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A Systematic Review: Use of GeoGebra in Mathematics Learning at Junior High School in Indonesia and Japan

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Abstract

The aim of this research is to analyze the implementation of GeoGebra in mathematics learning at junior high school in Indonesia and Japan. This research examines systematic literature reviews using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method with articles indexed by Web of Science (WoS) and Scopus from 2010 to 2024. The research findings show that; (1) most publicized use of Geogebra begins in 2022; (2) the topic most frequently used in research related to the application of GeoGebra in Indonesia and Japan is geometric transformation; (3) the highest percentage of student perspective analysis results in Indonesia is 25% with the experience, reflect and explain aspects, each of which consists of 6 topics (triangular properties, geometric transformation, matrix operations, cylinders, perform set operations and different parts of a circles); (4) the highest percentage of student perspective analysis results in Japan is 38% with the experience aspect consisting of 6 topics (square roots, quadratic function, triangle similarity condition, inverse of inscribed angle theorem, quadratic equation and Pythagorean theorem). It is hoped that this research can provide input for using GeoGebra in mathematics learning in these two countries, because GeoGebra not only helps students understand mathematical concepts better, but also facilitates more interesting and interactive learning.

Keywords: GeoGebra; Indonesia; Japan; Mathematics; PRISMA Method

Abstrak

Tujuan dari penelitian ini untuk menganalisis implementasi penggunaan GeoGebra pada pembelajaran matematika SMP di Indonesia dan Jepang. Penelitian ini mengkaji tinjauan literatur sistematik menggunakan metode Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) dengan artikel yang terindeks WoS dan Scopus dari rentang tahun 2010 hingga 2024. Temuan penelitian menunjukkan bahwa; (1) penggunaan Geogebra paling banyak

dipublikasikan dimulai pada tahun 2022; (2) topik yang paling sering digunakan dalam penelitian terkait penerapan GeoGebra di Indonesia dan Jepang yaitu transformasi geometri; (3) persentase tertinggi hasil analisis perspektif siswa di Indonesia yaitu 25% dengan aspek experience, reflect, dan explain yang masing-masingnya terdiri dari 6 topik (triangular properties, geometric transformation, matrix operation, cylinder, perform set operations dan different parts of a circle); (4) persentase tertinggi hasil analisis perspektif siswa di Jepang yaitu 38% dengan aspek experience yang terdiri dari 6 topik (square roots, quadratic function, triangle similarity condition, inverse of inscribed angle theorem, quadratic equation dan theorem pythagoras). Penelitian ini diharapkan dapat memberikan masukan untuk menggunakan GeoGebra pada pemebelajaran matematika di kedua negara tersebut, karena GeoGebra bukan hanya membantu siswa dalam memahami konsep matematika secara lebih baik, tetapi juga memfasilitasi pembelajaran yang lebih menarik dan interaktif.

Kata Kunci: GeoGebra; Indonesia; Jepang; Matematika; Metode PRISMA

Introduction

Mathematics education at the junior high school level plays a crucial role as a strong foundation for building a deep understanding of more complex mathematical concepts at higher levels (Ye et al, 2023). The importance of this mathematical understanding, the integration of technology in learning becomes essential. As highlighted by Alison et al. (2020) and Weinhandl et al. (2021), the technological era has become an inseparable part of daily life, making the utilization of technological tools in mathematics education increasingly important.

The integration of technology, mathematical software such as GeoGebra examine the mathematical concepts to be more visual, concrete, and intuitive (Prieto-González et al., 2023; Thomas & Adebowale, 2023). According to Azizah et al. (2021) and Chytas et al. (2023), by using GeoGebra, students can more easily understand complex mathematical abstractions through real visual representations. Apart from that, technology can also increase student engagement in learning, because it can offer a more interesting and motivating learning experience.

GeoGebra as an interactive mathematics software has attracted researcher and educators around the world to conducting various research design (Bedada & Machaba, 2022).This is due to its ability to provide a rich platform for visualization, exploration, and proof of mathematical concepts. GeoGebra integrates various mathematical tools, such as graphics, geometry, algebra, calculus, and statistics, in one dynamic and easy-to-use environment (Dahal et al., 2019; Yerizon et al., 2021; Zulnaidi et al., 2020).

