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YouTube Video Application In Mathematical Physics 1 Lecture: Effectiveness On Students' Conceptual Understanding

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ABSTRACT

This study investigates the effectiveness of YouTube videos in enhancing students' conceptual understanding in a Mathematical Physics course. Mathematical Physics concepts, particularly Multiple Integrals, are often challenging for students due to their abstract nature. Thus, digital video-based learning is proposed to improve student comprehension. The study employs an experimental design with two groups: an experimental group using YouTube videos and a control group using conventional methods. The YouTube videos used in this study featured animated visual explanations, step-by-step problem-solving demonstrations, and real-world applications of Multiple Integrals. The intervention was conducted over five sessions, integrating structured video lessons with guided problem-solving activities. Data collection involved pretests and posttests to assess improvements in conceptual understanding. Statistical tests included normality, homogeneity, and t-tests. Results showed a significant improvement in the experimental group, with a posttest mean of 82.75 compared to the control group's 67.57. A t-test revealed a significant difference between the groups ($p < 0.001$), indicating that YouTube videos significantly contribute to students' understanding. These findings highlight the potential of digital media, particularly YouTube, in addressing conceptual difficulties in Mathematical Physics and fostering more engaging learning experiences. The study provides practical recommendations for integrating video-based learning into physics education to improve student outcomes.

KEYWORDS: YouTube; Mathematical Physics; video learning; Conceptual understanding

1 INTRODUCTION

The study of "Mathematical Physics" is crucial due to its significant impact on various disciplines, especially in physics education. Mathematical Physics is a vital element in higher education curricula, combining mathematical concepts with physical principles to build a strong foundation for scientific understanding. The Kurikulum Merdeka implemented in Indonesia also underscores the importance of integrating mathematical concepts into physics education, aiming to provide students with a more comprehensive learning experience (Effendi et al., 2024). Therefore, a thorough conceptual understanding is essential.

In education, addressing misconceptions and promoting conceptual understanding are crucial components of effective teaching practices (Addido et al., 2022). Conceptual understanding helps students solve complex problems more easily (Saputra & Mustika, 2022). Particularly in science education, the development of conceptual understanding is vital for enhancing scientific literacy among students (Laelasari & Wakhidah, 2023). By focusing on conceptual transformation models and addressing

misconceptions, educators can improve students' ability to grasp scientific concepts more effectively (Flores et al., 2023).

One of the topics in Mathematical Physics that requires a deep conceptual understanding is Multiple Integrals. This topic is essential because it allows for an in-depth analysis of various physical phenomena. By studying differential forms and vector fields in classical vector calculus, students acquire powerful tools for analyzing phenomena such as electromagnetism, fluid dynamics, and mechanics (Pérez-Garrido, 2024).

In recent years, innovative teaching models have been implemented to enhance the learning experience, including understanding concepts in Mathematical Physics. These models emphasize independent learning, case studies, the application of mathematical modeling, and student-centered approaches. By integrating these elements into the curriculum, students are encouraged to actively engage with Mathematical Physics concepts, ultimately improving their understanding of the material (LeGresley et al., 2019).

However, in practice, students often struggle to grasp abstract concepts in Mathematical Physics, which limits their overall understanding of the subject, particularly conceptual understanding. For instance, in Multiple Integral lectures, researchers found that students frequently encounter difficulties in understanding basic integral concepts, geometric visualization, setting integration limits, performing manual calculations, and applying integral theorems to problem-solving. One of the main challenges in learning Multiple Integrals is students' difficulty in understanding fundamental concepts and geometric visualization. Many students struggle with defining Multiple Integrals, extending this concept to functions of several variables, and representing them symbolically (Gemechu et al., 2021). In addition to conceptual difficulties, students also face procedural challenges, such as understanding iterated integrals and changing the order of integration, which often lead to errors due to a lack of confidence in their single-variable calculus skills (Khaidir et al., 2024). The shift in thinking from single-variable to multivariable calculus presents an additional challenge, making it difficult for many students to master this topic (Gemechu et al., 2021). Other studies have also shown that many students in calculus-based physics courses struggle to understand the meaning of positive and negative quantities, even after completing Calculus I (White Brahmia et al., 2020).

