(JIML) JOURNAL OF INNOVATIVE MATHEMATICS LEARNING
Volume 8, No. 1, March 2025
P-ISSN 2621-4733
E-ISSN 2621-4741
https://dx.doi.org/10.22460/jiml.v8i1.p25262

EXPLORATORY DATA ANALYSIS ON MATHEMATICS LEARNING DIFFICULTIES FOR JUNIOR HIGH SCHOOL STUDENTS/MTs ON SOLVING STORY PROBLEMS IN TERMS OF GENDER

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ARTICLE INFO

Article history:

Received Aug 20, 2024
Revised Aug 23, 2024
Accepted Aug 28, 2024

Keywords:

Mathematics Learning
Difficulties
Story Problems
Gender
Junior High School

ABSTRACT

Mathematics subjects at various levels of education are still considered difficult. One of the mathematical skills that students still lack mastery of is mathematical communication. Otherwise in mathematics learning, as explained in NCTM, "communication is a fundamental element of mathematics learning," which means that communication is a basic element in mathematics learning. Mathematical story problems are a form of problem in mathematical communication competence. Moreover, based on the PISA report, with low language skills, students' ability to solve story problems also becomes much more difficult. This purpose study are to indentify and analyze the difficulties of junior high school students in solving math story problems and alternatives to overcome them, and also demography analyze these difficulties based on gender, age and elementary school educational background. Utilizing an Exploratory Data Analysis (EDA) approach, data were collected from 291 students in grades 7, 8, and 9. The findings indicate that most students struggle with understanding the text of word problems, identifying relevant information, and modelling mathematical problems. Further analysis reveals that 9th-grade students, particularly those older, encounter more complex challenges but demonstrate better problem-solving abilities. Gender differences were observed in learning strategies, with female students tending to use more structured strategies such as note-taking or diagramming.

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How to Cite:

Yusnita, I., Sumarmo, U., Fitriani,N. (2025). Exploratory Data Analysis on Mathematics Learning Difficulties for Junior High School Students/MTs on Solving Story Problems in Terms of Gender. *JIML,* 8(1), 100-112.

INTRODUCTION

Mathematics learning at the Junior High School (SMP) level is one of the crucial foundations in developing students' logical and analytical thinking skills. According to Piaget's theory of cognitive development, students at junior high school age are at the formal operational stage, where they begin to be able to think abstractly and logically. Hence, learning mathematics at this stage is essential to hone these skills (Piaget, 2016). However, various studies show that many students at this level still struggle to understand and solve math story problems. For example, research conducted by (Yunia & Zanthy, 2020) found that about 65% of junior high school students have difficulty translating math story problems into proper mathematical models, which hinders their ability to solve these problems.

The results of a national survey on Indonesian student achievement conducted by the Center for Educational Assessment (Puspendik) show that mathematics learning outcomes at the junior high school level are often below average. In this survey, the average mathematics score of junior high school students on the National Exam only reached 53.21 out of a scale of 100 in 2020, with many students showing a weak understanding of applying mathematical concepts in real situations. This situation reflects significant challenges in mathematics teaching, especially in applying mathematical concepts to story problems. (Puspendik, 2020)

Based on data from the Ministry of Education and Culture, only about 40% of junior high school students have achieved an adequate understanding of math story problems, while the other 60% are at the level of basic understanding or less. This data is corroborated by findings from (Kemendikbud, 2019)*Programme for International Student Assessment* (PISA) 2018, which shows that Indonesia's students' math scores are ranked 72nd out of 79 countries, with an average score of 379, well below the average *Organisation for Economic Co-operation and Development* (OECD) is 489. These findings emphasize the need to pay more attention to aspects of mathematics learning in Indonesia, especially in strengthening students' ability to understand and solve story problems that are representations of real-world problems. (OECD, 2019)

Previous research has identified several factors that affect students' difficulty in solving math story problems, such as a lack of understanding of texts, difficulties in modelling math problems, and limitations in students' problem-solving strategies. For example, a study by Van den Broek & Kendeou (2017) showed that poor text comprehension can hinder students' ability to identify essential and relevant information to solve math story problems. In addition, National Council of Teachers of Mathematics (NCTM) research found that many students had difficulty converting real-world situations presented in story problems into proper mathematical representations, which are crucial skills in mathematical problem-solving. (NCTM, 2014)

