



THE INTEGRATION OF GEOGEBRA IN TEACHING TRANSFORMATIONAL GEOMETRY TO IMPROVE STUDENTS' CONCEPTUAL UNDERSTANDING

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Abstract

This study aims to improve students' conceptual understanding of transformation geometry through the use of GeoGebra, employing the Kemmis and McTaggart Classroom Action Research (CAR) approach. The participants were 19 students from the Department of Mathematics Education, Universitas Flores. The research instruments included a conceptual understanding test and an observation sheet of student activities. The study was conducted in two cycles. The results indicated a significant improvement in classical mastery, increasing from 52.63% to 100%, while the average score improved from 75.16 to 81.84. In addition, the average level of student activity increased from 57.88% to 85.13%, and positive student responses rose from 68.42% to 89.47%. GeoGebra proved effective in supporting students' dynamic visualization, interactive exploration, and knowledge construction in understanding transformation geometry. Based on the data analysis, it can be concluded that the use of GeoGebra enhances students' conceptual understanding and engagement in learning transformation geometry.

Keywords: *Conceptual Understanding; GeoGebra; Geometric Transformation*

Abstrak

Penelitian ini bertujuan meningkatkan pemahaman konsep geometri transformasi mahasiswa melalui penggunaan GeoGebra dengan pendekatan Penelitian Tindakan Kelas (PTK) model Kemmis dan McTaggart. Subjek dalam penelitian ini sebanyak 19 mahasiswa Program Studi Pendidikan Matematika Universitas Flores. Instrumen yang digunakan meliputi tes pemahaman konsep dan lembar observasi aktivitas. Penelitian dilakukan dalam dua siklus. Hasil menunjukkan peningkatan ketuntasan klasikal dari 52,63% menjadi 100%, rata-rata nilai dari 75,16 menjadi 81,84, dan rata-rata aktivitas mahasiswa dari 57,88% menjadi 85,13%. Respons positif mahasiswa juga meningkat dari 68,42% menjadi 89,47%. GeoGebra terbukti membantu visualisasi dinamis, eksplorasi interaktif, dan konstruksi pengetahuan mahasiswa dalam memahami transformasi geometri. Berdasarkan hasil analisis data, dapat disimpulkan bahwa hal ini dapat meningkatkan pemahaman dan keterlibatan mahasiswa dalam pembelajaran transformasi geometri.

Kata kunci: Pemahaman Konsep; Geogebra; Geometri Transformasi

INTRODUCTION

Transformation geometry is a fundamental topic in mathematics with broad applications across various fields of science and technology. This topic includes concepts such as translation, rotation, reflection, and dilation, which are not only essential in academic contexts but also highly relevant in everyday life, ranging from graphic design and architecture to computer technology (Fatmawati & Yahfizham, 2024). However, classroom experience indicates that students often face difficulties in understanding transformation geometry concepts. The main problems identified include challenges in visualizing geometric transformations, limitations in connecting abstract concepts with concrete representations, and a lack of hands-on experience in exploring the properties of transformations. These

issues are largely attributed to conventional and abstract teaching approaches, which make it difficult for students to dynamically visualize and manipulate geometric objects. A study by Sieng & Thai (2024) shows that the use of GeoGebra significantly improves students' visual representation and conceptual understanding in geometry, thereby helping to reduce these difficulties.

Previous studies have shown that traditional approaches to teaching transformation geometry—primarily relying on the whiteboard and textbooks—often fail to provide deep conceptual understanding. Such methods tend to emphasize procedural aspects and memorization of formulas, without offering sufficient opportunities for students to explore concepts visually and interactively. Hollebrands (2003) found that students experience difficulties in understanding geometric transformations when taught using traditional methods that rely solely on static visualization. Similarly, Fife (2019) emphasized that learning transformation geometry requires an approach that views transformations as functions on the plane, rather than merely as mechanical procedures.”

