International Journal of Elementary Education
Volume 8, Number 3, Tahun 2024, pp. 519-527
P-ISSN: 2579-7158 E-ISSN: 2549-6050
Open Access: https://doi.org/10.23887/ijee.v8i3.85378

Assistive Technology in Mathematics Education: Investigating the Effectiveness of Math Manipulatives for Students with Disabilities

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ARTICLE INFO

Article history:
Received May 02, 2024
Accepted August 10, 2024
Available online August 25, 2024

Kata Kunci:
Math-Manipulatives, Assistive Technology, *Pembelajaran Matematika, Siswa Penyandang Disabilitas, Pendidikan Inklusif*

Keywords:
Math-Manipulatives, Assistive Technology, Mathematics Learning, Students with Disabilities, Inclusive Education

ABSTRAK

Pembelajaran matematika bagi siswa penyandang disabilitas sering kali menghadapi berbagai tantangan, seperti rendahnya pemahaman terhadap konsep abstrak dan keterbatasan dalam penggunaan media yang adaptif. Penelitian ini bertujuan untuk menginvestigasi pemanfaatan math-manipulatives *sebagai teknologi bantu (*assistive technology*) untuk mendukung pembelajaran matematika yang lebih inklusif dan interaktif. Penelitian ini menggunakan pendekatan kualitatif dengan desain eksploratif. Data dikumpulkan melalui* Focus Group Discussion *(FGD) dan wawancara mendalam dengan melibatkan guru dan siswa sebagai responden utama. Analisis data dilakukan menggunakan metode tematik untuk mengidentifikasi pola penggunaan* math-manipulatives *dalam pembelajaran. Hasil penelitian menunjukkan bahwa* math-manipulatives*, seperti papan bilangan, kartu angka, dan alat visual lainnya, memberikan dampak signifikan dalam meningkatkan pemahaman konsep matematika secara konkret. Penggunaan math-manipulatives juga mendorong motivasi belajar siswa serta keterlibatan aktif mereka dalam proses pembelajaran, terutama saat bekerja dalam kelompok. Selain itu, keberadaan media ini membantu guru dalam merancang pembelajaran yang lebih adaptif terhadap kebutuhan siswa. Simpulan penelitian menegaskan bahwa math-manipulatives sebagai teknologi bantu memiliki potensi besar dalam mendukung pembelajaran matematika bagi siswa penyandang disabilitas, baik dari aspek kognitif maupun afektif. Informasi terbaru pada penelitian ini memberikan kontribusi penting terhadap pengembangan ilmu pengetahuan dalam bidang pendidikan inklusif dan teknologi pendidikan.*

ABSTRACT

Mathematics education for students with disabilities often faces various challenges, such as difficulties in understanding abstract concepts and limitations in using adaptive media. This study aims to investigate the utilization of math manipulatives as assistive technology to support more inclusive and interactive mathematics learning. Employing a qualitative approach with an exploratory design, data were collected through focus group discussions (FGDs) and in-depth interviews involving teachers and students as primary respondents. Thematic analysis was used to identify patterns in the application of math manipulatives during the learning process. The findings reveal that math manipulatives, such as number boards, numeric cards, and other visual tools, significantly enhance students' comprehension of mathematical concepts concretely. Furthermore, the use of math manipulatives fosters students' learning motivation and active participation, particularly in group work. Additionally, these tools assist teachers in designing lessons that are more adaptive to students' needs. The study concludes that math manipulatives as assistive technology holds substantial potential to support mathematics education for students with disabilities, addressing both cognitive and affective aspects. The latest information in this research provides an important contribution to the development of science in the field of inclusive education and educational technology.

1. INTRODUCTION

Mathematics learning at the elementary school level has an important role in building the foundations of logical, numerical, and problem-solving thinking for students (Sidik et al., 2024; Siregar et al., 2024). However, the challenges faced by students with disabilities in understanding mathematical concepts are often more complex than those faced by students without disabilities. This is in line with previous research which states that children with special needs have difficulty learning Mathematics (Anditiasari, 2020; Sakiinatullaila et al., 2020). This can be caused by cognitive, sensory, or physical barriers that affect students' ability to receive and process information. To overcome these barriers, an inclusive learning approach and the use of assistive technology are needed to support students in understanding abstract mathematical concepts.