By using GeoGebra, students can visualize mathematical concepts concretely through dynamic graphical representations (Ramírez-Uclés & Ruiz-

Hidalgo, 2022). For example, students can draw graphs of functions, manipulate geometric objects, or display statistical data in the form of interactive diagrams. According to Dewantara et al. (2023), Harron et al. (2022) and Patsiomitou, (2023), it only helps students understand mathematical concepts visually, but also allows them to carry out in-depth independent exploration of the subject matter.

Study from Kustiawati & Siregar (2022) revealed that GeoGebra also facilitates visualization of mathematical concepts through a problem-oriented approach. By combining various mathematical tools in one integrated environment, GeoGebra allows students to ask questions, identify patterns, and actively explore mathematical relationships (Dahal et al., 2023). This process allows students to build a deep understanding and sustainable mathematical skills through solving real and relevant problems, especially those found in two countries with strong educational traditions such as Indonesia and Japan.

Indonesia and Japan as two countries with developing education, have shown increasing interest in utilizing technology in the context of mathematics learning. One technological tool that has received special attention in the mathematics education is GeoGebra (Lavicza et al., 2022; Sunzuma, 2023; Tejera et al., 2022). Although both countries have similar interest in the use of the technology, but there are the differences in educational culture, curriculum, and teaching practices may influence how GeoGebra is implemented and the extent of its effectiveness in the classroom.

In Indonesia, the use of digital learning media is still developing, especially in urban areas which have better accessibility to technological infrastructure (Aprianto et al., 2023). According to Siswanto & Peni (2023), the challenges faced include a lack of training for teachers in using technology in teaching, as well as limited access to devices and internet connectivity in some areas. In contrast, in Japan, the use of technology in education has become an integral part of teaching practices in many schools (Horita & Nagahama, 2023). A student-centered learning culture, supported by strong curriculum standards, has facilitated the integration of technology, including GeoGebra, in mathematics learning.

Indonesia and Japan both utilize Geogebra as an interactive tool in mathematics education at schools, encompassing concepts such as geometry, trigonometry, and calculus. Teachers and educators in both countries develop engaging learning materials, create simulations, activities, and interactive questions to reinforce students' understanding (Haleem et al., 2022). Geogebra is employed to bolster the comprehension of mathematical concepts through graphical visualization and direct manipulation of geometric objects. The Geogebra user communities are active in Indonesia and Japan, facilitating knowledge and

experience sharing and providing support for educators to enhance their skills in utilizing Geogebra.

On the other side, the differences of mathematics curriculum in Indonesia and Japan have correlation to the implementation of GeoGebra in learning mathematics (Maamin et al., 2021). According to Handican et al. (2023), the mathematics curriculum in Indonesia has a stronger emphasis on mastering basic concepts while according to Clark et al. (2020), the curriculum in Japan may place more emphasis on problem solving and developing critical thinking. Therefore, GeoGebra implementation will likely differ in terms of focus and teaching approach in these two countries. By understanding these differences, this study identify the challenges and opportunities associated with using GeoGebra in the context of mathematics education in Indonesia and Japan. Efforts to overcome challenges and effectively utilize the potential of technology in teaching mathematics can make a significant contribution to improving the quality of mathematics education in both countries (Sitopu et al., 2024).

This study focus on the use of GeoGebra in mathematics learning at junior high school in Indonesia and Japan. It is important to deep understanding how GeoGebra is used and understood by teachers and students in both countries. So that the challenges, opportunities, and best practices in integrating this technology at the junior high school mathematics curriculum can be identified. Therefore, this research may not only provide insights into the effectiveness of using GeoGebra in the context of mathematics education but also contribute valuable information for the development of mathematics curriculum and better teaching practices at the junior high school level in Indonesia and Japan.

Method

Research Design

The main exploration is the use of geogebra in mathematics learning at junior high school in indonesia and japan. Through a thorough examination of pertinent literature, this approach enables a comprehensive understanding of existing frameworks while pinpointing areas for further exploration (Riswanto et al., 2023). By consolidating, scrutinizing, and amalgamating various relevant sources, it becomes possible to assess specific hypotheses or formulate novel theories. This inquiry employs a systematic literature review methodology concentrating on self-efficacy and its significance within mathematics education.