However, most existing research has not deeply correlated how demographic factors such as age, Gender, and grade level interact with students' learning strategies and resources to overcome those difficulties. The age factor, for example, can affect a student's level of cognitive maturity in understanding the abstract and logical concepts required in mathematics. The Siegler & Booth (2004) study showed that older students had better abilities in modelling math problems than younger students. However, this study did not detail how age interacts with specific learning strategies. Similarly, gender differences in mathematics education have been widely discussed, but existing research often yields varied and inconsistent results. Hyde, Lindberg, Linn, Ellis, & Williams (2008) showed that although there is generally no significant difference between males and females in mathematical ability, there is variation in the use of problem-solving strategies, where male students are more likely to use an analytical approach while female students are more likely to use a procedure-based approach.

Furthermore, the grade level can affect students' exposure and experience to different questions and learning strategies. Gravemeijer & Cobb (2013) showed that higher-graders are more exposed to complex problem-solving strategies. Still, this study has not examined the interaction between grade level and other demographic factors in the context of mathematics learning.

Therefore, this study offers novelty by integrating an in-depth analysis of how age, Gender, and grade level factors interact and influence learning strategies and resource utilization in overcoming difficulties in solving math story problems. Thus, this research is expected to provide new and more comprehensive insights into the dynamics of mathematics learning at the junior high school level and help develop more effective and contextual learning approaches. This research provides novelty by integrating *the Exploratory Data Analysis* (EDA) approach to identify patterns not revealed in the context of students' difficulties in math story problems. Thus, this research is academically relevant and significantly contributes to improving the quality of mathematics education in Indonesia.

METHOD

The methodology of this study involves analyzing data collected from 291 Junior High School (SMP) students and *Madrasah Tsanawiyah* (MTs) consisting of students in grades 7, 8, and 9. The distribution of respondents included 55 7th-grade students, 141 8th-grade students, and 95 9th-grade students. Regarding Gender, the research sample consisted of 114 male students and 177 female students. The methodological approach used is *Exploratory Data Analysis* (EDA), which includes initial descriptive analysis, visualization of critical variable distributions, pattern and outlier identification, and correlation and crosstab analysis to explore the relationships between variables in the dataset. The data analyzed included various aspects related to students' difficulties in solving math story problems and the effectiveness of various learning resources, such as textbooks, worksheets, and teacher guidance. This analysis aims to provide in-depth insights into how factors such as age, Gender, and class affect students' learning experiences and their difficulty levels.

RESULTS AND DISCUSSION

Results

The *Exploratory Data Analysis* (EDA) process will involve preliminary analysis, pattern search, outlier identification, and looking at unexpected trends in the data.

Stage 1 Initial Descriptive Analysis

First, start with descriptive statistics to get an overview of the data. These descriptive statistics provide an overview of the dataset, including the distribution of categorical and numerical variables. Here are some crucial points: Gender: The majority of respondents are women; Grades: Most students are from 8th grade; Age: The average age of students is about 12 years old; Frequency of Difficulty: Most students report that they "sometimes" find it difficult to solve math story problems; Benefits of Learning Resources: Many students rate textbooks and guidance from teachers as "Highly helpful."

Stage 2 Visualization of Key Variable Distribution

Next, visualize some key variables to see their distribution.

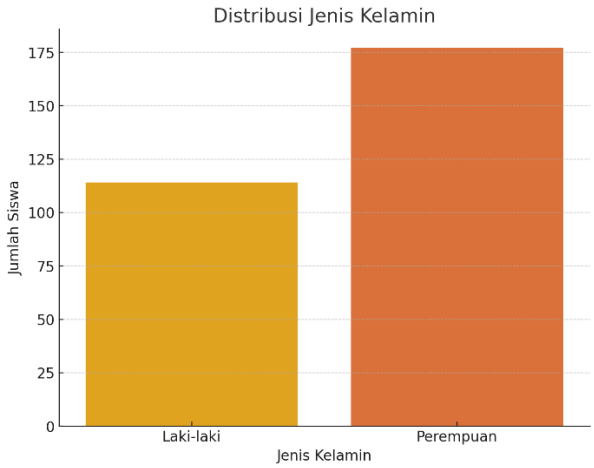

Figure 1. Gender Distribution

The distribution of Gender shows that most of the respondents are female. This distribution is essential in subsequent analyses, especially when comparing gender difficulties.