Clements and Battista (1992) also revealed that students frequently develop misconceptions in transformation geometry when instruction focuses primarily on procedural aspects without deep conceptual understanding. Likewise, Edwards (1991) highlighted that traditional teaching methods tend to emphasize procedures and memorization, limiting students' opportunities to explore concepts visually and interactively. Furthermore, Van de Walle (2007) confirmed that conventional geometry instruction often fails to develop the spatial understanding necessary for mastering transformation geometry. Kaput (1992) also noted that the limitations of traditional instructional media in providing dynamic representations constitute a major barrier in learning transformation geometry.”

The advancement of educational technology, particularly dynamic mathematics software such as GeoGebra, offers an innovative solution to these challenges. GeoGebra is a dynamic mathematics software that integrates geometry, algebra, and calculus into a single user-friendly platform. Its main advantage lies in its ability to provide dynamic and interactive visual representations, enabling students to explore transformation geometry concepts directly and in depth. Through GeoGebra, students can perform geometric transformations practically and interactively, making concepts such as translation, reflection, rotation, and dilation easier and more engaging to understand (Dahal et al., 2022). Students are able to manipulate geometric objects in real time, observe changes as transformations are applied, and understand the relationships between transformation parameters and their outcomes. The intuitive drag-and-drop features allow students to experiment with various configurations and observe emerging patterns, thereby fostering stronger conceptual understanding.”

In addition, GeoGebra supports collaborative and constructivist learning, where students actively construct their own knowledge through exploration and discovery. This interactive learning environment not only enhances student engagement but also facilitates the development of critical thinking and problem-solving skills. Therefore, the objective of this study is to examine the improvement of students' conceptual understanding in transformation geometry.”

METHOD

This study employed a Classroom Action Research (CAR) approach aimed at improving students' conceptual understanding of transformation geometry through the use of GeoGebra. CAR was selected because the study focuses on improving classroom teaching practices through collaboration between the researcher and the course instructor. The research followed the Kemmis and McTaggart (2010) model, which consists of four main stages: planning, acting, observing, and reflecting. These cycles were repeated until the predetermined success indicators were achieved. The participants were students of the Department of Mathematics Education, Universitas Flores, who were enrolled in the Transformation Geometry course in the even semester of the 2024/2025 academic year.

The instruments used in this study included a conceptual understanding test (pre-test and post-test) and an observation sheet. Data were collected through tests and structured observations. The data analysis techniques consisted of: (a) individual learning mastery analysis, calculated using the formula $(\text{score obtained} / \text{maximum score}) \times 100\%$, where students are considered to have achieved mastery if they obtain a score ≥ 75 ; (b) classical mastery analysis, calculated using the formula $(\text{number of students achieving mastery} / \text{total number of students}) \times 100\%$, where the learning process is considered successful if $\geq 85\%$ of students achieve mastery; and (c) activity analysis, calculated using the formula $(\text{number of active students} / \text{total number of students}) \times 100\%$. The activity indicators included: (1) effective use of GeoGebra, (2) participation in discussions, (3) completion of tasks or exercises, and (4) asking questions or providing responses. The activity criteria were categorized as follows: Very Active (81%–100%), Active (61%–80%), Moderately Active (41%–60%), Less Active (21%–40%), and Inactive (0%–20%).

RESULTS AND DISCUSSION

General Description of the Study

This classroom action research was conducted with 19 students from the Department of Mathematics Education at Universitas Flores. The study was implemented over two cycles, each consisting of four sessions, utilizing GeoGebra as a learning tool to enhance students' conceptual understanding of transformation geometry (Ridha et al., 2020; Hayati & Ulya, 2022; Gurmu et al., 2024).

