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Implementation of The Desmos Application in Learning Functions to Enhance Students' Conceptual Understanding

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Abstrak
Pemahaman konsep fungsi merupakan aspek fundamental dalam pembelajaran matematika, yang sering kali menjadi tantangan bagi siswa karena sifatnya yang abstrak. Pemanfaatan teknologi pembelajaran berbasis software seperti aplikasi Desmos yang interaktif dan mudah digunakan dapat mendukung proses pembelajaran dengan visualisasi grafis yang kaya, sehingga meningkatkan keterlibatan dan pemahaman siswa. Artikel ini mengkaji implementasi aplikasi Desmos dalam pembelajaran fungsi pada tingkat sekolah menengah atas, dengan fokus pada peningkatan pemahaman konsep siswa. Melalui penelitian kuantitatif dan kualitatif yang melibatkan 60 siswa kelas XI, ditemukan bahwa penggunaan Desmos meningkatkan hasil belajar, motivasi, dan aktivitas belajar siswa secara signifikan. Temuan ini mengimplikasikan perlunya integrasi teknologi visualisasi ke dalam pembelajaran matematika untuk mendukung pembelajaran konsep abstrak secara efektif

Abstract
Understanding the concept of functions is a fundamental aspect of mathematics education, which often poses challenges for students due to its abstract nature. The utilization of software-based learning technology, such as the interactive and user-friendly Desmos application, can support the learning process with rich graphical visualizations, thereby enhancing student engagement and understanding. This article examines the implementation of the Desmos application in function learning at the high school level, focusing on improving students' conceptual understanding. Through quantitative and qualitative research involving 60 eleventh-grade students, it was found that the use of Desmos significantly improved learning outcomes, motivation, and student learning activities. These findings imply the need for integrating visualization technology into mathematics education to effectively support the learning of abstract concepts.

INTRODUCTION

Mathematics, as one of the core subjects in high school, requires students to understand abstract concepts that can sometimes be difficult to visualize. One of the very important yet relatively complex mathematical concepts is the function. Functions, as a foundation in various branches of mathematics, play a crucial role in developing students' analytical skills and problem-solving abilities (Tall & Vinner, 1981). However, the material on functions often becomes a barrier for many students due to their difficulties in understanding the conceptual and indirect relationships between variables.

Traditional learning, which relies solely on theoretical explanations and textbooks, often fails to provide concrete visualizations for students. This affects students' ability to connect theory with practice and hinders the process of forming deep concepts (Sinaga & Zuhdi, 2019). Therefore, various modern learning approaches have been developed that involve technology to provide visual and interactive representations of function concepts.

In recent years, the use of interactive graphing software, such as Desmos, has increased at the secondary and higher education levels (Roschelle et al., 2010). The Desmos application is a web- based graphing calculator that allows users to build graphs of mathematical functions in real-time and interactively. The use of Desmos enables students to directly observe changes in graphs when functions are modified, thus helping them build an understanding of the properties of functions and the relationships between variables intuitively and effectively. This research aims to xamine the implementation of the Desmos application in function learning among

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eleventh-grade high school students, focusing on enhancing their understanding of function concepts. This study not only quantitatively measures students' learning outcomes but also observes changes in motivation and student activity during the learning process using Desmos.

This study seeks to explore the impact of using the Desmos application in the teaching and learning of mathematical functions, with a particular focus on students' conceptual understanding. The research is driven by the need to understand whether integrating dynamic, visual tools like Desmos can enhance students' grasp of abstract mathematical concepts, especially functions, which often pose challenges in traditional learning environments. In addition to examining cognitive outcomes, the study also investigates students' emotional and motivational responses during the learning process. It aims to capture how the interactive nature of Desmos influences student engagement, enthusiasm, and overall learning experience.

The primary objective of this research is to determine the effectiveness of the Desmos application in improving students' understanding of function concepts. Furthermore, the study aims to evaluate students' motivation and engagement levels throughout the learning process when Desmos is used as a pedagogical tool. Through this dual focus on both cognitive and affective dimensions the research aspires to provide insights into how technology enhanced learning environments can support deeper mathematical comprehension and foster a more positive attitude toward learning.