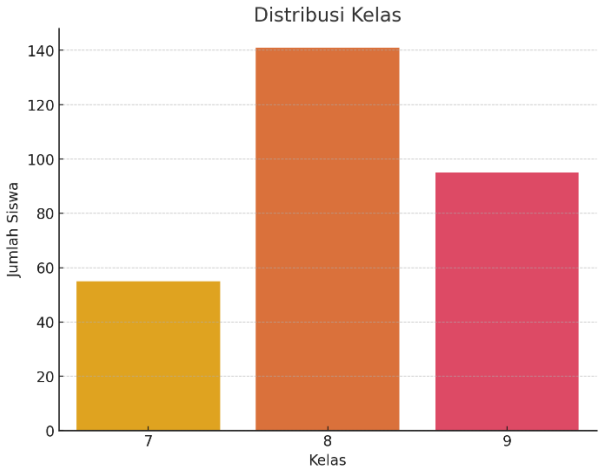

Figure 2. Class Distribution

The class distribution shows that most of the students are from grade 8. This distribution is important because this uneven distribution can affect the results of the analysis if not adequately accounted for.

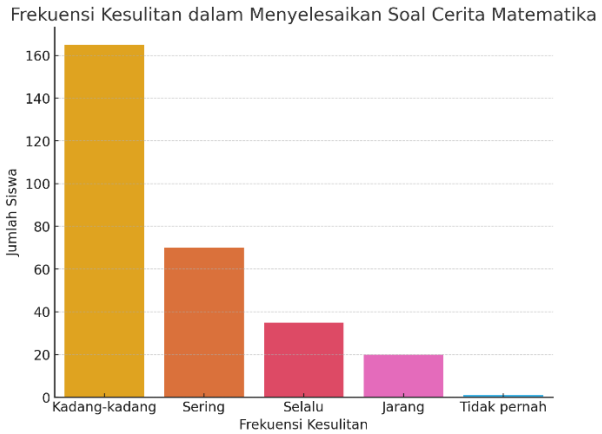

Figure 3. Frequency Distribution Difficulty

The frequency distribution of difficulty shows that most students feel they "sometimes" have difficulty solving math story problems. This distribution indicates that although the difficulty is frequent, every student may not feel it constantly.

Furthermore, it is shown how often students use specific strategies (e.g. reading questions more than once, taking notes/diagrams, discussing with friends). It is essential to see how students are coping with difficulties.

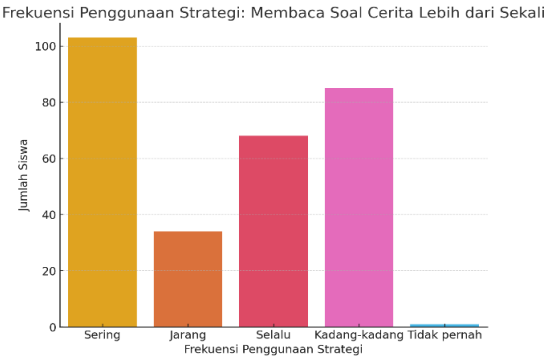

Figure 4. Frequency of Reading Story Questions More Than Once

The distribution of the "Read Story Questions More Than Once" strategy shows that many students often use this strategy. This distribution suggests that students may need to understand the problem in more depth before they can solve it.