Additionally, productive struggle, the process in which students face challenges in mathematical tasks to achieve deeper understanding, is a common phenomenon in mathematics education (Russo et al., 2021). However, in the context of Mathematical Physics, students often find it challenging to overcome these struggles. The abstract mathematical concepts combined with complex physical principles make the transition from concrete to abstract thinking particularly difficult. Students need to learn to apply mathematical reasoning effectively to understand and solve physics problems.

These difficulties can affect students' ability to apply mathematical principles effectively in the context of physical problems, which, in turn, hinders their engagement with the material and limits their ability to connect mathematical theory with physical phenomena.

The trend of using digital media in education has brought significant changes to teaching practices, creating new relationships between teachers and students (Hu, 2024). Teachers now frequently use interactive teaching methods and personalized learning experiences to enhance student engagement and understanding. Digital platforms such as YouTube, Facebook, blogs, Skype, and WhatsApp have been used in educational settings to support more effective learning experiences (Lathipatud Durriyah & Zuhdi, 2018). These platforms enable students to access educational content, interact with interactive materials, and collaborate with peers and educators. During the COVID-19 pandemic, digital content from these platforms became crucial in supporting effective learning (Fansury et al., 2020).

Several studies have shown the effectiveness of YouTube videos in supporting mathematics education and improving student learning outcomes. Anisa et al. (2023) examined the potential of YouTube as a source of mathematics learning for high school and vocational students. Khan et al. (2019) found that many STEM students voluntarily use YouTube to learn scientific topics, including mathematics. Insorio & Macandog (2022) also highlighted the effectiveness of educational videos on

YouTube channels as interventions in modular distance learning for mathematics. Additionally, Syafiq et al. (2021) found that YouTube videos were effective in improving speaking skills during English language learning in the COVID-19 pandemic, demonstrating the platform's flexibility in supporting various subjects.

In the context of education in Indonesia, this study is highly relevant to the implementation of the *Kurikulum Merdeka*, which emphasizes student-centered learning and the development of critical thinking skills. YouTube offers flexibility in providing various multimedia learning resources that can be adapted to different learning styles (Sartipa et al., 2022). Additionally, YouTube's interactive features, such as comments and discussions, allow students to actively participate in the learning process and share their understanding with peers (Kurniawan et al., 2024). However, it is crucial for educators to ensure that the videos used are highly credible and relevant to the course material, considering the varying quality of content available on YouTube (Dunnsiri et al., 2020). Therefore, this study provides valuable insights into how digital technology can be integrated into the curriculum to enhance student learning outcomes.

Although there are many studies on the effectiveness of educational videos, there is still limited research specifically exploring the use of YouTube videos in Mathematical Physics education. This study fills a gap in the literature by exploring the use of YouTube videos to enhance students' conceptual understanding in a Mathematical Physics course, particularly on the topic of Multiple Integrals. Some studies indicate that educational videos can enhance student understanding, but very few have examined the topic of multiple integrals in depth (Maziriri et al., 2020). Therefore, further research is needed to explore the specific impact of using YouTube videos as a learning tool in this context.

This study aims to evaluate the effectiveness of using YouTube videos to enhance students' conceptual understanding of multiple integrals in the Mathematical Physics 1 course. The novelty of this study lies in its specific focus on the use of YouTube videos as a learning medium in the context of Mathematical Physics, which has been rarely explored in previous research. The conceptual understanding in question refers to a deep understanding of mathematical concepts, operations, and the relationships between concepts. In other words, students not only know how to perform certain procedures, but they also understand why those procedures work and how the concepts are interrelated (Jeremy Kilpatrick et al., 2001). This type of understanding enables students to apply their knowledge in various situations and solve problems flexibly and creatively.

The hypothesis of this study is that the effective use of YouTube videos can improve students' conceptual understanding in the Mathematical Physics 1 course. The scope of the study includes third-semester students in the Physics Education Program at the State Islamic University of Mataram, with a focus on the topic of multiple integrals. The study will be conducted over five sessions, which include a pretest, delivery of material via YouTube videos, and a posttest.

This research is expected to make a significant contribution to the development of effective teaching strategies for Mathematical Physics, particularly through the use of digital media such as YouTube. The results of this study are expected to provide practical recommendations for lecturers on integrating YouTube videos as an effective teaching tool, as well as enriching the learning experience of students in the digital era.

2 METHOD

The design of this study uses a pretest-posttest control group design (Sugiyono, 2017). The research design can be seen in Table 1 below.