This study adopts the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Parums, 2021). The PRISMA guideline

incorporates a four-phase flowchart delineating the criteria for identification, screening, eligibility, and inclusion of studies within the review scope, with a particular emphasis on the quantitative aspect encompassing the number of studies incorporated and excluded. The application of the PRISMA approach assists researchers in selecting pertinent studies based on their research inquiries (Page et al., 2021; Utami et al., 2021). The PRISMA flowchart outlines steps to identify studies pertinent to the researcher's requirements concerning resilience in mathematics.

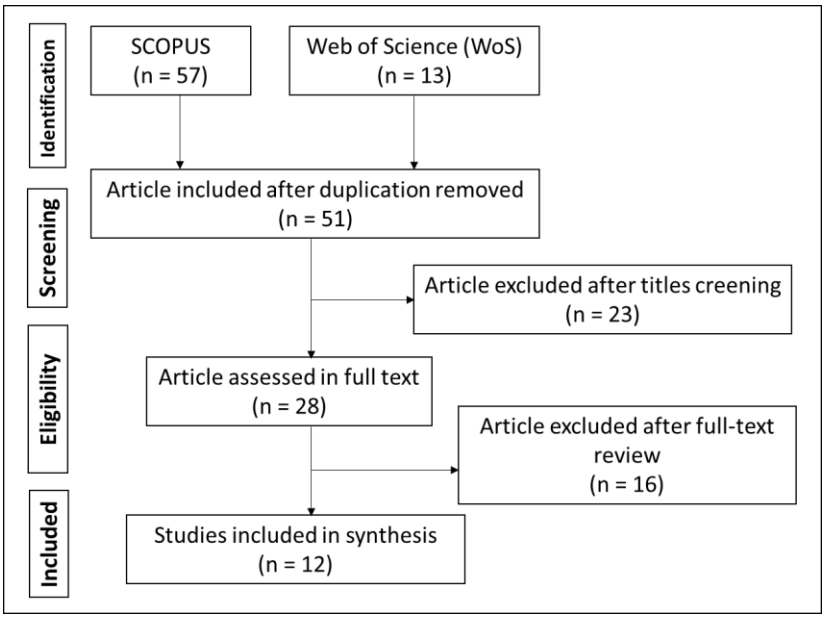

Figure 1. Illustrates the PRISMA Flow Diagram n this Study

To investigate students' perspectives on the integration of GeoGebra into mathematics instruction in both countries, an approach informed by Arends (2012) and Hideyo (2016) was adopted, and each classroom was evaluated. Five dimensions of the approach were delineated. The five dimensions including students' personal experiences, discovery/observation, result explanation, reflection, and development. This endeavor seeks to evaluate the utilization of Mathematics technology in teaching and learning at the junior high school level.

Study Procedure

The research articles used in this study consisted of articles originating from SCOPUS and Web of Science (WoS) with publication years between 2010 and 2024, enabling to direct our review towards the most recent literature while considering the retrieval and synthesis of information in the digital era. Therefore, every database and specific search criteria related to the topic were selected. The

topic was initially researched, then its abstract was examined to determine its suitability for the research. Furthermore, if it was determined that the study met the initial criteria, its full text was retained for comprehensive review and evaluation. The keywords used include "Geogebra in Indonesia" and "Geogebra in Japan".

Inclusion and Exclusion Criteria

The data collection process involved selecting articles across various databases in academic searches. These criteria are applied through filters and searches for certain keywords using the advanced search features on certain database sites. Several acceptance and rejection criteria were established, as shown in Table 1. Acceptance criteria included articles published from 2010 to 2024. Rejected articles include articles published before 2010, as well as articles that are not part of a journal or proceedings. The selected articles must be correlate with the implementation of GeoGebra in Indonesia and Japan. Articles were either defined through keyword search (n = 57) or through reference and manual search (n = 13). Excluded articles, as seen in Table 1 (n = 23), as well as discarded records (n = 51). Filtered articles (n = 28), and eligible articles after filtering (n = 28). Articles used for research analysis (n = 12), while articles without full text or titles not relevant to the research were excluded (n = 16).