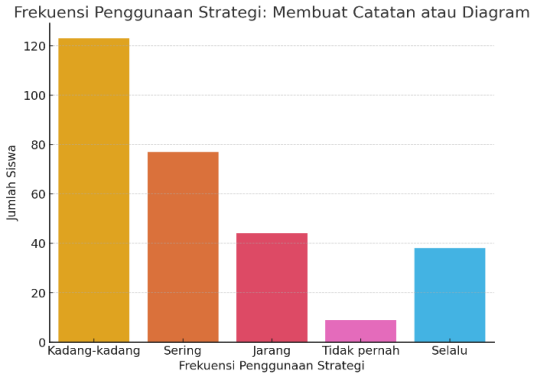

Figure 5. Frequency of Taking Notes or Diagrams

The distribution of the "Taking Notes or Diagrams" strategy shows that this strategy is also used quite often by students, although not as much as the strategy of reading the question more than once. This distribution indicates that some students must take additional notes to help them understand and solve the problem.

Figure 6. Frequency of Discussion with Friends

The distribution of the "Discuss with Friends" strategy shows that it is frequently used by students, with most students reporting that they "sometimes" use it. This distribution shows that collaboration with friends is one of the essential ways for students to overcome difficulties in math story problems.

Furthermore, how students assess the benefits of textbooks, LKPD, and teacher guidance will be shown. It provides insight into the effectiveness of the available learning resources.

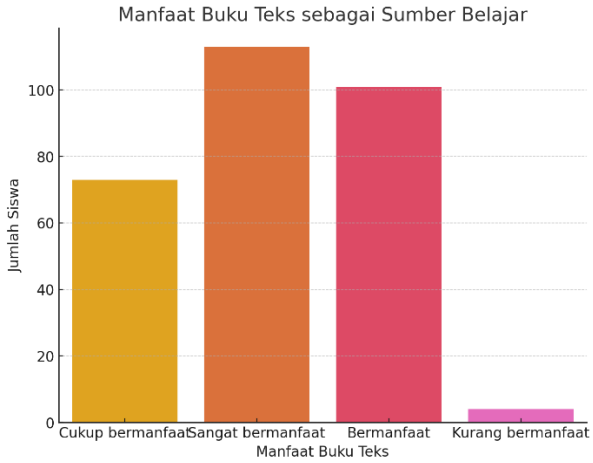

Figure 7. Frequency of Benefits of Textbooks as a Learning Resource

The distribution of textbook benefits shows that most students rate textbooks as "Highly Useful" or "Useful". This distribution emphasizes the importance of textbooks as a learning aid in mathematics.

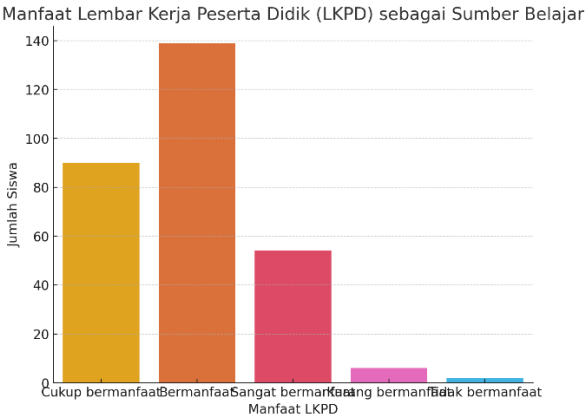

Figure 8. LKPD Benefit Frequency

The distribution of benefits from the LKPD shows that many students rate the LKPD as "Useful". This distribution indicates that LKPD is one of the most critical learning resources used by students in understanding mathematics material, especially in story problems.

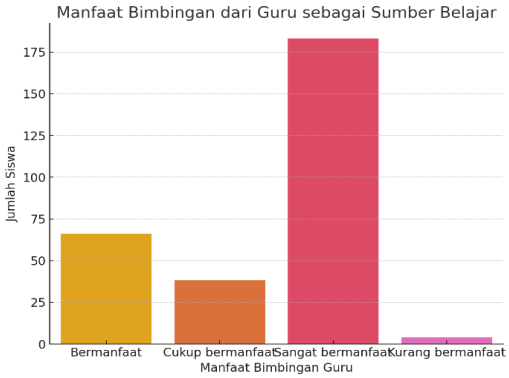

Figure 9. Teacher Benefits Frequency

The distribution of the benefits of tutoring from teachers shows that most students rate teacher tutoring as "Very Helpful". This distribution emphasizes the critical role of teachers in helping students understand and solve math story problems.

