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Analysis of Mathematical Instruction Barriers in Terms of Developing Students' Mathematical Reasoning

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ABSTRACT

This study aims to analyze the difficulty of teachers in implementing learning that focuses on improving students' mathematical reasoning abilities. The study was a descriptive study. Data were collected via an online form that included open-ended questions. Data were collected from 93 mathematics teachers. Data were analyzed by coding qualitative data using spreadsheet in Microsoft Excel. The categories were derived from the participants' own words or phrases. The results showed that 81.2 percent of respondents stated that the difficulty teachers experience to improve students' mathematical reasoning abilities is the lack of motivation and disengagement of students and other difficulties. This research also presents alternative solutions that can be practiced by teachers in their respective classes.

1. Introduction

Mathematical reasoning is a crucial skill to have because it is the foundation of many scientific and engineering fields, as well as everyday life. It helps us to think logically and solve problems in a systematic way. It enables us to think critically and make informed decisions. It is also a great way to develop problem solving skills, which are essential for success in any field. Mathematical reasoning also helps us to understand complex relationships and to recognize patterns and trends (Verschaffel et al., 2020).

Mathematical reasoning can be used to analyze the feasibility of achieving sustainable goals (Wahono & Chang, 2019). For example, when setting a goal to

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reduce greenhouse gas emissions, mathematical models can be used to determine the rate of reduction needed to achieve a specific level of emissions. This can help to identify necessary adjustments in energy production and consumption, transportation, and land use in order to reach the desired target. Additionally, mathematical models can be used to analyze potential costs associated with transitioning to renewable energy sources, as well as any potential economic and social benefits associated with reaching the goal. Mathematical reasoning can be used to assess the effectiveness of sustainable goals (Alsina & Mulà, 2019). By analyzing data from sources such as environmental impact studies, cost-benefit analyses, and stakeholder surveys, mathematical models can be developed to assess the potential for achieving sustainable goals. By using mathematical reasoning, decision-makers can gain a better understanding of the potential implications of pursuing sustainable goals and make more informed decisions.

Mathematical reasoning in the 21st century is a critical skill to have in order to stay competitive in the global economy (Maass et al., 2019). Increasingly, businesses and organizations rely on mathematical models to make decisions, solve problems, and develop products. In addition, mathematics is used to analyze data and uncover trends in many different fields. Mathematical reasoning is also important for understanding the implications of technological advances on society and for developing solutions to global challenges such as climate change. As the world becomes more complex and interconnected, having the ability to think through and analyze mathematical problems will become increasingly important.

If students do not have mathematical reasoning, they may have difficulty understanding and solving mathematical problems. They will face the difficulties to progress in their career (Abassian et al., 2019; Denton et al., 2020). They may also struggle to make connections between mathematical concepts (Joutsenlahti & Perkkilä, 2019; Xu et al., 2020). Without mathematical reasoning, students may find it difficult to complete tasks such as solving equations, analyzing data, and interpreting graphs. To help students develop their mathematical reasoning skills, teachers can provide a variety of activities and resources that require students to think critically and apply their knowledge. For example, teachers can offer students the opportunity to explore a problem by drawing diagrams, writing equations, or creating models. Additionally, teachers can offer students practice problems and provide feedback on their work.

Indonesian students typically have average to above average mathematical reasoning abilities compared to other students in the world (Kurniawan et al., 2021; Son et al., 2020). However, the level of mathematical reasoning abilities varies among Indonesian students depending on the type of instruction they receive in school. Generally, students that receive higher quality instruction, either through private tutoring or in the form of specialized math classes, tend to have better mathematical reasoning abilities than those that do not. Additionally, students from more affluent backgrounds tend to have better results in math than those from lower income backgrounds (Ilie et al., 2021; Wiberg, 2019). In comparison to other countries, Indonesian students generally score lower on international tests such as the Programme for International Student Assessment (PISA). However, Indonesia has made great strides in recent years to improve the quality of math education in the country and to raise the average mathematical reasoning abilities of its students.

Previous research has examined the implementation of various modifications

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to mathematics learning in an effort to improve students' reasoning abilities. Several variations of the implementation of mathematics learning that have been applied and researched are STEM learning (Bakerand et al., 2022), RME (Zubaidah Amir et al., 2021), problem-based learning (Zilda & Padang, 2022) and many others.