Table 1. Acceptance and Rejection Criteria for Articles

Criteria	Decider
Published 2010-2024	To determine the relevant period of 14 years
Indonesian, Japanese and English	The selected languages are Indonesian, Japanese and English
In the field of GeoGebra and Mathematics subjects	This systematic aim is to examine the use of Geogebra in junior high school mathematics

Data Analysis

Data collection was carried out by extracting the title, year, type of technological approach, and role of GeoGebra software use for each independent study article. Thematic analysis was used for categorized every article that correlate to this study. PRISMA method consist several steps, including identification, screening, eligibility and inclusion. Learning to do this gives qualitative researchers a foundation of basic skills necessary to use other approaches to data analysis. In addition, thematic analysis is a configurative approach that involves several activities, including interpretation as an ongoing

activity during the analysis and synthesis process (Basarir-Ozel et al., 2022; Gough et al., 2012).

Results

The results of this study are related to the analysis of 12 articles to address the research questions after undergoing a review process using the PRISMA method. The selected articles have been systematically analyzed using thematic analysis, with the initial steps being to present and compare the 12 selected articles as seen in the following table.

Table 2. Presenting and Comparing Selected Articles

Author	Year	Country	Topic
Setiawan et al.	2022	Indonesia	Quadrilateral
Ilmi et al.	2022	Indonesia	Geometric transformation
Marfuah et al.	2022	Indonesia	Matrix operation
Silwana & Qohar	2022	Indonesia	Cylinder
Amalia et al.	2020	Indonesia	Perform set operations
Ishartono et al.	2022	Indonesia	Different parts of a circle
Miyazaki et al,	2012	Japan	Three Dimensional
Bwalyza	2019	Japan	Geometric transformation
Komatsu & Jones	2022	Japan	Triangle similarity condition
Komatsu & Jones	2020	Japan	Inverse of inscribed angle theorem
Ju et al.	2022	Japan	Quadratic equation
Castro et al.	2021	Japan	Theorem Pythagoras

Research Distribution Based on Publication Year

The first research question pertains to the distribution of studies on the usage of Geogebra software based on publication year. Overall, Figure 1 illustrates the distribution of publication years in the usage of Geogebra software in mathematics education.

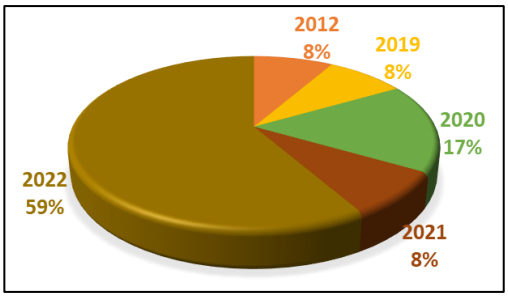

Figure 2. Year of Publication

Based on Figure 2, it can be observed that research findings on Geogebra technology in mathematics according to year, with the highest percentage of research being published in 2022, accounting for 59% of the studies. This is followed by 17% of research in 2020, and in 2012, 2019, and 2021, each with 8% of the studies. The research results indicate that the most published research on the usage of Geogebra started in 2022. This reflects a significant interest from researchers in conducting studies on Geogebra technology in the context of mathematics.

The Mathematical Topics in the Usage of Geogebra at Junior High Schools

Mathematical topics used in the research have been elucidated in the following Figure 3.

