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COMPARING TRADITIONAL AND TECHNOLOGY-ASSISTED LEARNING: THE USE OF MICROSOFT MATHEMATICS 4.0 TO IMPROVE CONCEPTUAL UNDERSTANDING IN CALCULUS

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Abstract

This study evaluates the effectiveness of Microsoft Mathematics 4.0 in improving students' mathematical conceptual understanding on the topic of derivatives in calculus courses. Using an experimental method, the study involved 50 students who were divided into two groups, namely an experimental group with software-assisted learning and a control group with traditional methods. Data were collected through a mathematical conceptual understanding test and observation of student activity, then analyzed using descriptive and inferential statistics specifically the t-test. The results showed that Microsoft Mathematics 4.0 assisted learning is more effective than traditional methods in improving concept understanding as seen from the results of the t test stating that the significance value (0.00 <0.05). Students in the experimental group also showed higher activity, especially in visualizing abstract concepts such as the topic of derivatives. This software provides advantages through visualization and interactive features that make it easier for students to understand the relationship between mathematical concepts. However, this study has limitations in terms of topic coverage, sample size, and does not evaluate long-term impacts. Further research is recommended to expand the topic of study, involve a larger sample, and examine the effects of this software over a longer period of time. This study supports the integration of technology in mathematics learning to improve the quality and effectiveness of learning in higher education

Keywords: Microsoft Mathematics; Calculus; Mathematics; Instructional; Conceptual Understanding

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Introduction

In the digital era, the integration of technology into learning activities has become indispensable. In the context of education, technology not only enhances students' intellectual capacities but also supports the effective delivery of complex learning processes (Churchill, 2005). The continual advancement of information and communication technology (ICT) has significantly improved the efficiency and efficacy of learning across various disciplines, including mathematics (Saefuddin et al., 2023; Supianti, 2018). ICT integration in mathematics education transcends the basic use of computers, emphasizing instead the application of technology to facilitate teaching in ways that foster deeper understanding and student engagement with mathematical concepts (Atteh et al., 2020). Research has demonstrated that ICT utilization enhances comprehension of abstract mathematical concepts, improves learning outcomes, and increases student motivation (Harsa, 2016; Sudihartinih et al., 2021).

One of the well-known ICT applications in mathematics education is Microsoft Mathematics 4.0, a free software developed by Microsoft Corporation to assist undergraduates in understanding and solving mathematical problems through clear visualization and step-by-step solutions. (Mendezabal & Tindowen, 2018). This software features a robust scientific calculator capable of graphing and solving equations across various topics, including Pre-Algebra, Algebra, Trigonometry, Calculus, Physics, and Chemistry. Specifically, Microsoft Mathematics aids in visualizing complex calculus problems, such as calculating the area under a curve or plotting three-dimensional graphs, thereby simplifying abstract concepts and enhancing engagement (Oktaviyanthi & Supriani, 2015). The software combines user- friendly functionality with advanced visualization tools, rendering it accessible to students at multiple educational levels (Hohenwarter et al., 2008). Moreover, Microsoft Mathematics fosters confidence among students, encouraging them to explore mathematical concepts in a supportive and interactive environment (Oktaviyanthi & Supriani, 2015).

Calculus, often considered one of the most challenging branches of mathematics, encompasses a variety of complex topics. Students commonly need help with foundational calculus concepts, such as the fundamental theorem of calculus and derivatives (Maharani, 2023; Monariska, 2019). Common errors observed among students in learning calculus include misinterpretation of problems, deficiencies in procedural and transformation skills, and inaccuracies in documenting problem-related information (Ningsi et al., 2022). These challenges are often attributed to insufficient practice with problem-solving tasks and a weak conceptual foundation in calculus (Monariska, 2019; Wahyuni, 2017). A technology- assisted learning approach offers a promising solution to these issues (Habinuddin & Binarto, 2020). Studies indicate that conceptual understanding, procedural skills, and student attitudes toward calculus can be significantly improved through the use of applications like Microsoft Mathematics (Ahmad et al., 2021; Mendezabal & Tindowen, 2018). For example, Oktaviyanthi and Supriani (2015). found that students utilizing Microsoft Mathematics demonstrated higher achievement in calculus compared to those taught through conventional methods. The software has also been shown to enhance students' understanding and procedural competencies in differential calculus (Mendezabal & Tindowen, 2018).