Table 1. Research Design

Group	Pretest	Treatment	Postest
Experiment	O_1	X	O_2
Control	O_3	-	O_4

Description:

O_1: Pretest for the experimental group

O_2: Posttest for the experimental group
X: Learning assisted by YouTube videos
O_3: Pretest for the control group
O_4: Posttest for the control group

This study consists of two groups: an experimental class that received treatment in the form of learning assisted by YouTube videos (X), and a control class using conventional learning methods. The population in this study included all students enrolled in the Mathematical Physics 1 course in the 3rd semester, divided into two classes. The selection of the experimental and control classes was done using the simple random sampling technique.

The research instrument consisted of 10 essay questions developed by the researcher to measure conceptual understanding in Mathematical Physics, specifically on the topic of multiple integrals. These questions were based on conceptual understanding indicators, including (1) Context and Application Understanding, (2) Coherent Knowledge Organization, (3) Knowledge Retention and Reconstruction, (4) Multiple Representation Ability, and (5) Knowledge Transfer (Jeremy Kilpatrick et al., 2001). Each indicator was represented by two questions, with each question worth 10 points.

3 RESULT AND DISCUSSION

Data analysis in this study includes descriptive and inferential analysis, with the assistance of the JASP program version 0.18.3.0. The results of the descriptive analysis are presented in Table 2.

Table 2. Descriptive Analysis Results of Pretest & Posttest

	Pretest Scores		Posttest Scores	
	Experimental group	Control group	Experimental group	Control group
Valid	20	21	20	21
Mean	52.35	51.762	82.75	67.571
SD	8.184	8.66	5.533	7.626
Minimum	35	35	75	50
Maximum	65	68	96	80

Table 2 presents descriptive statistics illustrating the performance of students in both the experimental and control groups during the pretest and posttest. In the pretest, the experimental group, consisting of 20 participants, had an average score of 52.35, while the control group, with 21 participants, had an average score of 51.76. After the intervention using YouTube videos, the average posttest score of the experimental group significantly increased to 82.75, while the control group increased to 67.57. Additionally, the standard deviation decreased from pretest to posttest, from 8.18 to 5.53 for the experimental group and from 8.66 to 7.63 for the control group, indicating a reduction in score variation.

The difference in average scores between the pretest and posttest can be more clearly seen in **Figure 1** below.

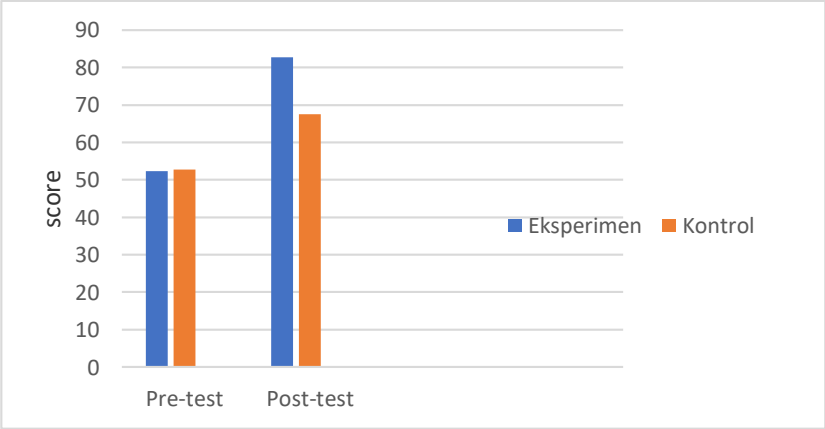

Figure 1. Average Pretest and Posttest Scores of the Experimental and Control Classes

From Figure 1, a significant increase in the experimental group is evident after the intervention using YouTube videos. Although the control group also experienced an increase, it was not comparable to that of the experimental group.

The findings of this study support previous research showing that the use of digital media, especially educational videos, can improve students' learning outcomes. For instance, Maziriri et al. (2020) noted that YouTube can be an effective educational tool across various disciplines, including Mathematical Physics. Moreover, the decrease in standard deviation in the experimental group indicates improved consistency in students' understanding after using YouTube videos. This is consistent with the findings of Humaidi et al. (2021), which showed that video-based learning can enhance conceptual understanding more evenly among students.

The effectiveness of YouTube videos in this learning context was further analyzed using a t-test (independent sample t-test). Before conducting the t-test, assumption tests such as the normality test and homogeneity test were performed. The results of the assumption tests can be seen in Table 3 and Table 4 below.