Results of Cycle I

Individual and Classical Learning Mastery

Table 1. Results of the Concept Understanding Test, Cycle I

No.	Initial	Pre-Test	Post-Test	Remarks
1	AK	45	70	Not Mastered
2	BL	50	78	Mastered
3	CM	35	65	Not Mastered
4	DN	60	82	Mastered
5	EO	40	72	Not Mastered
6	ABP	55	80	Mastered
7	BK	48	75	Mastered
8	KP	42	68	Not Mastered
9	PT	58	85	Mastered
10	HP	38	70	Not Mastered
11	TR	52	78	Mastered
12	YM	46	73	Not Mastered
13	AR	62	88	Mastered
14	AN	44	76	Mastered
15	LVB	50	74	Not Mastered
16	NM	56	81	Mastered
17	MK	41	69	Not Mastered
18	NK	54	77	Mastered
19	RM	47	71	Not Mastered
Average		48,58	75,37	

The analysis of learning mastery in Cycle I indicates that 10 out of 19 students achieved mastery, while 9 students did not. The level of classical mastery reached 52.63%. Furthermore, the average pre-test score was 48.95, which improved to 75.16 in the post-test. The N-Gain was calculated using the formula

$\frac{(Posttest - Pretest)}{(100 - Pretest)}$. The average N-Gain score in Cycle I was 0.52, indicating a moderate level of improvement.”

Table 2. Student Activities in Cycle I

Activity Indicators	Meeting 1	Meeting 2	Meeting 3	Meeting 4	Average
Using GeoGebra	58%	63%	68%	74%	65,75%
Participating in Discussions	42%	47%	53%	58%	50%
Completing Tasks	68%	74%	79%	84%	76,26%
Asking Questions	32%	37%	42%	47%	39,5%
Average Activity	50%	55,25%	60,5%	65,75%	57,88%

Based on the questionnaire on students' responses to learning using GeoGebra, the results show that 68.42% of students (13 students) gave positive responses, 26.32% (5 students) gave moderately positive responses, and 5.26% (1 student) gave fewer positive responses

The reflection of Cycle I revealed several challenges, including students' difficulties in operating GeoGebra, suboptimal time management due to software adaptation, limited understanding of rotation and dilation concepts, and insufficient interaction during classroom discussions (Wen & Bajuri, 2024). To overcome these issues, several improvements were proposed for Cycle II, including providing intensive tutorials, developing structured usage guidelines, incorporating progressively challenging exercises, and implementing cooperative learning strategies to enhance student interaction (Barkley et al., 2014)

Results of Cycle II

Individual and Classical Learning Mastery

Table 3. Conceptual Understanding Test Results in Cycle II

No.	Initial	Pre-Test	Post - Test	Remarks
1	AK	45	76	Mastered
2	BL	50	85	Mastered
3	CM	35	75	Mastered
4	DN	60	88	Mastered
5	EO	40	78	Mastered
6	ABP	55	86	Mastered
7	BK	48	82	Mastered
8	KP	42	76	Mastered
9	PT	58	92	Mastered
10	HP	38	75	Mastered
11	TR	52	84	Mastered
12	YM	46	80	Mastered
13	AR	62	95	Mastered
14	AN	44	82	Mastered
15	LVB	50	78	Mastered
16	NM	56	88	Mastered
17	MK	41	77	Mastered
18	NK	54	84	Mastered
19	RM	47	79	Mastered
Average		48,58	82,11	

The results of Cycle II indicate that all 19 students achieved learning mastery, resulting in a classical mastery level of 100%. Furthermore, the average pre-test score remained at 48.95, while the average post-test score increased significantly to 81.84. The N-Gain analysis in Cycle II showed an average score of 0.67, indicating a moderate level of improvement.

Table 4. Student Activities in Cycle II

Activity Indicators	Meeting 1	Meeting 2	Meeting 3	Meeting 4	Average
Using GeoGebra	84%	89%	95%	100%	92%
Participating in Discussions	74%	79%	84%	89%	81,5%
Completing Tasks	89%	95%	100%	100%	96%
Asking Questions	63%	68%	74%	79%	71%
Average Activity	77,5%	82,75%	88,25%	92%	85,13%

Based on the questionnaire on students' responses to learning using GeoGebra, the results indicate that 89.47% of students (n = 17) expressed positive responses, 10.53% (n = 2) expressed moderately positive responses, and no students (0%) expressed fewer positive responses.