The Concept of Functions in Mathematics Education A function is a fundamental concept in mathematics that connects each element in the domain set to one element in the codomain set. Tall and Vinner (1981) define the importance of "concept image" and "concept definition," emphasizing that conceptual understanding goes far beyond merely mastering formal definitions. One of the main challenges in learning functions is building a cohesive and intuitive concept image for students so that they can understand mathematical representations meaningfully and applicably in various contexts. According to Duval (1995), mathematics learning heavily relies on students' ability to internally convert conceptual representations (conversion) and between external representations such as symbols, graphs, and tables (treatment). In the context of learning functions, the ability to switch between these representations becomes key to achieving deep understanding.

Technology-Based Mathematics Learning The development of information technology has provided significant opportunities to enrich the mathematics learning experience. According to Tatar and Robinson (2007), the use of software such as graphing calculators and mathematics software enhances the quality of learning by providing graphical visualizations that build concepts. Technology allows students to manipulate variables, explore patterns, and test hypotheses directly. Interactive graphic software facilitates collaborative and inquiry-based learning, which supports problem-solving and active learning (Castillo Garsow et al., 2013). In teaching functions, visualization through software can reduce abstraction barriers and help students build conceptual understanding.

The Desmos Application and Its Advantages Desmos is an online graphing calculator widely used in education due to its ease of access, interactive interface, and ability to represent various mathematical functions with realistic and dynamic graphs (Desmos, 2024). According to Roschelle et al. (2010), this application enhances student engagement and enables discovery based learning. The main advantages of Desmos include the ability to change function parameters in real-time, allowing students to observe the direct impact on the graph's shape, structuring learning activities with the help of teachers, and integrating with assessments and quizzes (Shemwell, 2016). Desmos also supports various advanced features such as parameter sliders, graphs of trigonometric and exponential functions, as well as the ability to play with simple animated functions.

In terms of technology use, the researchers chose to use Desmos. Desmos is a mathematics platform that provides a variety of interactive tools for mathematics education. This platform can be used to teach mathematics and analytical geometry in a variety of ways and has been identified as very engaging (Ebert, 2014). Here are some applications of Desmos in learning mathematics and analytical geometry: (1) Graphical Visualization: users can easily and interactively create graphs that represent mathematical functions. This allows students to see the relationship between algebra and geometry more clearly. Desmos can be used in analytical geometry to illustrate the equations of graphs of lines, circles, and other curves, thereby enhancing conceptual understanding; (2) Exploration and Experimentation: Desmos allows students to experiment with parameters in mathematical functions; (3) Simulation: Desmos also provides mathematical simulation tools, which allow students to conduct virtual experiments in a mathematical context. For example, in analytical geometry, students can use Desmos to create and manipulate geometric objects such as triangles, rectangles, and other geometric shapes; and (4) Collaboration and Project-Based Learning: Desmos allows students to collaborate in learning mathematics. They can share graphs, problem-solving techniques, and math projects with other students or teachers (Chorney, 2022).

Related Research Several studies have been conducted to explore the benefits of Desmos in mathematics learning. Hafiz et al. (2020) found that the use of Desmos improved conceptual understanding and problem-solving abilities in trigonometric functions among college students. Research by Nugroho and Fajar (2018) at the secondary school level stated that function learning using Desmos resulted in significant increases in learning motivation and test scores compared to conventional methods. Unlike traditional approaches, Desmos gives students the freedom to experiment and explore function concepts independently and interactively (Heid, 2011). This aligns with constructivist learning theory, which emphasizes active learning experiences to build knowledge (Piaget, 1973; Vygotsky, 1978).

While previous studies have shown that Desmos can improve conceptual understanding and motivation in mathematics learning especially in topics like trigonometry and general function concepts there are still several underexplored areas: Limited focus on representational fluency: Most studies emphasize outcomes like test scores or motivation, but few deeply investigate how Desmos supports students' ability to transition between symbolic, graphical, and tabular representations (as highlighted by Duval's theory). Lack of integration with conceptual frameworks: Although Tall and Vinner's ideas on "concept image" and "concept definition" are foundational, existing research rarely connects Desmos use directly to these cognitive constructs. Contextual relevance: Many studies are conducted in Western or urban educational settings. There's a gap in understanding how Desmos functions in diverse cultural or regional contexts such as Aceh where local pedagogical values and digital literacy may differ.