Table 3. Results of Normality Test (Shapiro-Wilk)

		W	p
Posttest score	Experimental	0.936	0.204
	control	0.966	0.644

Note. Significant results suggest a deviation from normality.

The normality test was conducted using the Shapiro-Wilk test. The W statistic for the experimental group in the posttest was 0.936 with a p-value of 0.204, while the control group had a W value of 0.966 with a p-value of 0.644. Since the p-values for both groups are greater than 0.05, it can be concluded that the posttest data for both groups do not significantly deviate from a normal distribution.

Tabel 4. Results of homogeneity test (Levene's)

	F	df_1	df_2	p
Posttest score	1.248	1	39	0.271

The homogeneity of variance test was conducted using Levene's Test. The results showed an F-value of 1.248 with df1 = 1 and df2 = 39, and a p-value of 0.271. A p-value greater than 0.05 indicates that there is no significant difference in variance between the experimental and control groups.

The fulfillment of the normality and homogeneity of variance assumptions is crucial for the validity of the research results. In the context of using YouTube videos as a learning medium, these results show that the comparison of effectiveness between the experimental and control groups can be conducted

confidently, as the data meet the necessary assumptions for further statistical analysis. These findings reinforce the conclusion that the improvement in understanding of multiple integrals through YouTube videos is not only statistically significant but also supported by valid assumptions. This provides a strong foundation for further research and the application of digital media in education, as recommended by previous studies (Handoko et al., 2022; Listiantomo & Dwikoranto, 2023).

After the assumption tests were fulfilled, the analysis continued with a t-test. The t-test (independent sample t-test) results are presented in Table 5 below.

Table 5. Results of the t-test (Independent Samples T-Test)

	Test	Statistik	df	p	Mean Difference	SE Difference
Posttest score	Student	7.263	39.000	< .001	15.179	2.090
	Welch	7.319	36.487	< .001	15.179	2.074

Table 5 shows the results of the t-test evaluating the differences between the experimental and control groups on posttest scores. The Student's t-test resulted in a t-value of 7.263 with 39 degrees of freedom (df) and a p-value of less than 0.001. These results indicate a highly statistically significant difference between the two groups. The mean difference between the experimental and control groups was 15.179, with a standard error of the mean difference (SE Difference) of 2.090. Welch's t-test confirmed these results with a t-value of 7.319, df of 36.487, and a p-value of less than 0.001, with the same mean difference and a slightly different SE Difference of 2.074.

These findings align with previous research highlighting the effectiveness of video-based educational interventions. For example, Amin et al. (2021) and Saleh & Ahmed Althaqafi (2022) demonstrated that students in experimental groups using video-based learning media showed significant improvements in performance and positive perceptions of learning. Fayasari et al. (2023) also supported these findings, showing that using videos as a learning medium significantly enhanced students' knowledge and attitudes. Similar findings from Alzoubi et al. (2023) and Akihary et al. (2023) emphasize that YouTube in education can enhance student engagement and learning outcomes, while fostering the development of critical thinking skills.

This study provides strong evidence that using YouTube videos as a learning tool is effective in improving students' understanding, particularly of multiple integrals in Mathematical Physics courses. The highly significant p-value ($p < 0.001$) indicates that the difference between the experimental and control groups is not due to random variability, but rather a real effect of the intervention. This confirms that YouTube-based teaching methods offer clearer explanations and enhance student engagement, as reported by Johnrey R. Libit et al. (2023) and Mohammed & Ogar (2023).

These findings highlight the importance of integrating digital media into teaching, especially in courses that contain abstract and complex concepts like Mathematical Physics. The significant increase in average scores and the consistency of the results in the experimental group indicate that YouTube videos can serve as an effective learning tool for deepening students' understanding of multiple integrals.

The basic concept of "conceptual understanding" refers to an individual's ability to grasp patterns, relationships, and principles that underlie various concepts. This goes beyond mere memorization of facts, involving the synthesis of deep knowledge, enabling individuals to think flexibly and creatively when faced with complex problems (Sukarelawan et al., 2024). This understanding allows students to connect mathematical ideas and apply them in different situations (Jeremy Kilpatrick et al., 2001), including in physics concepts. Conceptual understanding is also essential for developing abstract thinking abilities and classifying objects based on abstract ideas (Mangangantung et al., 2021). It allows individuals to absorb and apply abstract ideas effectively (Rohmah et al., 2020).