Table 5. Comparison of Research Results

Aspect	Cycle I	Cycle II	Improvement
Classical Mastery	52,63	100	47,37
Average Score	75,16	81,84	6,68
N-Gain	0,52	0,67	0,15
Student Activity	57,88%	85,13%	27,25%
Positive Responses	68,42%	89,47%	21,05%

Discussion

Improvement of Conceptual Understanding in Transformation Geometry

The results of this study indicate that the use of GeoGebra significantly improves students' conceptual understanding of transformation geometry. In Cycle I, classical mastery reached only 52.63%, but it increased to 100% in Cycle II. This improvement supports the findings of, who stated that dynamic technology can help students better understand geometric transformations (Turgut, 2022). The improvement can be seen from several aspects of the learning process. First, dynamic visualization allowed students to directly observe the process of geometric transformations rather than only focusing on the results, as they could manipulate objects and see changes in real time (Zhang et al., 2025). Second, the interactive exploration features enabled students to experiment with various transformation parameters and identify emerging patterns, which supported deeper conceptual understanding instead of simple memorization (Prit Kaur et al., 2022). Third, learning with GeoGebra facilitated the construction of knowledge, as students were able to develop their own understanding through exploration, experimentation, and discovery during the learning activities (Sofwatun et al., 2025).

Student Activity in Learning

Student learning activity also increased significantly, rising from 57.88% in Cycle I to 85.13% in Cycle II. This improvement indicates that the integration of GeoGebra in the learning process positively influenced students' engagement (Hidayat et al., 2024). One contributing factor was technological adaptation, as students became more familiar with using GeoGebra after receiving more intensive guidance during Cycle II (Ardina et al., 2025). In addition, the use of interactive digital media encouraged active engagement in learning, where students were more involved not only in operating the software but also in participating in group discussions and problem-solving activities (Wibowo et al., 2023). Furthermore, the presence of visual and interactive features in GeoGebra increased students' learning motivation, making the learning process more interesting and stimulating for students studying transformation geometry (Schmid & Korenova, 2024).

Student Responses to Learning

Students' responses to the learning process also showed a significant improvement, increasing from 68.42% in Cycle I to 89.47% in Cycle II. This indicates that students had a more positive perception of learning activities that integrated GeoGebra. Many students expressed greater satisfaction with the learning process because it was more interactive and visually engaging compared to conventional teaching methods (Yeh, 2022). GeoGebra also helped students understand abstract mathematical concepts by transforming them into more concrete and visual representations, making the material easier to comprehend (Pfeiffer et al., 2025). In addition, the learning activities supported the development of students' technological skills, as they gained experience using digital tools to explore and understand mathematical concepts more effectively (Engelbrecht & Borba, 2024).

CONCLUSION

The findings of this study demonstrate that the implementation of GeoGebra effectively enhances students' conceptual understanding of transformation geometry in the Department of Mathematics Education at Universitas Flores. This effectiveness is reflected in the significant improvement in classical mastery, which increased from 52.63% in the initial stage to 100% after the learning intervention. In addition, student learning activities showed a considerable rise from 57.88% to 85.13%, indicating that the use of GeoGebra encouraged greater engagement and participation during the learning process. Students' responses toward the learning activities were also highly positive, improving from 68.42% to 89.47%, which suggests that the integration of technology in mathematics learning can increase students' interest and motivation. Furthermore, the N-Gain score of 0.67 indicates a moderate level of learning improvement, demonstrating that the instructional strategy provided a meaningful contribution to students' understanding of transformation geometry concepts. Overall, these results suggest that GeoGebra is a viable and effective instructional medium for improving the quality of transformation geometry learning at the tertiary education level, particularly in supporting interactive, visual, and concept-based mathematics instruction.

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