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Technology plays an important role in various fields, including education (Isti'ana, 2024; Fricticarani et al., 2023; Manan, 2023). 21st century learning is closely related to technology and information.(Rahayu, Iskandar, & Abidin, 2022; Septikasari & Frasandy, 2018). One form of assistive technology that is increasingly being used in mathematics learning for students with disabilities is math-manipulatives. Previous research suggests that virtual manipulatives can support the learning of students with disabilities (Bouck et al., 2020; Park et al., 2022). Math-manipulatives are concrete learning tools that allow students to manipulate physical objects to understand mathematical concepts more visually and kinesthetically. The use of manipulatives such as building blocks, magnetic numbers, geometry boards, and others, not only help students visualize abstract concepts, but also give them the opportunity to be actively involved in the learning process. For students with disabilities, manipulatives also function as assistive technology that can overcome physical and sensory limitations, while increasing their participation in learning. Assistive technology or assistive technology is a tool for assisting, adaptive, and rehabilitative purposes for individuals with disabilities that includes almost anything that can be used to compensate for a lack of a particular ability (Desmond et al., 2018; MacLachlan et al., 2018). Assistive technology can help children with disabilities learn (Azzahra et al., 2024; Zen, Rachim, & Apsari, 2024). Previous research states that assistive technology can overcome the learning difficulties of blind students in mathematics (Rosita et al., 2022; Daroni et al., 2018).

A number of studies have shown that the use of manipulative Mathematics media can improve students' learning outcomes, conceptual understanding, motivation, and self-confidence in Mathematics learning (Rahmat et al., 2023; Martiasari & Kelana, 2022; Murni et al., 2022). However, the limited number of studies that specifically examine the effectiveness of math-manipulatives as assistive technology in the context of learning for students with disabilities in elementary schools opens up space for further research. This is important considering the differences in characteristics and needs of each student with disabilities, which require an individual approach in the application of learning aids. This study aims to investigate how math-manipulatives are used as assistive technology to support mathematics learning for students with disabilities in elementary schools. Specifically, this study will explore the types of math-manipulatives used, how they are used, and their impact on students' understanding of mathematical concepts, student engagement, and their ability to solve mathematical problems. It is hoped that the results of this study will provide new insights into the importance of utilizing math-manipulatives as inclusive assistive technology and provide recommendations for educators in designing more adaptive learning for students with disabilities.

2. METHOD

Study Design

This research uses a qualitative approach with an exploratory design (Mudjiyanto, 2018). This study aims to analyze and describe in depth the use of math-manipulatives as assistive technology in mathematics learning for students with disabilities in elementary schools. The exploratory design was chosen because it is appropriate for exploring a comprehensive understanding of complex and under-researched phenomena, especially related to the use of math-manipulatives in the context of inclusive education. This approach allows researchers to explore more broadly the role of assistive technology in supporting the understanding of mathematical concepts for students with various special needs. Through qualitative methods, researchers can interact directly with teachers, students, and related parties who have practical knowledge on this topic, thus allowing for deeper data collection on perceptions, experiences, and challenges faced in the use of math-manipulatives in inclusive classrooms (Tracy, 2019).

Participants

Participants in this study consisted of a number of teachers and students with disabilities who were in an inclusive elementary school. The teachers involved were mathematics teachers with experience in using math-manipulatives as a learning aid. These teachers were selected based on the criteria of experience teaching students with disabilities, so they were expected to have a deep understanding of student needs and adaptive teaching strategies. Meanwhile, the students who participated were students with disabilities with various special needs backgrounds, such as physical disabilities, sensory disabilities, and cognitive barriers. The selection of students was carried out by purposive sampling, with the criteria of students who had difficulties in understanding mathematical concepts and had been involved in learning using math-manipulatives. Their involvement in this study was important to explore direct experience in utilizing math-manipulatives as assistive technology in mathematics learning, as well as to understand the impact of this tool on their involvement and understanding of concepts.