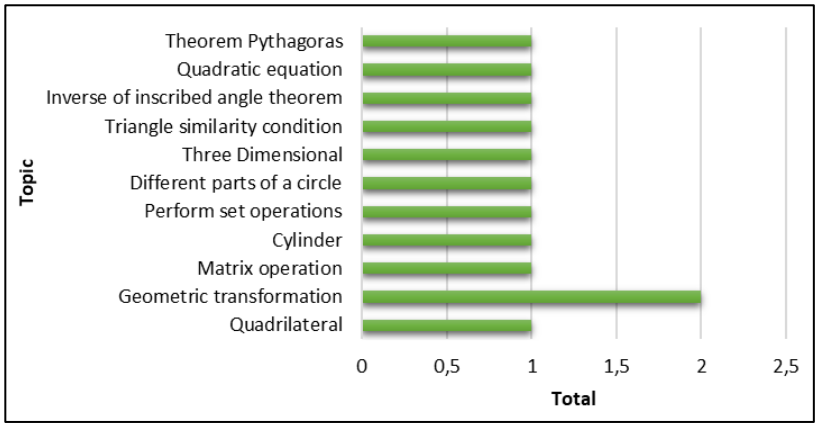

Figure 3. Mathematical Topics

Based on the above Figure 3, geometric transformation is the most frequently utilized topic in research related to the implementation of GeoGebra in Indonesia and Japan. Additionally, other topics such as theorem pythagoras, quadratic equation, inverse of inscribed angle theorem, triangle similarity condition, three dimensional, different parts of a circle, perform set operations, cylinder, matrix operation, and quadrilateral are also included in the topics used in research related to the application of GeoGebra in teaching mathematics at the junior high school level.

Analysis of Geogebra Usage Based on 5 Aspects of Combined Student Perspectives By Arends (2012) and Hideyo (2016) in Indonesia

The analysis results of 6 topics from Indonesia can be seen in the table below.

Table 3. Analysis of 6 Topics in Indonesia

	Experience	Discover	Explain the results	Reflect	Develop
Triangular Properties	√		√	√	√
Geometric transformation	√	√	√	√	√
Matrix operation	√		√	√	√
Cylinder	√		√	√	
Perform set operations	√		√	√	
Different parts of a circle	√	√	√	√	√

The first topic is triangle properties. Based on this table, it was found that students can experience, explain the results, reflect on, and develop the content of triangle properties using GeoGebra, but they cannot discover the content of triangle properties using GeoGebra. The second topic is geometric transformations. According to this table, it was found that students can fulfill all perspectives of student thinking. Furthermore, the third lesson topic is matrix operations. Based on this table, it was found that students can experience, explain the results, reflect on, and develop the content of matrix operations using GeoGebra, but they cannot discover the content of matrix operations using GeoGebra.

The fourth topic is cylinders. Based on this table, it was found that students can experience, explain the results, and reflect on the content of cylinders using GeoGebra, but they cannot discover and develop the content of cylinders using GeoGebra. The fifth topic is performing prescribed operations. According to this table, it was found that students can experience, explain the results, and reflect on the content of performing set operations using GeoGebra, but they cannot discover and develop the content of performing set operations using GeoGebra. Lastly, the topic is different parts of a circle. Based on this table, it was found that students can fulfill all perspectives of student thinking.

Percentage of student perspective analysis results in Indonesia are as follows: for the aspects of Experience, Reflect, and Explain the result, each of the 6 topics has a percentage of 25%; the aspect of Develop for 4 topics is 17%; and the aspect of Discover for 2 topics is 8%. This can be seen in the following Figure 4.

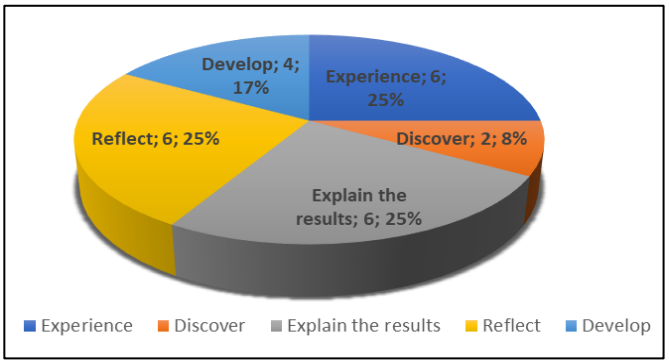

Figure 4. Percentage of 5 aspects of student perspectives related to Geogebra in Indonesia

Analysis of Geogebra Usage Based on 5 Aspects of Combined Student Perspectives By Arends (2012) and Hideyo (2016) in Japan

The analysis results of 6 topics from Japan can be seen in the table below.