The application of Microsoft Mathematics in educational research has been well-documented. Oktaviyanthi and Supriani (2014) examined its role in calculus education, focusing on student comprehension, attitudes, and engagement through a descriptive quantitative analysis. Fahira (2021) investigated the use of Microsoft Mathematics in a STEM-based learning context to enhance conceptual understanding among high school students, incorporating an analysis of personality types using a quasi- experimental design. Similarly, Taufiq et al. (2024) explored the software's role in fostering Self- efficacy in algebra among junior high school students, also employing a quasi-experimental approach.

Several studies have investigated the application of Microsoft Mathematics software in mathematics education. Oktaviyanthi and Supriani (2014) explored the use of Microsoft Mathematics in calculus learning, focusing on students' comprehension, attitudes, and perceptions of the software during learning activities. Their study employed a quantitative descriptive analytical approach and targeted first-semester students. Fahira (2021), in contrast, examined the impact of a STEM-based learning approach assisted by Microsoft Mathematics on the mathematical conceptual understanding of Grade XI high school students, analyzing the outcomes in relation to students' personality types using a quasi-experimental design. Similarly, Taufiq et al. (2024) analyzed the use of Microsoft Mathematics in algebra instruction to enhance the Self-efficacy of Grade IX junior high school students, also employing a quasi-experimental design.

Despite these contributions, notable gaps remain in the research on Microsoft Mathematics. For instance, the study by Oktaviyanthi and Supriani (2014) was conducted with students majoring in computer systems, whereas the current research focuses on mathematics education students whose characteristics differ substantially. Meanwhile, Fahira (2021) and Taufiq et al. (2024) centered on high school and junior high school students, whose educational contexts and developmental stages are distinct from the higher education focus of this study.

The novelty of this research lies in its focus on first-semester students enrolled in a mathematics teacher education program, specifically pre-service teachers, and its emphasis on the topic of derivatives within calculus. This study aims to evaluate the effectiveness of Microsoft Mathematics 4.0 in enhancing students' conceptual understanding of calculus. The research underscores the importance of technology in facilitating improved learning outcomes, particularly for complex and abstract subjects like calculus. Many students need help with topics such as derivatives, integrals, and other calculus applications due to the inherent difficulty of connecting these abstract concepts to practical, everyday experiences. Microsoft Mathematics 4.0 is anticipated to serve as a learning tool that helps students not only grasp theoretical aspects but also apply their understanding to solve a variety of problems. Tanjung and Yahfizham (2024) assert that Microsoft Mathematics aids in simplifying complex mathematical concepts, fosters independent learning, enhances critical thinking, and supports problem-solving skills. Additionally, incorporating technology into integral calculus learning has been shown to improve students' perceptions and readiness, as they generally exhibit positive attitudes toward the use of computers in education, thereby increasing their engagement and understanding (Zakaria & Salleh, 2015).

The present study focuses on three primary research questions: (1) the effectiveness of Microsoft Mathematics 4.0 in improving students' conceptual understanding of calculus; (2) the significant differences in calculus comprehension between students using Microsoft Mathematics 4.0 and those relying on traditional teaching methods; and (3) the software's role in assisting students in visualizing abstract concepts in derivatives. These research questions form the basis for assessing the potential of technology in advancing mathematics education. By addressing these issues, this study is expected to contribute to the development of innovative, technology-based teaching strategies for higher education.

Methods

Research Design

This study adopts an experimental research design to evaluate the effect of Microsoft Mathematics 4.0 on students' conceptual understanding of calculus. The experimental approach was selected to establish a causal relationship between the independent and dependent variables. The independent variable in this study is the use of Microsoft Mathematics 4.0, while the dependent variable is students' conceptual understanding of mathematics.

Participants

The sample in this study was 50 mathematics education students who programmed calculus I course with the topic of derivatives. Students were divided into two groups consisting of 25 experimental groups and 25 control groups, with group divisions done randomly. The experimental group received instruction using Microsoft Mathematics 4.0, whereas the control group engaged in traditional learning methods, which included whiteboard-based explanations and no technological support. Assignment to the experimental and control groups was conducted after confirming the homogeneity of the participants using statistical tests.

Research Instruments and Procedure

The research instruments comprised observation sheets, pre-test items, and post-test items designed to measure students' conceptual understanding of calculus. To ensure their validity and reliability, a two-stage validation process was conducted. In the first stage, three experts in the field of calculus, assessed the instruments in terms of content relevance, clarity, and alignment with the learning objectives. This expert review confirmed that the instruments were both valid and reliable for use in the study. Following the validation process, the research was implemented through the following procedural stages: (1) grouping participants into experimental and control groups, (2) administering a pre-test to both groups to assess their initial abilities, (3) conducting learning activities over three sessions, during which the experimental group utilized Microsoft Mathematics 4.0 and the control group received conventional instruction, (4) observing and documenting students' participation throughout the learning process, and (5) administering a post-test to both groups to evaluate learning outcomes based on the instructional approach.