Accordingly, this research explores several critical dimensions, including; Conceptual depth: this research moves beyond surface-level outcomes to explore how students build and internalize mathematical meaning. Dual focus on cognition and affect: Not only measuring conceptual understanding but also capturing student motivation and engagement providing a holistic view of the learning experience. Technology in local context: Conducting this study in Aceh adds cultural and educational nuance, offering insights into how global tools like Desmos adapt to local learning environments and potentially enrich them.

METHODS

This study employs a mixed-method approach with a concurrent integration model, in which quantitative and qualitative methods are implemented simultaneously within a single research period. The quantitative approach is applied through a quasi-experimental design using pretest and posttest to measure changes in students' conceptual understanding of functions. In parallel, the qualitative approach involves observations and in-depth interviews to evaluate students' learning motivation and activities during the Desmos-based instructional process. The integration of both methods enables the researcher to obtain a more comprehensive picture, encompassing both learning outcomes and the dynamics of the learning process. Research Subjects and Location The research subjects are 60 eleventh-grade science students at MUQ Sigli High School, selected purposively based on the availability of technological facilities and school agreement. The research was conducted over four weeks during the odd semester of the 2024/2054 academic year.
Research Instruments

Concept Understanding Test: A written test media consisting of 20 objective and descriptive questions designed to measure aspects of function concepts such as definitions, graphical representations, domains and codomains, and function applications. Learning Motivation Questionnaire: Contains 15 statements with a 1-5 Likert scale that has been tested for validity and reliability. Learning Activity Observations: Field notes and video recordings to observe students' responses, enthusiasm, and interactions during Desmos learning. Structured Interviews: Conducted with 10 selected students to explore their opinions and experiences during the learning process.

Research Procedure The steps of the research implementation include: 1. Administering a pretest to measure students' initial understanding of functions, 2. Implementing function learning over 4 meetings using the Desmos application as the main medium, 3.Assigning exploration project tasks using Desmos in each meeting to enhance learning activity, 4.Administering the learning motivation questionnaire at the end of the learning cycle, 5. Conducting a posttest to measure conceptual understanding of functions after the intervention, 6. Observing and recording classroom activities for qualitative analysis, 7. Conducting in-depth interviews with selected students as qualitative data complements.

RESULT AND DISCUSSION

Based on research conducted at MUQ Sigli High School, data was obtained that illustrates changes in students' conceptual understanding, as well as the dynamics of their motivation and engagement during the Desmos-based learning process. The data is presented systematically in the following table to provide a clearer picture of the impact of the learning intervention.

Table 1. The descriptive statistics of students' test scores in both the experimental and control classes, covering pretest, posttest, and normalized gain (N-Gain).

Class	Test	Skor Max	Skor Min	Mean	Median	Varians	Std. Deviasi	Skewness	Kurtosis
Experiment	Pretest	75	24	52,85	55	211,292	14,536	- 0,380	- 5,594
	Postest	95	65	81,95	82,50	81,208	9,012	- 0,326	- 0,860
	N-Gain	0,80	0,41	0,6347	0,6147	0,012	0,11054	- 0,113	- 0,839
Control	Pretest	70	20	44,05	40	203,760	14,274	0,332	- 0,880
	Postest	86	50	70,73	71	115,065	10,727	- 0,513	- 0,615
	N-Gain	0,66	0,05	0,4728	0,4856	0,024	0,15627	- 1,210	1,536

In the experimental class, the pretest scores ranged from 24 to 75, with a mean of 52.85 and a standard deviation of 14.536. The posttest scores showed a significant improvement, ranging from 65 to 95, with a higher mean of 81.95 and a lower standard deviation of 9.012, indicating more consistent performance. The N-Gain average was 0.6347, suggesting a substantial increase in conceptual understanding. The skewness and kurtosis values across all phases indicate a relatively symmetrical distribution with light tails, especially in the posttest and N-Gain.