Data Collection

The data collection method in this study was carried out through Focus Group Discussion (FGD) and in-depth interviews to explore more comprehensive information related to the use of math-manipulatives as assistive technology in mathematics learning for students with disabilities in elementary schools. FGD involved teachers who had experience in teaching students with special needs, aiming to discuss their experiences, strategies, and challenges they faced in utilizing math-manipulatives. This group discussion provided an opportunity for participants to share views and best practices, while revealing various perspectives on the role of assistive technology in supporting inclusive mathematics learning. FGD also allowed researchers to capture the dynamics of interactions between teachers, as well as obtain richer data through the exchange of ideas and joint reflection. In addition to the FGD, in-depth interviews were conducted individually with teachers and students with disabilities who were participants. In-depth interviews were designed to dig deeper into the participants' personal experiences, especially regarding the effectiveness of using math-manipulatives in improving students' understanding of mathematical concepts. With these interviews, researchers were able to identify perceptions, challenges, and special needs experienced by students and teachers in the learning process.

Instruments

The instruments used in the Focus Group Discussion (FGD) and in-depth interviews were designed to collect relevant data on the use of math-manipulatives as assistive technology in mathematics learning for students with disabilities. This instrument is in the form of a semi-structured discussion and interview guide, which provides flexibility for researchers to further explore participant responses, while remaining focused on the research objectives. Examples of questions used as guidelines in the implementation of FGD and in-depth interviews are presented in Table 1.

Table 1. The Example of questions

Data Collection Methods	Target	Example of Questions
Focus group discussion		What is your experience in using math-manipulatives in mathematics learning for students with disabilities? What types of math manipulatives do you use most often, and how effective do you think they are? What are some challenges you face when using math manipulatives with students who have a variety of special needs? How do you think math-manipulatives can help increase the engagement of students with disabilities in learning? Do you feel there are any special needs or modifications that should be made to better accommodate students with specific disabilities?
In-depth interview	Teacher	Can you tell us more about your experiences using math manipulatives with specific students with disabilities? How do students respond when using math-manipulatives? Do they find it easier to understand the material? What technical or pedagogical barriers have you encountered when using math manipulatives in the classroom? How do you think math manipulatives can be adapted to be more effective for students with different disabilities?
	Student	How do you feel when learning math using tools like math-manipulatives? Did the tool help you understand the lesson? If so, which part did you find most helpful? Are there any difficulties you experience when using math-manipulatives? Do you find it easier to learn math with these tools than with other methods? Why?

Data Analysis

Data analysis in this study was conducted using a thematic analysis approach, which allows researchers to identify, analyze, and report key patterns or themes that emerge from data collected through Focus Group Discussions (FGDs) and in-depth interviews. The analysis process began with the transcription

of all recorded discussions and interviews, followed by a thorough reading to understand the context and content of the data. Next, the researcher coded the data by marking relevant pieces of information according to themes related to the use of math-manipulatives as assistive technology. After coding, the themes that emerged were analyzed in depth to understand their meaning and implications in the context of mathematics learning for students with disabilities. The results of the analysis were then compiled in the form of a narrative that describes the experiences, perceptions, and challenges faced by teachers and students, so as to provide comprehensive and in-depth insights into the research topic.

Validity and Reliability

To determine the credibility and validity of this research data, the researcher applied several triangulation strategies, including triangulation of sources, methods, and researchers. Source triangulation was carried out by comparing information obtained from various participants, such as teachers and students, to ensure consistency and diversity of perspectives in the use of math-manipulatives. Furthermore, method triangulation was applied by using FGD and in-depth interviews as data collection methods, so that it could produce more comprehensive and in-depth data. The researcher also involved colleagues in the data analysis process to obtain objective feedback and enrich the interpretation of the results. In addition, the researcher conducted member checking by confirming the initial findings with several participants to ensure that the interpretation of the data produced was in accordance with their experiences. Through these steps, the credibility and validity of the research data can be strengthened, providing more confidence in the findings produced.

Ethical Considerations

This study has obtained ethical approval from the Research Ethics Committee, Ganesha University of Education, Indonesia. Throughout the research process, research ethics standards were strictly followed, including obtaining written consent from all participants through the informed consent process.informed consent. Participants were given detailed explanations about the purpose, procedures, and potential benefits of the study and their right to withdraw at any time without any consequences. Confidentiality of participant data was ensured by using anonymous identification codes and storing data in a secure format. Participation in the study was voluntary, and no pressure or coercion was applied to participants to participate in the study.