However, the difficulties faced by teachers in implementing these learnings are not discussed in depth and there are no various possible solutions to the difficulties experienced. Therefore, this study aims to provide an analysis of the difficulty of teachers in implementing learning that focuses on improving students' mathematical reasoning abilities. This article also presents alternative solutions that can be practiced by teachers in their respective classes.

2. Method

The study was a descriptive study, one of the qualitative research methods. The data was collected via an online form that included open-ended questions. Data were collected from 101 mathematics teachers. The online form was integrated as an attendance list for all online workshop participants. The online form was filled out by participants from October to December in 2022. Three prominent speakers were invited to the online workshop and 257 participants enrolled in the workshop. A hundred and one mathematics teachers from all around Indonesia made it to the first meeting and had a chance to fill out the online form.

Indicator of mathematical reasoning are a dynamic process of brainstorming, generalizing, determining the reasons behind, and creating and assessing arguments (Herbert, 2019). The research instrument was the questionnaire on teachers' difficulties in compiling lesson plans. The questionnaire consists of closed questions and open questions. There are 3 closed questions that asked name of the teachers as participants, institution, province of the school. Two open questions included 1) what are difficulties that teachers encountered in improving mathematical reasoning, 2) Write cases based on teachers experiences in class. Data were collected through questionnaires. Questionnaires were distributed online for participants in the mathematical reasoning workshop. The data were in the form of personal statement data from research subjects related to open questions given in questionnaires.

The three steps of the data analysis models used in these studies. Data analysis methodologies are data reduction, data presentation, and conclusion. Researchers collected data from respondents through questionnaires. By putting data from questionnaires into categories starting from the most frequent answer that teachers wrote to the very least answer. Each teacher can write more than one possible answer. Ideas from participant phrases in google form was analyzed by coding qualitative data using spreadsheet in Microsoft Excel. Coding qualitative data allows it to be organized in a way that can be more easily sorted for review and analysis. The categories were derived from the participants' own words or phrases. The number of codes will be driven by the amount of content. When creating codes, the researchers kept the number to the minimum required, because as the number of codes grows, so does the complexity of organizing the data. The coding in the research were students' engagement, prior knowledge, time constraints, limited resources, math anxiety, difficult concepts, learning styles, and other difficulties. Data were presented in bar chart, and were shown in figure 1. While the final stage was the conclusions.

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3. Results and Discussion

Teachers face difficulties in teaching in the classroom (Keddie, 2019; Mikami et al., 2020; Valente et al., 2019), especially if the teacher has a special goal, which is to improve the skill like mathematical reasoning. The following are the results of the research collected through an online form to teachers. Teachers were asked to write more than one difficulty they encountered in fostering mathematical reasoning, researchers code all the responses and data are presented in figure 1.

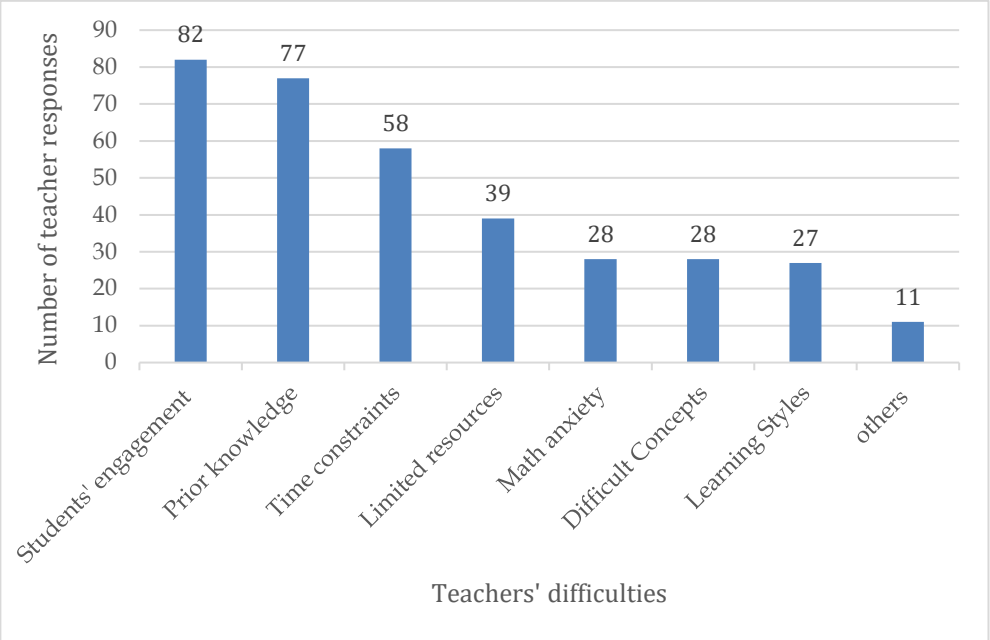

Figure 1. Teachers' difficulties in implementing mathematics instruction in terms of improving mathematical reasoning