In contrast, the control class started with a lower pretest mean of 44.05 and a wider score range (20–70). Posttest scores improved to a mean of 70.73, but the N-Gain average was lower at 0.4728. The higher standard deviation in both pretest and posttest (14.274 and 10.727 respectively) suggests greater variability in student performance. The skewness and kurtosis values in the N-Gain data for the control class indicate a negatively skewed and leptokurtic distribution, reflecting uneven learning gains among students.

Table 2. Mean Difference Test

class	*t-test for Equality of Means*				
	t-count	Df	Sig. (2-tailed)	Sig. (1-tailed)	Conclusion
Experiment control	2,639	60	0,00043	0,000215	Reject H_0

Based on the table 2. Mean ifference test, it can be seen that in the ability to think critically in mathematics with a tcount value = 2.639 and a Sig. (2-tailed) value = 0.00043. From the Sig. (2-tailed) value = 0.00043, the Sig. (1-tailed) value is obtained, then the Sig. (2-tailed) value must be divided by two, becoming the Sig. (1-tailed) value = 0.000215. Because the Sig. (1-tailed) value = 0.000215 <α= 0.05, this makes H0 rejected and Ha accepted. So it can be concluded that there is an increase in student understanding with the implementation of the desmos application in learning functions.

Motivation Questionnaire Data The questionnaire indicated an increase in learning motivation, with an average post-learning motivation score of 4.2 on a scale of 5 with categories very unmotivated, unmotivated, moderately motivated, motivated and very motivated. The following are the motivation categories: Observations and Interviews During the learning process, students showed a high level of engagement. Many students appeared interested in trying various functions and parameters in Desmos to understand their effects. Here are some interview quotes: "With Desmos, I can see the graph change immediately when I change the numbers. It makes it easier for me to understand the function concept that was previously hard to grasp." (Student A). "Learning in class becomes more enjoyable and not boring because we can explore freely" (Student B). "At first, I was confused when looking at function graphs, especially when the numbers kept changing. But with Desmos, I could try it myself and see the results directly. Even though I still don't fully understand everything, I've become more confident to give it a try" (Student C). Teachers also observed that students were more active in discussions and asking questions compared to conventional methods.

Discussion

Improvement in Understanding Function Concepts The findings of the increased posttest scores suggest that the Desmos application is effective in strengthening students' understanding of functions. Direct graphical visualization helps students concretize the abstract concept of functions, improving the transfer of knowledge from theory to practical application. This aligns with Duval's (1995) theory, which emphasizes the importance of visual representation in mathematics learning.

Student Motivation and Engagement The high motivation scores demonstrate that interactive learning media like Desmos can enhance students' interest and enthusiasm. The active engagement and independent experimentation facilitated by this application support the integration of active learning in line with the constructivist paradigm (Piaget, 1973).

Implications for Mathematics Learning Practice The integration of interactive technology in mathematics learning should be a primary concern for teachers, especially for difficult and abstract concepts like functions. Desmos provides a simple and effective platform for visual and interactive learning that can enrich teaching methods.

Limitations of the Research This study has limitations, including the location and subjects being confined to one school and the relatively short duration of the intervention. External factors such as students' initial abilities and technical conditions may also influence the results.

CONCLUSION AND RECOMMEDATIONS

Based on the results of the study, the implementation of the Desmos application in learning functions significantly improved students' conceptual understanding, as evidenced by a 35% increase in post-test scores compared to the pre-test. In addition, qualitative data from student interviews revealed a marked increase in motivation and willingness to explore mathematical concepts independently, especially among students with lower academic abilities. The interactive and visual features of Desmos were consistently cited by students as helpful in making abstract concepts more tangible. These findings confirm that Desmos is not only effective in enhancing cognitive outcomes but also in fostering a more engaging and student-centered learning environment. Therefore, it is strongly recommended that teachers and schools integrate Desmos into their instructional strategies, particularly in topics involving abstract mathematical reasoning, to promote deeper understanding and active learning.

Recommendations for further research, it is hoped that there will be researchers who conduct research on the implementation of the use of software that is integrated with the context of problems related to regional wisdom

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