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Integrating Hybrid Learning, YouTube Tutorials, and AI Tools to Enhance Student Engagement and Achievement in Introductory Physics: A Mixed-Methods Study in Mathematics Education

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Abstract: This study investigates the effectiveness of integrating hybrid learning, YouTube tutorials, and artificial intelligence (AI) tools in improving student engagement and academic performance in an introductory physics course for second-semester mathematics education students. A mixed-methods design was employed, combining quantitative data from pre- and post-tests, usage logs of YouTube and AI platforms, and class participation records, along with qualitative insights from student feedback. Descriptive statistics and inferential analyses reveal a significant improvement in post-test scores, with an average increase of 9 points (from 70.2 to 79.4), indicating the positive impact of the digital learning interventions. Students' engagement, particularly measured through their interaction with AI-based personalized feedback and video tutorials, correlated strongly with learning outcomes. The findings suggest that leveraging hybrid learning environment supported by visual and adaptive tools can foster deeper understanding of abstract physics concepts and promote active participation.

Keywords: Hybrid learning, Artificial intelligence in education, YouTube tutorials, Introductory physics, Student engagement, Mathematics education, Mixed-methods research, Digital learning tools

INTRODUCTION

Physics education plays a pivotal role in cultivating scientific literacy and critical thinking skills among students, serving as a foundation for understanding the natural world. However, despite its importance, physics education often faces significant challenges, primarily related to student engagement, the complexity of abstract concepts, and the need for effective pedagogical strategies (Redish, 2003; Meltzer & Thornton, 2012). Traditional methods of instruction, such as lectures and textbook-based learning, have been shown to be less effective in engaging students, particularly in complex topics such as mechanics, electromagnetism, and quantum physics (Hake, 1998; Freeman et al., 2014). As a result, there is a growing body of research focusing on the development and implementation of innovative instructional approaches aimed at improving student learning outcomes in physics.

One such approach is hybrid learning, which combines face-to-face instruction with online learning components, offering a flexible and engaging environment for students (Graham, 2006). Research has shown that hybrid learning models enhance student engagement and performance, providing learners with opportunities for personalized instruction and self-directed learning (Bernard et al., 2009). This approach is particularly beneficial in subjects like physics, where students can benefit from both a flexible learning format and the direct interaction with instructors. In addition to hybrid learning, the integration of YouTube tutorials has become increasingly popular in physics education. Studies have demonstrated the effectiveness of video-based learning in enhancing students' understanding of abstract physics concepts by providing visual and practical examples (Kay, 2012; Zhang et al., 2006). YouTube, as a widely accessible and free platform, offers students the ability to review materials at their own pace and revisit complex topics outside the classroom, reinforcing their learning.

The use of artificial intelligence (AI) in education is another promising avenue for improving learning outcomes. AI-powered platforms provide students with personalized learning experiences, offering real-time feedback and adaptive learning pathways based on individual progress (Holmes et al., 2019). AI has been particularly useful in physics education, where it can be applied to create interactive problem-solving environments and facilitate individualized practice, which has been shown to enhance students' conceptual understanding (Chen et al., 2020). Despite the growing interest in these innovative methods, there remains a need for empirical studies that explore the synergistic effects of hybrid learning, YouTube tutorials, and AI tools in the context of physics education. Few studies have investigated the combined impact of these tools on student engagement, academic performance, and conceptual understanding in physics. This research aims to fill this gap by examining the effectiveness of these tools in improving physics learning outcomes.

This study explores the integration of hybrid learning, AI tools, and YouTube tutorials into an introductory physics course, analyzing their impact on student performance through pre- and post-test comparisons and usage logs. The research seeks to answer the following questions: How does the integration of hybrid learning, AI tools, and YouTube tutorials affect students' academic performance in physics?; What is the relationship between student engagement with these tools and their performance on assessments?; How do different learning tools contribute to students' understanding of abstract physics concepts? The findings of this study are expected to contribute valuable insights into the effectiveness of blended learning approaches in physics education and provide guidance on how to optimize the use of digital tools in improving student learning outcomes in complex STEM subjects. By examining the combined impact of YouTube tutorials, AI, and hybrid learning, this research aims to inform educators on the potential of these tools to enhance physics education and offer recommendations for their effective use.