Microsoft Mathematics 4.0 was employed in this study as a visual and interactive tool to facilitate the teaching of derivatives. Educators utilize this software to visually demonstrate function graphs, derivatives, and rate changes, so that students can see the connection between abstract concepts in calculus concretely. Before being actively used in learning, students are given basic training on how to operate Microsoft Mathematics 4.0. This training includes an introduction to the interface, the main functions (such as graph plotting, solving equations, and symbolic manipulation), and how to interpret the visualization results. With this training, students are expected to have the basic competencies to be able to use the software independently when completing assignments or exploring concepts in more depth.

Data Analysis

The data analysis was conducted to determine the effectiveness of Microsoft Mathematics 4.0 in improving students' conceptual understanding of calculus, with a particular focus on derivatives. Descriptive statistical methods, including the calculation of mean, median, and standard deviation, were used to provide an overview of the data distribution. Hypothesis testing was performed using inferential statistical techniques, specifically the t-test, to compare the post-test results between the experimental and control groups.

Results

The findings of this study are presented in alignment with its research objectives, which are to evaluate the effectiveness of Microsoft Mathematics 4.0 in enhancing students' understanding of derivative concepts in calculus, compare the conceptual understanding levels of students utilizing Microsoft Mathematics 4.0 with those engaged in traditional instructional methods, and analyze the software's impact on students' ability to visualize abstract mathematical concepts. Data analysis was performed using both descriptive and inferential statistical techniques to ensure a comprehensive examination of the results.

Comparison of Mathematical Conceptual Understanding Between Experimental and Control Groups

A comparative analysis of students' mathematical understanding of the topic of derivatives was conducted using inferential statistical methods. The initial step involved prerequisite tests, including normality and homogeneity tests.

Normality Test

The normality test for both groups was conducted using the Kolmogorov-Smirnov method, with the results summarized in **Table 1**.

Table 1. Normality Test Results

	Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Learning	Group A	.277	25	.400	.807	25	.700
Outcomes	Group B	.236	25	.301	.870	25	.604

a. Lilliefors Significance Correction

Table 4. 1 displays significance values for each group, which are greater than 0.005. These results indicate that the data for both groups are normally distributed.

Homogeneity Test

The homogeneity test was performed using Levene's Test for Equality of Variances, and the results are presented in **Table 2**.

Table 2. Homogeneity Test Results

		Levene's Test for Equality of Variances	
		F	Sig.
Learning	Equal variances assumed	.919	.343
Outcomes	Equal variances not assumed		

Based on **Table 2**, a significance value of 0.343, which is greater than 0.05, was obtained. This result indicates that the variances of the two groups are homogeneous.

Independent Samples t-Test

Following the prerequisite tests, which confirmed that the data were normal and homogeneous, inferential analysis was carried out using an independent samples t-test to determine the significance of the learning outcomes between the two groups. The results of the independent samples t-test are shown in **Table 3**.

Table 3. Independent Samples Test Results

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Learning Outcomes	Equal variances assumed	.919	.343	-8.265	48	.000	-14.800	1.791	-18.400	-11.200
	Equal variances not assumed			-8.265	44.052	.000	-14.800	1.791	-18.409	-11.191

Table 3 reveals a significance value smaller than 0.05, indicating a significant difference between the experimental and control groups. This finding suggests that the class using Microsoft Mathematics 4.0 achieved significantly better learning outcomes than the class employing traditional teaching methods.

Effectiveness of Microsoft Mathematics 4.0 in Enhancing Students' Mathematical Conceptual Understanding

Descriptive analysis of students' conceptual understanding without using Microsoft Mathematics 4.0 is presented in **Table 4**.

Table 4. Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Learning Outcomes	25	60	75	65.20	5.299
Valid N (listwise)	25				

Based on **Table 4**, the control group, which did not use Microsoft Mathematics 4.0, had an average learning outcome of 65.20, with the highest score being 75 and the lowest score 60. The descriptive analysis results for the experimental group, which used Microsoft Mathematics 4.0, are presented in **Table 5**.