In this context, YouTube acts as a learning tool that bridges abstract mathematical concepts with concrete applications, providing students with a deeper understanding. YouTube can be a valuable resource for improving conceptual understanding, especially in Mathematical Physics (Wahyuni et al.,

2024). By using this technology, educators can support more contextual and meaningful learning, enhancing students' abilities to solve problems and apply their knowledge in various situations. The visual nature of YouTube videos helps clarify complex Mathematical Physics concepts, thus deepening student comprehension.

The qualitative perspective of students further reinforces how YouTube plays a crucial role in supporting lectures. Students in the experimental group indicated YouTube-assisted learning had significantly enhanced their ability to visualize and apply multiple integrals, aligning with previous research which underscored the benefits of video-based instruction in promoting mathematical comprehension (Alzoubi et al., 2023; Akihary et al., 2023). Qualitative feedback revealed students considered video explanations particularly effective for mastering step-by-step problem-solving techniques, often challenging to grasp fully through traditional lectures. The ability to pause, rewind, and replay content had facilitated deeper understanding and improved retention.

The structured format of YouTube videos enabled students to control the pace of their learning, fostering self-directed learning skills. This flexibility was especially advantageous for students struggling with complex calculus concepts, as it enabled them to revisit difficult sections multiple times until they felt confidence in their understanding. Moreover, students reported higher levels of motivation and engagement with YouTube-based learning compared to traditional lecture methods. The visual and interactive nature of video content was considered effective for maintaining interest and reducing cognitive overload.

However, some students experienced challenges maintaining focus during self-paced video learning. This feedback suggested the need for complementary instructional strategies, such as guided discussions, interactive exercises, and formative assessments, to reinforce learning outcomes and sustain engagement.

These findings suggest YouTube-based instruction effectively enhances conceptual understanding but is most effective within a structured learning environment. Incorporating active learning strategies, such as problem-solving exercises and collaborative discussions, further reinforces comprehension. This suggests video-based learning complements rather than replaces traditional instructional methods for optimal outcomes.

Variables such as students' prior knowledge, cognitive load, and individual learning preferences could affect engagement and retention. Understanding these factors would enable educators to tailor video-based instruction to diverse student needs, enhancing its overall efficacy across contexts. Moreover, longitudinal studies on the long-term retention of concepts from video-based instruction are essential. Evaluating how students apply these concepts in subsequent coursework or real-world scenarios would illustrate YouTube-assisted learning's lasting benefits. Such research offers insights into its role in sustained academic success.

Although digital platforms have both positive and negative impacts on learning outcomes, their presence remains crucial in modern education settings (Husnawati & Rakhmawati, 2024; Nurwahida, 2024; Rani et al., 2021). The results of this study can guide educators in selecting more effective teaching methods, while emphasizing the importance of innovation in teaching approaches, especially in traditionally challenging subjects like Mathematical Physics. The integration of technologies like YouTube not only enhances conceptual understanding but also provides a more dynamic and interactive learning experience, which is essential in the context of modern education. These findings support the need for further exploration and adoption of new technologies in education to ensure that students not only understand the material but can also apply it effectively in real-world situations.

4 CONCLUSION

This study demonstrates that the use of YouTube videos as a learning aid significantly improves students' conceptual understanding of multiple integrals in the Mathematical Physics course. The statistical test results show a highly significant difference between the experimental and control groups, with a p-value of less than 0.001, confirming the effectiveness of the intervention. The substantial mean difference between the two groups strengthens the evidence that YouTube-based teaching methods not

only enrich the learning experience but also enhance students' academic achievement. Therefore, the integration of instructional videos into the curriculum can be an effective strategy for deepening the understanding of complex concepts in physics and mathematics while increasing student engagement in the learning process. This research contributes to the educational literature by providing empirical evidence of the benefits of using digital media in higher education, particularly in courses that require a deep understanding of abstract concepts.

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AUTHOR CONTRIBUTIONS

This research was conducted solely by Nevi Ernita, who assumes full responsibility for the research concept, methodology design, data collection, data analysis, and interpretation of the results. Additionally, the author drafted all sections of the manuscript, conducted the literature review, and revised the manuscript for publication. The author also managed all administrative and ethical aspects of the research.

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