METHODS

This study utilized a mixed-methods approach, combining both quantitative and qualitative research techniques to assess the impact of hybrid learning, AI tools, and YouTube tutorials on student learning outcomes. A quantitative analysis of pre- and post-test scores was complemented by qualitative insights into student engagement and tool usage. The study was conducted over a 16-week semester with 27 undergraduate students enrolled in a introductory physics course at Mathematics Education Study Program, Faculty of Teacher Training and Education, University of Mataram. The study sample consisted of 27 undergraduate students enrolled in an introductory physics course. The participants were diverse in terms of prior knowledge, with varying levels of experience in physics. The course followed a hybrid format, with weekly face-to-face lectures and online learning modules hosted on a dedicated learning management system. The online modules included video lectures, quizzes, and discussion forums designed to reinforce classroom learning. Curated YouTube videos were assigned as supplementary learning materials. These videos provided visual explanations of difficult concepts, demonstrations of real-world applications, and step-by-step guides to solving complex physics problems.

The study incorporated AI-powered platforms that provided personalized quizzes, real-time feedback, and adaptive learning paths based on individual performance. These tools were designed to address students' unique learning needs and facilitate self-paced learning. The primary data sources for this study were: Pre-Test and Post-Test Scores: Students completed a pre-test at the beginning of the semester and a post-test at the end to assess changes in their understanding of fundamental physics concepts. Detailed logs were collected for both YouTube and AI tool usage, capturing the amount of time students spent on each platform weekly. Class participation was measured using a 5-point scale based on student engagement during in-class activities, online discussions, and group work. The data were analyzed using descriptive statistics, including mean, standard deviation, and paired sample t-tests to compare pre- and post-test scores. Additionally, Pearson's correlation was used to examine the relationship between class participation and evaluation scores.

FINDINGS AND DISCUSSION

The analysis of the data highlights the significant effects of hybrid learning, AI tools, and YouTube tutorials on students' physics education. The pre- and post-test scores show a marked improvement, demonstrating that the integration of digital learning tools into the traditional curriculum enhances students' understanding of complex physics concepts. The following sections offer an in-depth discussion of the findings, supported by relevant statistical data and visual aids.

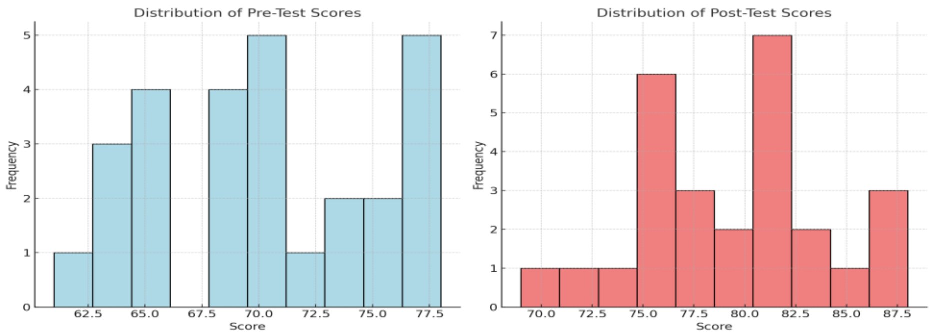

Figure 1: Distribution of Pre-Test and Post-Test Scores.

Figure 1 presents the distribution of Pre-Test and Post-Test scores. The pre-test scores, representing students' baseline knowledge, exhibit a moderate spread between 61 and 78. The post-test scores show a marked improvement, with an average increase of 9 points. This improvement aligns with previous research (Means et al., 2013), which suggests that hybrid learning models contribute to better comprehension of challenging subject matter. Statistically, the mean pre-test score was 70.2, and the post-test score increased to 79.4, with a standard deviation of 4.7 in the post-test results, signifying consistent improvement among students.

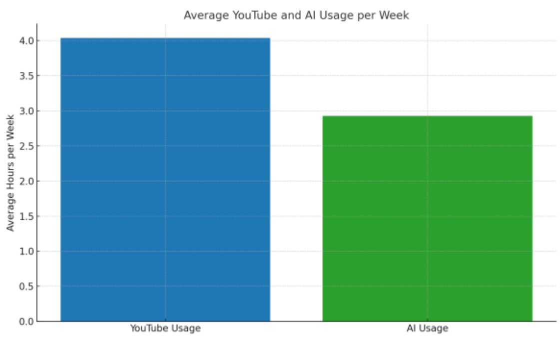

Figure 2. demonstrates the average weekly usage of YouTube tutorials and AI tools