Table 4. Analysis of 6 topics in Japan

	Experience	Discover	Explain the results	Reflect	Develop
Square roots		√		√	
Quadratic function	√			√	
Triangle similarity condition	√		√	√	
Inverse of inscribed angle theorem	√	√	√	√	√
Quadratic equation		√		√	
Theorem Pythagoras	√			√	

The content of the first topic is square roots. Based on this table, it was found that students can discover and reflect on the content of square roots using GeoGebra, but they cannot experience, explain outcomes, and develop the content of square roots using GeoGebra. The content of the second topic is quadratic functions. Based on this table, it was found that students can experience and reflect on the content of quadratic functions using GeoGebra, but they cannot discover, explain outcomes, and develop the content of quadratic functions using GeoGebra. Furthermore, the content of the third topic is triangle similarity condition. Based on this table, it was found that students can experience, explain outcomes, and reflect on the content of triangle similarity condition using GeoGebra, but they cannot discover and develop the content of triangle similarity condition using GeoGebra.

The content of the fourth topic is the inverse of the angle theorem. Based on this table, it was found that students can fulfill all perspectives of student thinking methods. The content of the fifth topic is quadratic equations. Based on this table, it was found that students can discover and reflect on the content of quadratic equations using GeoGebra, but they cannot experience, explain outcomes, and develop the content of quadratic equations using GeoGebra. Hopefully, the last topic to be discussed is the Pythagorean theorem. Based on this table, it was found that students can experience and reflect on the content of the Pythagorean theorem using GeoGebra, but they cannot discover, explain outcomes, and develop the content of the Pythagorean theorem using GeoGebra.

The percentage of analysis results of student perspectives in Japan is shown as follows: for the Reflect aspect, 6 topics with a percentage of 38%; for the Experience aspect, 4 topics with a percentage of 25%; for the Discover aspect, 3 topics with a percentage of 19%; for the Explain the result aspect, 12%; and for the Develop aspect, 1 topic with a percentage of 6%. This can be seen in the following Figure 5.

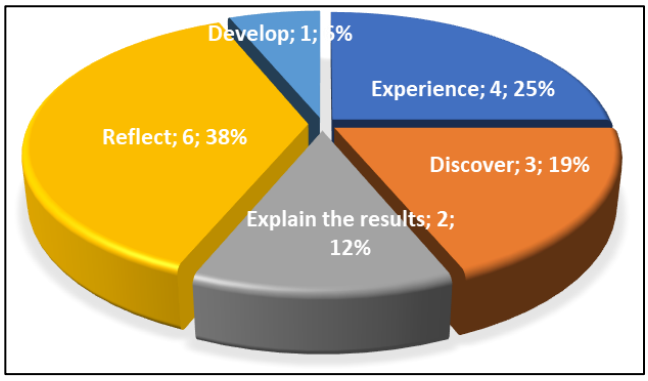

Figure 5. Percentage of 5 Aspects of Student Perspectives Related to GeoGebra in Japan

Discussion

The purpose of this study is to analyze the implementation of GeoGebra in mathematics learning at junior high school in Indonesia and Japan. The study utilizes the PRISMA method incorporating a four-phase flowchart delineating the criteria for identification, screening, eligibility, and inclusion of studies within the review scope, involves research findings indicating that the usage of GeoGebra software has increased from 2010 to 2024. This reflects researchers' interest in examining the use of GeoGebra in mathematical topics. The reason is GeoGebra

software can be used for free and user-friendly. Relate with the findings, Ngwabe & Felix (2020) and Zulnaidi et al. (2020) states that using GeoGebra as a teaching tools can reduce misconceptions than traditional methods. Furthermore, Suratno & Waliyanti (2023) also indicates that GeoGebra software has a significant impact on mathematical communication, reasoning and proving, as well as problem-solving.

Research findings based on country indicate that Indonesia and Japan are conducting research related to GeoGebra software in mathematical topics. Additionally, in 2022, Indonesia and Japan also became the focus of high research related to software usage, especially GeoGebra. These findings are in line with other studies, such as Courtney et al. (2022), Setiawan et al. (2022) and Siswanto et al. (2024), which report that the usage of mathematical software has a significant influence on students' mathematical abilities. However, some other studies conducted by Priyono & Hermanto (2017) and Yuan et al. (2023) report that the usage of mathematical software in education has an influence, but not significant.