Teaching mathematics to improve mathematical reasoning can be a difficult task. Students must be able to make the necessary connections between mathematical concepts and the real-world applications. To do this, they need to be able to interpret and apply the mathematical concepts to solve problems. Without the necessary background knowledge and understanding of the concepts, students can become frustrated and unmotivated (Mazana et al., 2019). The following sections are the analysis of teachers' difficulties and recommendation to overcome the difficulties:

3.1. Students' Engagement

Many students find mathematical reasoning to be boring and tedious, so it can be difficult to keep them engaged in the lesson. Some students become disengaged when presented with mathematical reasoning tasks due to the abstract nature of the subject. Incorporating real world examples into lessons will help bring relevance into what may otherwise seem like abstract concepts (Clarke & Roche, 2018). That helps motivate students by showing them why understanding these topics matters outside of school walls too.

Suggested solution to solve student disengagement in mathematical reasoning: 1) Focus on Student Interests: Ask students about their interests and incorporate those topics into mathematical reasoning activities. Connecting mathematics to topics that students find interesting can help them engage with the

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material and make it more meaningful. 2) Use Different Learning Styles: Vary the types of activities used in the classroom to accommodate different learning styles. For example, visual learners may benefit from graphically-based activities, while auditory learners may benefit from listening to a lecture or podcast. 3) Provide Opportunities for Collaborative Learning: Allow students to work together in small groups to solve mathematical reasoning problems. This can help foster communication and collaboration while providing students with the opportunity to learn from each other (Strauß & Rummel, 2020). 4) Utilize Technology: Incorporate technology into the classroom to help engage students in mathematical reasoning. There are many online tools and resources available that can be used to provide visual and interactive learning experiences. 5) Ask Questions: Engage your students in class discussions by asking questions about their learning and the material. This can help identify areas of difficulty and provide students with the opportunity to explain their reasoning (Martin, 2019).

3.2. Prior Knowledge

Mathematical reasoning relies heavily on prior knowledge of the subject matter (Hunt et al., 2022), so students who lack this prior knowledge can have difficulty understanding and applying the concepts. Many students lack the prerequisite knowledge needed to understand and operationalize mathematical reasoning. This can make it difficult for teachers to help students to develop their skills and understanding.

Ways to solve problem of student lack of prior knowledge: 1) Identify the student's current level of knowledge: Ask the student to complete a diagnostic assessment to determine their baseline knowledge (Wu et al., 2022). 2) Help the student build a strong foundation: Provide the student with activities and resources that will help them build a strong foundation in the subject matter. 3) Use scaffolding: Use a variety of strategies such as chunking, graphic organizers, and other support tools to help the student bridge the gap between their current level of knowledge and the desired outcome. 4) Provide timely feedback: Provide the student with timely and meaningful feedback on their progress so that they can make adjustments and build on their successes. 5) Encourage collaboration: Opportunities for collaborative learning can help the student build on the knowledge of others and gain a better understanding of the material.

3.3. Time Constraints

Teaching mathematical reasoning requires a great deal of time and practice, and teachers often have very limited time to work with students. Many teachers are pressed for time and may not have enough time to adequately cover mathematical reasoning concepts. This leaves little room for exploring more complex concepts such as mathematical reasoning. As a result, many teachers may not be able to provide enough instruction on this subject or devote sufficient practice opportunities so that students can gain mastery of it (Shagiakhmetova et al., 2022).

Possible solutions to solve time constraint problem in teaching mathematics: 1) Use visual aids: Using visual aids such as diagrams and pictures can help students understand mathematical concepts more quickly. This can help to reduce the amount of time spent on explaining complex concepts. 2) Break down problems into smaller steps: Breaking down problems into smaller steps can help students better understand how to solve them. This also helps to reduce the amount of time spent on completing a task. 3) Use technology: Using technology such as online calculators, videos, and apps can help students understand

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mathematical concepts more quickly. 4) Provide extra practice: Providing students with extra practice problems can help them become more comfortable with solving mathematics problems and can help them learn concepts more quickly. 5) Use different teaching methods: Different teaching methods can help students understand mathematical concepts in different ways (Laursen & Rasmussen, 2019). For example, using a hands-on approach or providing interactive activities can help students better grasp concepts.