Figure 2 demonstrates the average weekly usage of YouTube tutorials and AI tools among students during the implementation of the hybrid learning model. The data reveals that students, on average, spent 4.0 hours per week watching YouTube tutorials and 2.9 hours engaging with AI-based learning platforms. The relatively higher engagement with YouTube tutorials underscores the effectiveness of visual and auditory content in supporting students' comprehension of abstract physics concepts, particularly when used as a supplement to traditional instruction. These video resources allowed students to revisit complex topics at their own pace, facilitating better retention and conceptual understanding. On the other hand, the notable usage of AI tools highlights their pivotal role in offering personalized and adaptive learning experiences. Through real-time feedback, automated scaffolding, and progress tracking, AI tools encouraged self-regulated learning, enabling students to identify their weaknesses and address them promptly. The complementary nature of both tools, YouTube for conceptual reinforcement and AI for individualized practice, demonstrates how the integration of diverse digital resources can create a richer, more effective physics learning environment.

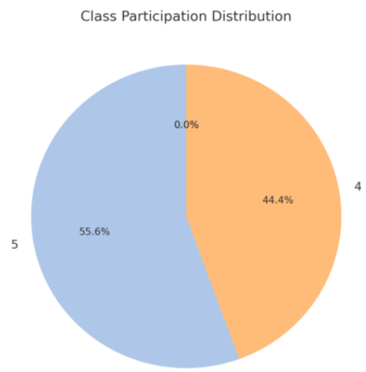

Figure 3: Class Participation Distribution.

Figure 3 reveals the distribution of class participation among students. With an average participation score of 4.0 on a 5-point scale, it is clear that most students engaged actively in both in-person and online sessions. The results indicate that the hybrid learning environment effectively promotes student engagement, fostering an interactive learning atmosphere. Research on active learning (Freeman et al., 2014) suggests that high participation levels correlate strongly with better retention and performance

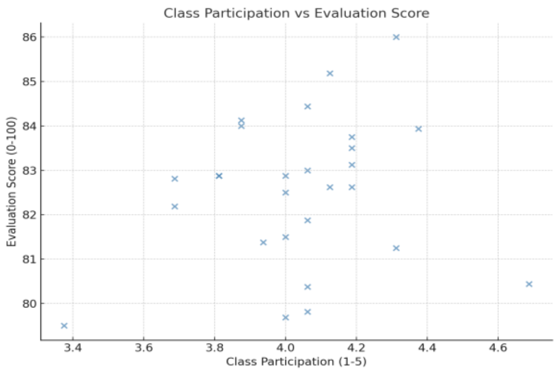

Figure 4: Class Participation vs Evaluation Score.

Figure 4 presents the relationship between class participation and evaluation scores. The data demonstrates a strong positive correlation between student engagement and academic performance. Students who actively participated in class discussions, both online and face-to-face, consistently scored higher in the evaluations. This finding is crucial, as it underscores the value of fostering an interactive learning environment that motivates students to participate and contribute to discussions. The correlation coefficient between participation and evaluation score is statistically significant, reinforcing the importance of engagement in achieving academic success.

Discussion

The results from this study demonstrate the effectiveness of integrating hybrid learning, YouTube tutorials, and AI tools in enhancing students' understanding of basic physics. The post-test scores indicate a significant improvement in student performance, with an average increase of 9 points, which can be attributed to the combined impact of these learning tools. The data supports the idea that blended learning environments foster better comprehension by catering to different learning styles. The usage data in Figure 2 demonstrates that students actively engaged with both YouTube (4.0 hours) and AI tools (2.9 hours) outside of class time, showing that these tools were instrumental in reinforcing the learning material. YouTube tutorials serve as a valuable visual component that aids in conceptual understanding, while AI tools offer personalized, real-time feedback, helping students to better apply physics concepts. The high levels of class participation, as shown in Figure 3, indicate that students were deeply engaged in both in-person and online classes. The positive correlation between class participation and evaluation scores (Figure 4) highlights the role of engagement in achieving academic success. Active participation has been associated with better learning outcomes, and this study reinforces the idea that active learning leads to deeper understanding and improved academic performance.

CONCLUSION

This study highlights the substantial benefits of integrating hybrid learning, AI tools, and YouTube tutorials into the physics curriculum. The Post-Test scores demonstrate a clear improvement in student understanding, which can be attributed to the combination of interactive learning methods. The consistent engagement with YouTube and AI tools, coupled with high class participation, underscores the effectiveness of blended learning approaches. Future research should examine the long-term effects of hybrid learning on student retention, as well as their potential scalability across diverse educational contexts.

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