Table 5. Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Learning Outcomes	25	70	95	80.00	7.217
Valid N (listwise)	25				

Table 5 shows that the experimental group achieved an average learning outcome of 80, with the highest score being 95 and the lowest score 70. The data in **Table 4** and **Table 5** demonstrate the high effectiveness of Microsoft Mathematics 4.0 in improving students'

conceptual understanding. This finding is evident from the experimental group's average score of 80, which is significantly higher than the control group's average score of 65.20.

Impact of Microsoft Mathematics 4.0 on Visualizing Abstract Concepts

The impact of Microsoft Mathematics 4.0 was analyzed through observations of students' engagement during classroom learning. A summary of the analysis of students' engagement in the learning process is presented in **Table 6**, based on observational data.

Table 6. Summary of Observation Results on Participant Activity

Session	Participant Engagement	
	Control Group	Experiment Group
1	60%	90%
2	85%	95%
3	87%	100%
Mean	77,33%	95%

Table 6 indicates that the average student engagement during learning for the group using Microsoft Mathematics 4.0 was 95%, whereas the average engagement for the group not using the software was 77.33%. This data demonstrates that students using Microsoft Mathematics 4.0 were more active in visualizing and understanding abstract concepts.

Discussion

Comparison of Mathematical Conceptual Understanding Between Experimental and Control Groups

The findings of this study reveal that the experimental group, which utilized Microsoft Mathematics 4.0, achieved a significantly higher mean score compared to the control group. Statistical analysis confirmed a substantial difference, with the experimental group attaining an average score of 80, as opposed to 65.20 in the control group. These results are consistent with the findings of Oktaviyanthi and Supriani (2015), who reported that the use of Microsoft Mathematics in calculus learning not only enhances students' mathematical performance but also motivates them more effectively than traditional teaching methods. The superior performance of the experimental group may be attributed to the interactive and visual nature of the software, which supports students in grasping complex concepts more intuitively and efficiently. These results suggest that integrating technology into instruction provides significant benefits in enhancing students' understanding of abstract concepts, such as derivatives in calculus.

The visualization features offered by Microsoft Mathematics 4.0 played a crucial role in the observed differences. According to Auliya et al. (2020), Microsoft Mathematics 4.0 facilitates the understanding of complex mathematical concepts through 2D and 3D graphical displays. The software's ability to visually represent graphs simplifies complex calculations and helps students connect theory with practical applications. This finding supports the research of Pranata and Kristianto (2019), which revealed that the integration of technology in mathematics learning transforms abstract concepts into more concrete and comprehensible forms, thereby increasing learning effectiveness. Moreover, technology-based visualization tools enhance student engagement during the learning process (Sitorus, 2022). However, despite these advantages, some students in the experimental group reported initial difficulties in navigating the software and understanding its full functionality, particularly those who were less experienced with digital tools. These challenges were generally overcome over time but may have temporarily hindered learning for some individuals.

Nonetheless, traditional teaching methods retain certain advantages, such as fostering critical thinking skills through direct discussions. Sormin et al. (2023) highlighted that traditional, discussion- based mathematics instruction cultivates critical thinking by encouraging students to explore problems collaboratively. However, challenges exist for students unfamiliar with technology, as adaptation difficulties may negatively affect learning outcomes. Guzmán et al. (2019) noted that some students encounter obstacles when using technology-based tools due to limited familiarity with such platforms or restricted access to devices and internet connectivity. Thus, while Microsoft Mathematics 4.0 offers distinct advantages, it should complement rather than replace traditional methods. A combined approach can leverage the strengths of both strategies, providing a more comprehensive and effective learning experience (Voskoglou & Salem, 2020).

Effectiveness of Microsoft Mathematics 4.0 in Enhancing Students' Mathematical Conceptual Understanding

The study demonstrates that Microsoft Mathematics 4.0 significantly improves students' conceptual understanding of calculus, particularly on the topic of derivatives. The experimental group's higher average performance underscores the effectiveness of the software in facilitating learning. These findings corroborate previous studies by Ilmadi and Rusdiana (2019) and Oktaviyanthi and Supriani (2015), which reported that students using software-assisted learning achieved superior outcomes compared to those instructed through traditional methods. The software's interactive, step-by-step problem-solving features provide an intuitive and in-depth learning experience, enhancing both conceptual understanding and procedural skills (Mendezabal & Tindowen, 2018).