3.4. Limited Resources

Teachers do not have enough access to the resources they need to effectively teach mathematical reasoning (Goldenberg et al., 2021). Lack of proper teaching aids and materials can make it difficult for teachers to effectively explain mathematical concepts and foster mathematical reasoning. Insufficient training and support can result in teachers not being able to effectively address individual student needs and support their mathematical development. These limitations can result in students not fully grasping mathematical concepts, becoming frustrated with mathematics, and losing interest in the subject.

Resources for teachers to improve students' mathematical reasoning : 1) Attend Professional Development Workshops: Professional development workshops are an excellent way for teachers to learn new methods to improve mathematical reasoning in their students (Redman et al., 2018). 2) Utilize Online Resources: There are a variety of online resources available to teachers to help them improve their students' mathematical reasoning skills. 3) Use Mathematics Games: Mathematics games are a great way to engage students and help them improve their mathematical reasoning skills. 4) Connect with Other Educators: Connecting with other educators is a great way to find out about new resources and strategies for improving mathematical reasoning skills. Joining a local teacher's organization or joining online forums can help teachers connect with other educators and find new resources.

3.5. Math Anxiety

Many students struggle with math anxiety, which can be a barrier to developing mathematical reasoning skills. Math anxiety refers to a feeling of fear or worry when faced with mathematical tasks (Boaler, 2014). This can lead to negative attitudes and beliefs towards math, which in turn can negatively impact a student's ability to learn and perform mathematical tasks effectively. This can result in difficulties with developing mathematical reasoning skills, as students may become too focused on their anxiety to think critically about mathematical problems. Over time, this can lead to a vicious cycle, where poor performance reinforces anxiety, and anxiety reinforces poor performance.

Approaches to tackle math anxiety and encourage the mathematical reasoning: 1) Provide a positive learning environment: Create a safe and supportive space for students to ask questions and make mistakes. Encourage collaboration and celebrate successes (Sasson et al., 2022). 2) Make math relevant: Connect mathematics to real-world applications and explain how it can be used to solve everyday problems. 3) Use hands-on activities: Allow students to explore mathematical concepts through tactile activities. This will allow them to understand the concepts more easily. 4) Break down concepts: Break down complex concepts into smaller, more manageable parts. This will help them understand the material better. 5) Foster curiosity: Encourage students to ask

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questions and explore their own interests in mathematics. 6) Talk positively about math: Use positive language when talking about math and emphasize the importance of perseverance. 7) Provide resources: Offer students access to extra resources, such as online tutorials, worksheets, and practice problems. 8) Encourage practice: Provide students with ample practice opportunities to help them become more comfortable with the material.

3.6. Difficult Concepts

Some concepts related to mathematical reasoning are difficult for students to grasp and require a great deal of practice and repetition (Okolie et al., 2021). Difficult concepts can act as a barrier to developing mathematical reasoning skills because they can cause frustration and confusion, leading to a lack of motivation and engagement. When students are unable to understand a concept, they may give up trying to find a solution or may develop misconceptions that impede their future learning. This can lead to a negative attitude towards mathematics and limit the development of critical thinking and problem-solving skills, which are essential for mathematical reasoning.

Strategies to address students while learning difficult concept: 1) Break the concept down into manageable pieces. Start with the basics and build up to more complex ideas. 2) Provide plenty of examples. Show how the concept is applied in different scenarios and contexts. 3) Use visuals. Pictures and diagrams can help students visualize and understand the concept better. 4) Engage students in the learning process. Ask questions and encourage discussion so students can learn from each other. 5) Use real-world examples. Explain the concept in terms of everyday life, so students can see its relevance. 6) Allow students to make mistakes and learn from them. Mistakes are part of the learning process (Hoeve et al., 2019), so don't be too quick to correct them. 7) Encourage practice. Have students apply the concept in different ways, so they can gain a deeper understanding.