3. RESULT AND DISCUSSION

Result

The Use of Math-Manipulatives in Mathematics Learning

The findings from the Focus Group Discussion (FGD) and in-depth interviews revealed that various types of math-manipulatives are used in mathematics learning for students with disabilities, which serve to facilitate understanding of concepts and increase student engagement. One of the most commonly used types is physical teaching aids. For example, number blocks and beads are used to teach concepts.addition and subtraction. These tools allow students to directly see and feel numbers, thus helping them to better understand basic mathematical operations. In addition, number boards are also often used. Number boards allow students to visualize the relationship between numbers and number concepts, and help them learn to arrange numbers in sequence. Students can use their fingers to point to the numbers on the board, thus supporting their fine motor development while strengthening their numerical understanding.

Number cards are another type of math-manipulative that is widely used. They can be used in a variety of activities such as card games to teach number order or number recognition. Teachers report that students show increased interest and engagement when using number cards, which makes the learning process more interactive and fun. In addition to physical tools, there are also educational software or applications based on augmented reality (AR) that are utilized by some teachers. These applications allow students to interact with mathematical concepts in an engaging virtual environment. For example, using an AR application to draw geometric shapes in the air, students can see and manipulate the shapes in real-time, providing a richer learning experience.

Finally, visual aids such as diagrams and graphs also fall under the category of math-manipulatives. These tools help students understand relationships between data, as well as visualize numerical information in a clearer way. Venn diagrams or bar graphs are used to teach the concepts of comparison and classification, which are very useful in simple statistics lessons.

Teachers' Experiences in Using Math-Manipulatives

Teachers highlighted that the use of math-manipulatives has brought significant changes in the way they teach and the way students understand mathematical concepts. One experience that is often shared is the use of number blocks. Teachers reported that this tool not only makes it easier for students to understand addition and subtraction, but also helps them develop fine motor skills. “When they hold and arrange the number blocks, I see them become more active and enthusiastic about learning,” said one teacher.

Positive experiences also emerged when using the number board. Teachers observed that the number board greatly helped students understand the order of numbers and number concepts. One teacher explained, “I often use the number board to introduce the concept of fractions. This way, students can see and feel for themselves how fractions are formed.” The teacher emphasized that the number board allows students to interact directly with the concepts being taught, thus deepening their understanding.

Number cards have also become a popular tool among teachers. They create various games using them to teach number recognition and basic operations. “I often play games with number cards, and students really enjoy them. They not only learn numbers, but also learn to work together with their friends,” said one teacher. The use of number cards provides a fun and interactive learning atmosphere, which has been shown to increase student motivation.

Some teachers also reported positive experiences when using augmented reality (AR)-based educational software. One teacher shared, “When I use AR applications to teach geometry, I see students are so captivated. They can manipulate 3D shapes, and this really helps them understand concepts that were previously difficult.” The use of this technology allows students to interact with the subject matter in an innovative and engaging way. In addition, teachers reported that they faced several challenges in using math-manipulatives. One major challenge was the limited tools and resources available in the school. “We often have difficulty getting the right manipulatives. Sometimes, we have to make the tools ourselves so that we can use them in our lessons,” explained one teacher. Despite the challenges, teachers remain optimistic and committed to creating the best learning experience for their students.

The teachers' experience in using math-manipulatives shows that this tool not only functions as a teaching aid, but also as a link between students and the mathematical concepts being taught. Through the use of math-manipulatives, teachers can create a more inclusive learning environment and523responsive to the needs of students with disabilities.

Students' Perceptions of Math-Manipulatives

Students generally feel that math-manipulatives are very helpful in understanding previously difficult mathematical concepts. One type of math-manipulative that is often used is number blocks. Students said that by using number blocks, they can more easily describe and manipulate numbers in addition and subtraction operations. "I like playing with these blocks. They make the numbers look real and I understand them better," said one student.

In addition, the use of number boards also has a positive impact. Many students feel more engaged when they can use the number board to draw or show numbers. “With the number board, I can see and arrange the numbers the way I want. It really helps when I’m learning fractions,” said one student. This interactive experience allows them to understand the relationship between numbers and mathematical concepts in a more concrete way.