A key advantage of Microsoft Mathematics 4.0 lies in its ability to simplify complex calculations, allowing students to concentrate on developing a deeper understanding of underlying concepts. Rabi et al. (2022) emphasized that Microsoft Mathematics enhances calculus learning by enabling visualization of abstract and intricate concepts. By automating tedious calculations, the software allows students to focus on analyzing functional relationships and exploring mathematical properties. Furthermore, features such as dynamic graphs and detailed visual explanations clarify challenging concepts, such as changes in functional values and derivations.

However, reliance on technological tools may lead to dependency, potentially undermining students' manual problem-solving abilities. Mayasari et al. 2021 warned that over-reliance on software might diminish students' ability to perform calculations independently. Educators must ensure that such tools are integrated as supplements rather than substitutes for traditional instructional approaches. As Naganjaneyulu et al. (2020) argued, Microsoft Mathematics should serve to complement traditional methods by enhancing visualization and conceptual understanding without neglecting the development of manual problem-solving skills. Striking an appropriate balance between these approaches is crucial for maintaining students' overall mathematical proficiency (Auliya et al., 2020; Noor et al., 2023; Oktaviyanthi & Supriani, 2014).

Impact of Microsoft Mathematics 4.0 on Visualizing Abstract Concepts

The study highlights the effectiveness of Microsoft Mathematics 4.0 in aiding students' visualization of abstract mathematical concepts, particularly in derivative topics, which are often challenging to comprehend through conventional teaching methods. Ilmadi & Rusdiana (2019) emphasized that platforms like Microsoft Mathematics are valuable for translating abstract mathematical concepts into more tangible forms, thereby enhancing conceptual understanding. Observational data from this study further support these findings, with the experimental group demonstrating a higher average engagement rate of 95%, compared to 77.33% in the control group. This elevated engagement indicates the software's capacity to foster interactive and participatory learning environments.

Visualization is particularly important in calculus education, as many concepts, such as the area under a curve or changes in functional values, are difficult to relate to real-world experiences. By providing clear graphical representations, Microsoft Mathematics enables students to grasp these abstract concepts better, ultimately improving their analytical and problem-solving skills (Naganjaneyulu et al., 2020; Rabi et al., 2022; Svitek et al., 2022). Such visualizations allow students to observe functional behaviors and relationships, thus strengthening their mathematical reasoning abilities.

Despite its benefits, the adoption of software such as Microsoft Mathematics requires adequate training for both students and instructors, especially for those less familiar with technology. Abdullah et al. (2020) emphasized the importance of equipping users with sufficient guidance to maximize the software's potential. Providing initial training and ongoing support ensures that students can effectively utilize the platform's features, thereby optimizing their learning outcomes. To effectively utilize Microsoft Mathematics 4.0, educators should not only use it as a visualization tool, but also integrate it strategically in the learning process, for example through concept demonstrations, interactive exercises, and independent exploration by students. Educators are advised to develop learning scenarios that combine the use of this software with constructivist approaches, such as group discussions, contextual problem solving, and technology-based projects. In addition, technical training for lecturers and the provision of learning resources that support the use of Microsoft Mathematics 4.0 are important so that implementation is not hampered by limited digital competencies. Educational institutions also need to ensure the availability of adequate infrastructure and encourage collaboration between lecturers in designing technology-based materials, in order to create a more meaningful and adaptive mathematics learning experience.

Conclusion

This study contributes to the development of knowledge in mathematics education by showing that the integration of technology, particularly Microsoft Mathematics 4.0, can significantly improve students' understanding of mathematical concepts, particularly on the topic of derivatives in calculus. This study provides empirical evidence that the use of this software not only makes learning more interesting, but also more effective in helping students master abstract concepts that have been a major challenge in learning college-level mathematics. The main contribution of this research lies in the use of interactive visualization as a means of supporting the learning of derivative concepts. This confirms that digital technology can be a catalyst in changing the approach to teaching mathematics from conventional to more innovative and contextual.

Thus, this study expands the discourse on the importance of educational technology in supporting conceptual understanding and improving the quality of student learning outcomes. However, this study has limitations in terms of topic coverage and limited number of participants. Therefore, further research is needed on other mathematics topics and with a more diverse population to test the generalizability of these findings. One potential direction of development is to integrate Microsoft Mathematics 4.0 with active learning models such as project-based learning models.

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Conflicts of Interest

The authors declare no conflict of interest regarding the publication of this manuscript. In addition, the authors have completed the ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies.

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Author Contributions

Author One: Conceptualization, writing - original draft, editing, and visualization; **Author Two:** Writing - review & editing, and formal analysis; **Author Three:** Validation instrument, and methodology; **Autor Four**: review & editing.

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