3.7. Different Learning Styles

Different students learn in different ways, so teachers must be able to accommodate a variety of learning styles to effectively teach mathematical reasoning (Dewi et al., 2019). Each student has a unique way of processing and retaining information, which can make it difficult to provide a one-size-fits-all approach to teaching. Adapting lessons to meet the needs of different learning styles can be time-consuming, which can make it difficult to cover all the material within the limited time available in a class period. Teachers may not have the resources or training to accommodate a diverse range of learning styles in the classroom, making it challenging to effectively reach all students.

Strategies to accomodate students different learning styles in improving mathematical reasoning: 1) Use a variety of teaching methods to accommodate different learning styles. For example, visual learners can benefit from diagrams, charts and color-coded examples; auditory learners can benefit from verbal explanations; and kinesthetic learners can benefit from physical activities like manipulatives or hands-on activities. 2) Allow students to work in groups with peers of different learning styles. This will allow students to learn from each other, as well as allow them to learn from different perspectives (Dewi et al., 2019). 3) Provide multiple ways for students to demonstrate their understanding of mathematical reasoning. For example, allow students to explain their reasoning verbally, draw diagrams to explain their thought process, or write out their solutions. 4) Ask open-ended questions that promote critical thinking (Schoevers

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et al., 2019). This will encourage students to think beyond the facts and explore the underlying principles of mathematical reasoning. 5) Incorporate technology into lessons to help engage all learners. For example, use digital tools like interactive whiteboards or online programs to supplement lessons and encourage exploration.

In order to improve mathematical reasoning, it is important to provide students with an environment that encourages exploration and discovery (Schoevers et al., 2019; Shimizu, 2020). This can be accomplished through the use of hands-on activities and real-world examples. By providing this type of environment, students can build upon their prior knowledge and begin to make the necessary connections between mathematical concepts and the real world. Besides, motivation in learning is essential to foster mathematical reasoning because it helps learners to develop the skills and confidence to tackle complex problems. When learners are motivated and engaged in their learning, they are more likely to persist in problem-solving and be creative in their thinking.

Motivation helps learners to develop a deeper understanding of mathematical concepts and encourages them to use mathematical reasoning to draw conclusions and solve problems. Additionally, motivation in learning helps learners to self-regulate and take ownership of their own learning (Thibodeaux et al., 2019). This helps to build a strong foundation for mathematical reasoning and problem-solving, which is essential for success in mathematics.

Another important factor to consider is the ability of the teacher to properly explain the concepts. The teacher should be able to explain the concepts in a way that is understandable and easy to follow. If the teacher is unable to properly explain the concepts, the students will not be able to comprehend and apply them. Finally, it is important to provide students with the necessary tools and resources to help them understand and apply the mathematical concepts. This includes textbooks, calculators, and other visual aids. By providing these resources, students can better understand and apply the reasoning skill (Mamun et al., 2020).

4. Conclusions

The results showed that 81.2 percent of respondents stated that the difficulty teachers experience to improve students' mathematical reasoning abilities is the lack of motivation and disengagement of students. The implication of this study is that teachers are reflective of the learning carried out. By knowing the possible difficulties, teachers now can put more effort identifying the strategies to face the difficulties. Educators must put their attention into fostering a supportive learning environment for their pupils. They are required to be aware of any difficulties that pupils can encounter when learning mathematics. To make sure that students have a positive experience and are inspired to engage in mathematical reasoning, strategies including providing meaningful and interesting exercises, encouraging collaboration, and providing feedback should be used. Teachers should also be ready to offer extra help to students who may be having trouble with particular mathematical ideas. Finally, educators must be conscious of their own attitude toward mathematics and work to foster a pleasant learning environment. In this study, various suggestions have also been written that can be practiced according to the difficulties experienced. The limitation of this study is that data collection is only based on teacher responses through online google forms. Further research is recommended to triangulate data, collect data from various other methods such as

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conducting interviews, observations etc.

This can help to identify necessary adjustments to implement any practices in teaching mathematics. By using these findings, teachers and decision-makers in education department can gain a better understanding of the potential implications of pursuing higher mathematical reasoning skill and make more informed decisions.

Author Contributions

Second author contributed to sample preparation and data collection. First author and third author contributed to data analysis and the interpretation of the results. First author as corresponding author revised the article based on review from reviewer and journal editor. First author took the lead in writing the manuscript and wrote the paper with input from all authors. Second author and third author gave final approval of the version to be published. All authors provided critical feedback and helped shape the research, analysis and manuscript.

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Declaration of Competing Interest

No potential conflict of interest was reported by the author(s).

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