The research findings also reinforce the statements by Bedada & Machaba (2022) indicating that students have a positive attitude towards learning mathematics, achieving the expected achievements in their learning through the use of GeoGebra software. Technological developments have had an impact and changes on the teaching and learning process worldwide. The use of GeoGebra technology in education has transformed teaching and learning from traditional to interactive. This statement is also supported by research Nzaramyimana et al. (2021), Tamam & Dasari (2021) and Yildiz & Arpaci (2024) stating that technology applications such as GeoGebra software are used in teaching and learning to make learning more meaningful and conceptual.

The research findings indicate that the topic of geometric transformation is the most widely used in research. This finding is in line with research Machromah et al. (2019), Uwurukundo et al. (2020) and Yorganci (2018) stating that GeoGebra can be applied in mathematics, especially in teaching and learning calculus, algebra and geometry. It is widely recommended to be applied in various activities based on mathematical concepts. Additionally, GeoGebra is very helpful in explaining concepts and procedures through the creation of graphs, images, and symbols that often appear in topics such as theorem pythagoras, quadratic equation, inverse of inscribed angle theorem, Triangle similarity condition, three dimensional, different parts of a circle, perfom set operations, cylinder, matrix operation, and quadrilateral. Furthermore, GeoGebra software is used to enhance students' conceptual and procedural understanding based on the need to integrate technology into mathematics teaching and learning. This statement is supported by research Tong et al. 2021 and Ziatdinov & Valles (2022) which determines that

using GeoGebra as a cognitive tool and considering dynamic aspects for teaching about exponential and logarithmic functions helps mathematics teachers interpret better and identify relationships between algebraic representations and function graphs.

Furthermore, the research findings state that the implementation of GeoGebra regarding the 5 aspects of combined student perspectives according to Arends (2012) and Hideyo (2016) in Indonesia is that in all 6 lesson topics, GeoGebra is actively integrated into the learning process to engage students in direct exploration, explain mathematical concepts, and promote self-reflection. Consistent with this, Dewi (2022) and Dhungana (2023) states that allowing students to explore various mathematical concepts and gain better experiences through self-reflection. Additionally, it was found that GeoGebra is consistently used in various capacities in these mathematics classes in Indonesia, enhancing student engagement and understanding through experience, explanation, and reflection.

Meanwhile, the implementation of GeoGebra regarding the 5 aspects of combined student perspectives according to Arends (2012) and Hideyo (2016) in Japan is that through the use of GeoGebra, students can more effectively reflect on, understand, and internalize mathematical concepts as they can engage in visual, interactive, and exploratory experiences. Additionally, it was found that GeoGebra is mainly used in classes since the effectivity in helping students understand the mathematical concepts

Conclusion

Based on the results and discussion, the implementation of GeoGebra in mathematics education in Indonesia and Japan is presented, highlighting its potential impact and benefits in the classroom. By examining how GeoGebra is used in both countries, this study identifies various aspects of GeoGebra usage that affect mathematics learning, including student interactions, teacher responses, and its impact on understanding mathematical concepts.

Furthermore, the integration of GeoGebra into mathematics education in Indonesia and Japan shows the potential to enhance students' learning experiences and teacher instructional strategies. By providing interactive, visual, and exploratory opportunities, GeoGebra contributes to deeper mathematical understanding and fosters a culture of reflection and engagement in both countries. Through the use of GeoGebra, students are encouraged to actively explore mathematical concepts, ask questions, and solve problems in a more independent and creative manner. On the other hand, teachers can use GeoGebra

as a tool to design student-centered learning, facilitate discussions, and provide more focused feedback to students.

Thus, the integration of GeoGebra into mathematics education in Indonesia and Japan not only opens doors to deeper understanding of mathematical concepts but also shapes a dynamic and inclusive learning culture in both countries. Therefore, GeoGebra serves not only as a teaching tools but also as a catalyst in mathematics learning approaches, enhancing the quality of teaching and learning, and promoting student independence in mathematics learning.

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