must be available in all schools. Continuous evaluation is also necessary to ensure pedagogical integrity and to identify areas for improvement. Future research should explore the long-term impacts of this media on knowledge retention, the development of higher-order thinking skills, and its applicability across other science domains. By fostering more engaging and conceptually grounded learning experiences, interactive animation media has the potential to truly transform science education in Malaysia and beyond, paving the way for more innovative and student-centered approaches.

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