Students also expressed their joy when using number cards in learning activities. Number cards are used in various games that involve recognizing and sequencing numbers. “I really like this card game! It feels like playing, but I also learn a lot about numbers,” said one student, showing how games can make the learning process fun.

Meanwhile, when talking about the use of educational software based on augmented reality (AR), students showed high enthusiasm. They felt that this technology brought a new and interesting learning experience. “When I see 3D shapes in the AR application, I feel like I am in another world! I can rotate and see the shape from different sides,” said a student excitedly. This experience not only improved their understanding of geometry but also made them feel more confident in learning.

However, not all students’ perceptions were positive. Some students expressed challenges they faced when using math-manipulatives. For example, some students felt confused about the use of certain tools, such as diagrams and graphs. “Sometimes, I don’t know where to look. The diagrams look complicated,” complained one student. These challenges show that while math-manipulatives have benefits, it is important for teachers to provide the right support and guidance so that students can maximize their use.

Challenges in Implementing Math-Manipulatives

One of the main challenges identified was the lack of tools and resources. Many teachers reported that they did not always have adequate access to the various types of math-manipulatives needed. For example, several teachers complained about the lack of number blocks and number cards that could be used effectively in the classroom. "We often lack the tools needed to help students learn. I have to make some of my own tools to teach basic concepts," said one teacher. These limitations hinder teachers' efforts to provide optimal learning experiences for students.

Another challenge is related to teacher training and knowledge in using math-manipulatives. Some teachers feel inadequately trained in how to effectively integrate math-manipulatives into the learning process. "I feel like sometimes I don't know the best way to use the tools. There are a lot of tools out there, but I feel confused about which one is best for my students," said one teacher. This lack of knowledge about the use and application of math-manipulatives can reduce the effectiveness of the tools in improving student understanding.

In addition, students themselves also experienced challenges in adapting to the math-manipulatives used. For example, when using diagrams and graphs, some students found it difficult to understand the information presented. "Sometimes, I get confused looking at the diagram. It looks complicated and I don't know what to do," said one student. This difficulty shows that although math-manipulatives can improve understanding, they also require sufficient guidance to ensure that students can use the tools effectively.

Classroom space issues also pose a significant challenge. Several teachers mentioned that limited classroom space makes it difficult to use physical teaching aids optimally. "We don't have enough space to spread out these tools. When we try to use the number board, for example, the classroom becomes too crowded," explained one teacher. This limited space hinders interactive activities involving math-manipulatives, which would otherwise increase student engagement.

Benefits of Math-Manipulatives for Students with Disabilities

One of the most frequently mentioned benefits is an increased understanding of concrete mathematical concepts. Math-manipulatives such as number blocks and number boards help students see and feel abstract concepts more clearly. For example, using number blocks allows students to visualize addition and subtraction operations. One teacher commented, "Number blocks make it easier for students to understand the concept of addition and subtraction. They can move the blocks around and see the results clearly."

Another benefit is increased student engagement and motivation in learning. Many students feel more interested in learning mathematics when they use interactive and fun math-manipulatives. "My students are more enthusiastic when using number cards in math games. They are happy because they are learning while playing," said a teacher. This higher student engagement not only increases their interest in math lessons but also encourages their active participation in the learning process.

Additionally, math manipulatives provide important support for students in developing cognitive and motor skills. Using manipulatives such as plastic coins to understand fraction concepts or interactive rulers to measure lengths provides students with opportunities to practice their motor skills while deepening their cognitive understanding of math concepts. "I find that my kids are more focused and engaged when they can touch and manipulate objects directly," said one teacher. This support is especially important for students with disabilities who require a wider variety of learning methods to meet their needs.

Students also reported that math-manipulatives helped them solve problems and boosted their confidence. Using a number board, for example, allows students to visually understand the steps involved in solving more complex math problems. One student said, "With the number board, I can clearly see how the numbers move. It makes me feel more confident that I can solve the problems." This sense of confidence is crucial in learning math, as many students with disabilities feel fearful or anxious when faced with the subject.

Another benefit found was the increase in social interaction between students during the learning process. Some math-manipulatives were used in the context of group games, where students were encouraged to work together and discuss with their friends. For example, in the use of number game cards, students collaborated to complete tasks involving sequencing or number operations. "When they play together with manipulatives, they learn more than just math. They also learn to work together," said one teacher, highlighting the positive impact of using math-manipulatives on the development of students' social skills.