Stage 3 Pattern and Outlier Search

Next, patterns and *outliers* will be searched in the data. One good way to get started is to check the age distribution and see if there are any *conspicuous* outliers.

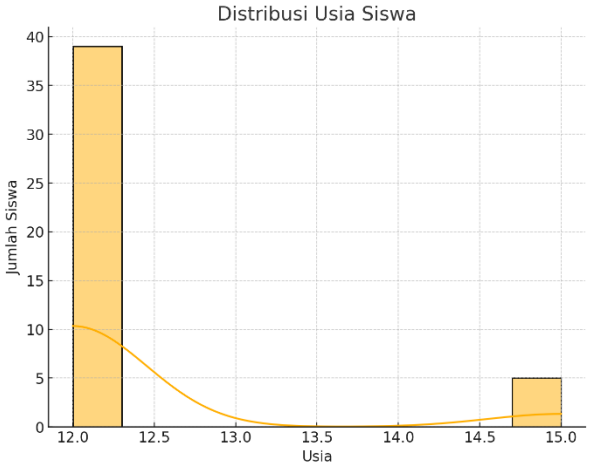

Figure 10. Outlier Student Age

The age distribution of students shows that most students are in the 12 to 14-year-old age range, which corresponds to the average age range for grades 7 to 9. There is no clear *outlier* in this distribution.

To identify outliers on other distributions, we will examine some critical variables by using visualizations and statistics that can indicate the existence of *outliers*. The "Difficulty Frequency" variable is categorical, so it cannot be visualized directly using *the boxplot*. Instead, the approach to checking *outliers* on categorical variables will be changed. *Outliers* in categorical variables are usually identified by looking for categories that are far fewer in number than others. From the distribution of "Frequency of Difficulty," we see that the "Never" category has a deficient number; only one student reports that they have never felt difficulty. It can be considered an outlier in the context of difficulty frequency distribution.

Next, let's check for any outliers in the distribution of strategy usage. Each strategy will be examined individually. In the "Strategies for Reading Questions More Than Once" distribution, we also saw that the category "Never" was only reported by one student. This response is an outlier in the context of using this strategy. In the distribution of the "Taking Notes or

Diagrams" strategy, the "Never" category was reported by only nine students. This respondent can be considered an outlier but is less extreme than the "Never" category on other strategies. In the "Discuss with Friends" strategy distribution, the "Never" category was reported by six students. It is also an outlier, although not as extreme as other "Never" categories.

Next, the distribution of benefits from learning resources is examined to see if there are outliers. On the distribution of benefits from textbooks, the category "Less useful" was reported by only four students. It can be considered an outlier in the context of the perception of the benefits of textbooks. In the distribution of benefits from LKPD, the category "Not useful" was reported by only two students, who were outliers in the perception of LKPD benefits. In the distribution of benefits from teacher guidance, the category "Less useful" was reported by only four students, who could also be considered *outliers*.

From the analysis of the distribution of outliers based on variables such as Gender, class, age, and school origin, the following findings can be drawn: In Gender, 63.6% of students who fall into the outlier category are male. 36.4% are female. This pattern suggests that male students appear more often as outliers in the categories that have been identified. In Grade: 50% of the outliers are from grade 9. 31.8% from grade 8. 18.2% from grade 7. Students in grade 9 appear more often as outliers, which can indicate that their difficulties or perceptions of learning strategies and resources are different compared to students in lower grades. Age: All identified outliers are 15 years old. This respondent may be related to the fact that most students in 9th grade (who are mostly 15 years old) show up as outliers. In Educational Origin: 77.3% of students who fall into the outlier category are from elementary school. 22.7% came from MI (Madrasah Ibtidaiyah). This response shows that students from elementary school appear more often as outliers than students from MI. So, boys and 15-year-old grade 9 students appear more often as outliers in the various categories that have been identified. Students from elementary school are also more often outliers than students from MI. These patterns can indicate that specific factors influence the perception or experience of certain students more strongly than others.

Stage 4 Correlation Analysis

Now, you will see the correlation between the numerical variables to look for relationships that may be unexpected.

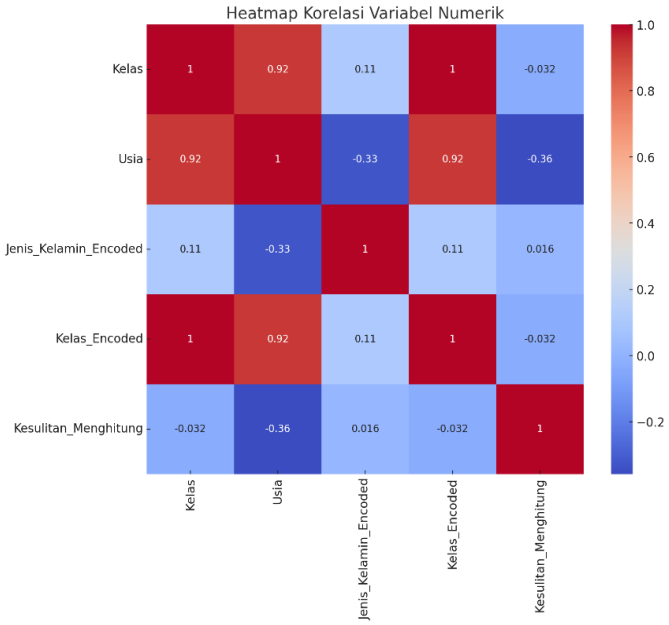

Figure 11. Correlation Heatmap

This correlation heatmap shows the relationship between the numerical variables in the dataset. One of the things that can be observed on this map is that there is no robust correlation between the variables, which means that most of the variables may have an independent influence on the measured results.

Based on these results, it was decided to try using other methods. Spearman Correlation Analysis will be helpful when unsure whether the data is normally distributed or when the variables are ordinal. Spearman correlation will be calculated for this dataset.

Table 1. Spearman Correlation Analysis

Variable	Class	Age	Gender	Class	Difficulty Counting	Outlier
Class	1.000	-0,327	0.098	1.000	-0,024	0.078
Age	0.819	1.000	1.000	0.819	-0,358	0.426
Gender	0.098	-0,327	-0,327	0.098	0.016	-0,143
Class	1.000	0.819	0.819	1.000	-0,024	0.078
Difficulty Counting	-0,024	-0,358	-0,358	-0,024	1.000	0.132
Outlier	0.078	0,426	0.426	0.078	0.132	1.000

Source: Data Processing

This Spearman correlation helps identify *monotonic* relationships (both *linear* and *non-linear*) between variables, especially if the data is not normally distributed. Findings from the Spearman Correlation show a correlation between Age and Difficulty Counting: There is a negative correlation between age and difficulty counting, which may indicate that older students feel less difficulty in counting. Correlation between Age and *Outliers*: Age has a relatively strong positive correlation with *outliers*, which may indicate that older students are more likely to be *outliers* in the context of the variables we analyzed.

Stage 5: More In-Depth Analysis with Crosstab

As a final step in EDA, we'll use *crosstabs* to look in-depth at the relationships between some categorical variables. For the final step in EDA, let's look for patterns or trends that may be unexpected by combining some variables. For example, we can see how class and Gender interact with specific difficulties. Let's look at the distribution of the main difficulties by class and Gender.