Discussion

The discussion of the findings of this study revealed that math-manipulatives play an important role in supporting mathematics learning for students with disabilities. This finding is consistent with previous studies which stated that learning with the help of manipulative teaching aids effectively improves the

mathematical imagination skills of students with special needs, especially deaf students (Siahaan et al., 2022; Ni'mah & Sugiman, 2020). Mathematical manipulative teaching aids can help students to more easily understand abstract mathematical concepts (Yulia et al., 2021; Kania, 2018). The results of this study reinforce these findings, with the addition of a specific context for students with disabilities in elementary schools.

In terms of the use of math-manipulatives, this study revealed that teachers face challenges in selecting and integrating these tools into everyday learning. Teachers often feel under-trained and under-confident in using them. This is in line with previous studies that state that teachers act as facilitators in the application of manipulative media, other studies also state that teachers must train themselves in using math manipulative media so that students can use them effectively (Lantz & Miller, 2020; Hasyim et al., 2019). Teachers' inability to select the right tools for a particular learning situation can hinder the full benefits of math-manipulatives. In the context of this study, teachers reported that tools such as number cards and number boards were very useful, but their use required further training to maximize their potential.

Students' perceptions of math-manipulatives also showed positive results, where students felt more confident and interested in learning mathematics when manipulatives were used. This finding is in line with previous research which found that math-manipulatives can increase students' self-confidence and motivation (Wondo & Meke, 2021; Ristanti, 2016). In this study, math-manipulatives such as number boards and visual diagrams helped students with disabilities to better understand abstract concepts in a more fun and interactive way. However, some students reported initial difficulties in adapting to these tools, which underscores the importance of proper support and guidance from teachers during the learning process.

In terms of challenges in implementation, limited resources and lack of support from the school are the main obstacles faced by teachers. This is in line with previous research findings which stated that limited funds and teacher knowledge are the causes of limited manipulative teaching aids in schools, other studies also stated that teachers lack knowledge and skills in using concrete mathematical manipulative media (Setiyani et al., 2021; Suryawan et al., 2021). In addition, the limited classroom space was also a challenge in this study, which made the use of math-manipulatives such as number boards more difficult to implement in optimal learning situations. These limitations show that in addition to providing the right tools, adequate training and infrastructure support are also important to ensure the success of using math-manipulatives in mathematics learning.

In terms of the benefits of math-manipulatives for students with disabilities, the results of this study confirm the positive impact of using these tools in increasing student understanding and engagement. Previous studies have shown that manipulatives can help students with special needs by providing concrete representations of abstract mathematical concepts, other studies have also mentioned that the use of manipulatives for teaching mathematics has been successful for students who are at risk or identified with disabilities (Tjandra, 2023; Peltier et al., 2019). Moreover, the benefits of math-manipulatives in this study also include improving students' social skills, especially when used in group activities. These findings suggest that in addition to supporting cognitive understanding, math-manipulatives also have the potential to improve students' social interactions through collaboration and cooperation.

The results of this study provide an important contribution to the development of science in the field of inclusive education and educational technology. This study underscores the need for the integration of manipulative tools in mathematics learning, especially for students with disabilities. The impact of these findings suggests the importance of developing more in-depth teacher training programs and providing adequate resources in schools to ensure that math-manipulatives can be implemented effectively. Thus, the latest information in this study not only supports previous research on the benefits of math-manipulatives, but also expands the discourse on the importance of systemic support for teachers and students in inclusive mathematics learning.

4. CONCLUSION

The conclusion of this study shows that the use of math-manipulatives as assistive technology in mathematics learning for students with disabilities in elementary schools has a significant positive impact. Math-manipulatives, such as number boards, number cards, and other visual tools, help students understand mathematical concepts more concretely, increase learning motivation, and strengthen social skills through group work. However, challenges in its implementation include limited resources, classroom space, and lack of teacher training, indicating the need for further support from schools. Overall, the latest information in this study confirms the importance of math-manipulatives in inclusive education and the need for adequate training and infrastructure to increase the effectiveness of its use.

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