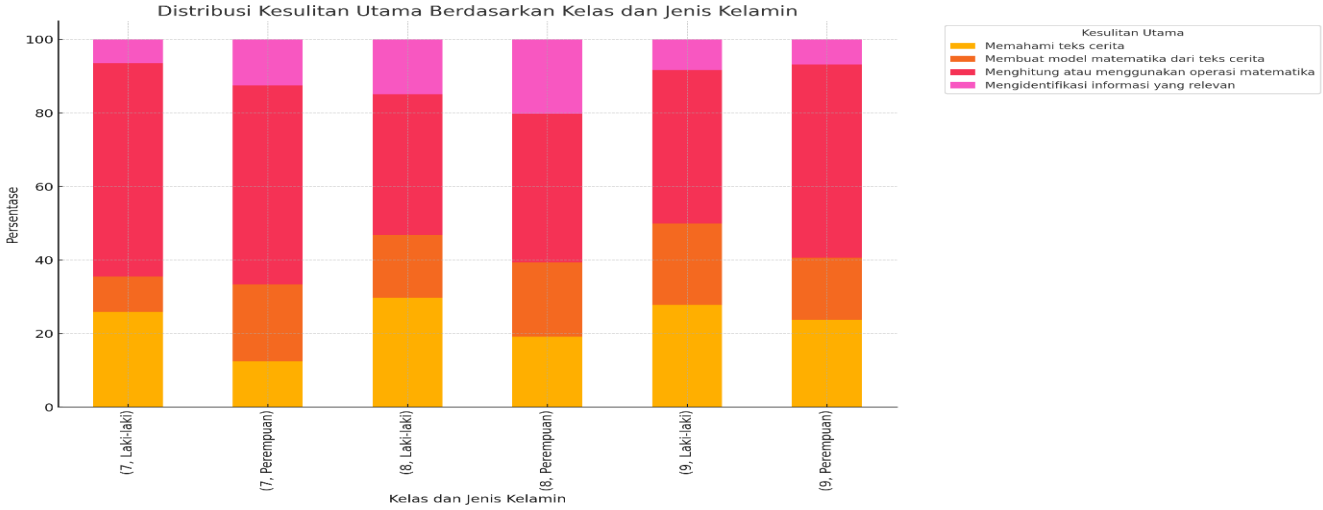

Figure 11. Crosstab Analysis

The graph above shows the distribution of the main difficulties reported by students by grade and Gender. The crosstab results show how reported difficulties vary by class and Gender:

1. In terms of difficulty understanding story texts, male students in grade 8 reported this difficulty more often than female students, while in grades 7 and 9, the difference was also quite significant.
2. On the difficulty of making a mathematical model from story texts, female students in grades 7 and 8 reported this difficulty more often than male students.
3. The difficulty of calculating or using mathematical operations was reported more by male students in 7th grade, but it was pretty balanced between the genders in 8th and 9th grades.
4. On the difficulty of identifying relevant information, female students in 8th grade reported this difficulty more often than male students.

Discussions

The results of this study show several significant findings related to students' difficulties in solving math story problems and the use of different learning strategies based on demographic factors such as age, Gender, and grade level. These findings generally confirm significant differences in students' experiences and approaches to math story problems, which cannot be separated from these demographic factors.

1. Difficulties in Understanding Math Story Problems

One of the study's key findings was that most students reported having difficulty understanding math story problems, especially in understanding the text and identifying relevant information. This result is in line with Piaget's theory of cognitive development, which states that students at junior high school age are in the formal operational stage but are not yet fully mature in complex abstraction and logic skills. A study by (Piaget, 2016)Van der Kleij, Eggen, Timmers, & Veldkamp (2015) shows that students who have difficulty understanding the text tend to have problems identifying the critical elements of the story problem, ultimately hindering their ability to solve the problem. In addition, research from TIMSS shows that the level of mathematical literacy among Indonesian students is still low, which contributes to the difficulties faced in solving story problems.(Martin & Mullis, 2019)

2. The Effect of Age and Grade Level on Learning Difficulties and Strategies

The study also found that older students, particularly 9th graders, appeared more often as *outliers* in various learning difficulties and strategies categories. This result can be explained by referring to the research of Siegler & Braithwaite (2017), which states that older students show more advanced cognitive development in mathematical problem-solving. However, they also face more significant challenges because of more complex problems. A study by Ingram, Elliott, & Shilvock (2019) supports these findings by showing that complexity increases in advanced problems requiring more in-depth and sophisticated problem-solving strategies.

3. Gender Differences in the Use of Learning Strategies

The analysis also showed gender differences in the use of learning strategies. For example, female students reported using strategies such as note-taking or diagramming more often, while male students were likelier to use strategies to discuss with friends. These results are consistent with Lindberg, Hyde, Petersen, & Linn (2010), which shows that although the difference in overall mathematical performance between the sexes is relatively small, there are differences in learning strategy approaches. Research also shows that female students use structured strategies more often, which can reflect a more planned cognitive approach to math problems (Else-Quest, Hyde, & Linn, 2010).

4. Correlation Between Variables and Their Implications

The results of Spearman's correlation in this study showed a negative correlation between age and difficulty in counting, which indicates that older students tend to experience less difficulty in counting. These findings are supported by research by Gravemeijer & Cobb (2013), which states that students show an increased ability to use more effective problem-solving strategies. In addition, research by Hattie & Donoghue (2016) suggests that using better metacognitive strategies in older students may explain why they face fewer difficulties in math tasks involving calculations.

5. Research Contribution and Novelty

This study significantly contributes to expanding the understanding of how demographic factors interact with learning strategies and difficulties in math story problems. Not many previous studies have explored the interaction between age, Gender, and grade level in the context of math learning. For example, Leinwand et al. (2014) emphasized the importance of structured problem-solving strategies in mathematics education. Still, this study offers a new perspective by tying those strategies to demographic factors, providing a more holistic insight into how students from different backgrounds face similar challenges.

Overall, the findings of this study reinforce the argument that mathematics learning approaches need to be better adapted to the demographic characteristics of students to optimize their learning outcomes. This finding can be done by developing more individualized teaching strategies considering student age, Gender, and grade level differences and by providing resources that support diverse learning strategies. Thus, this study provides a better understanding of students' difficulties in math story problems and offers practical recommendations that can be implemented in educational practice to improve the quality of mathematics learning at the junior high school/MTs level.

CONCLUSION

This study has revealed several significant findings related to students' difficulties in solving math story problems at the junior high school/MTs level and how demographic factors such as age, Gender, and grade level affect their learning experience. From the results of the study, it can be concluded that:

1. Most students struggle to understand and interpret math story problems, especially in identifying relevant information and modelling math problems. This result emphasizes the importance of strengthening students' mathematical literacy skills for effective problem-solving.
2. Students who are older and at higher grade levels (9th grade) tend to face more significant challenges in math story problems, especially in more complex aspects. However, they also showed better abilities in specific problem-solving strategies, which improved cognitive abilities with age and experience.
3. Gender differences play a role in how students use learning strategies. Female students are more likely to use structured strategies, such as taking notes or diagrams, while male students are more likely to discuss with friends. This result reflects the difference in approaches to solving mathematical problems that must be considered in the teaching process.
4. Correlation analysis shows that age is negatively correlated with difficulty in counting and positively correlated with a tendency to be an outlier in various variables. These findings suggest that older students may be better prepared for math challenges but are also more exposed to complexities that can lead to specific difficulties.

Based on the findings of this study, several suggestions can be given to improve the quality of mathematics learning at the junior high school/MTs level:

1. Teachers and education providers must focus on improving mathematical literacy, especially in understanding the text of story problems. This improvemmet can be done through integrated learning that links mathematics to language literacy and by providing varied practice questions in real-world contexts.
2. Given the differences in age, Gender, and grade levels that affect students' learning experiences, a more differentiated learning approach is needed. Teachers need to recognize and adapt their teaching strategies to meet the specific needs of different student groups, including using more interactive and collaborative teaching methods.
3. The use of diverse learning resources, such as textbooks, LKPD, and teacher guidance, must be optimized. Teachers should encourage students to use the learning strategies that are most effective for them and provide adequate support for students who are experiencing difficulties.
4. Further research is needed to explore other factors that may affect difficulties in math story problems and test the effectiveness of the proposed learning approach. Further research may also focus on developing specific interventions to address the difficulties specific groups of students face.

ACKNOWLEDGMENTS

As a researcher, I would like to thank all parties who have helped in the completion of my article. Especially to the honorable lecturer of my thesis, who was tireless in providing direction during the preparation of this article. Also to the Principal of MTsN 2 Bandung, teachers, and students, of whom I am proud, who have given me research permission and always supported me in continuing this postgraduate study. And most importantly, to my beloved husband and children as a supporting system and encouragement to me to complete my studies.

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