An Analysis Type of Mathematics Ability, Cognitive Determinants, and Gender Differences in Mathematics Performance of Students with Mathematical Difficulties in Inclusive Elementary Schools

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Abstract. This research is essential to know and analyze various mathematical difficulties, cognitive characteristics, and gender differences in Mathematics Performance of students with MLD. This research used a descriptive qualitative method. The research subject consisted of 17 students with 4th-grade MLD in inclusive schools. Data collection techniques were tests, interviews, and documentation. The test instrument included aspects of mathematical skills with about 30 items. The results based on the type of mathematical difficulty showed that the operations of counting whole numbers were difficulty 67.7%, fractions 58.8%, measurements 82.3%, angles, flat shapes, 57.8 &, area, circumference, and volume 80.8%, data processing and story questions 67%. The research findings on the cognitive abilities showed difficulties in mathematical aspects, concepts, operating numbers, working memory, executive function, phonological processing accuracy, non-verbal problem solving, and a combination of reading difficulties. It is also related to the finding of mathematical ability based on the gender differences that male students are more dominant in geometry, while female students are more dominant in arithmetic operations and story problems. So this finding reinforced the idea that students with MLD are heterogeneous disorders.

Keywords: Type of Mathematics Skills, Cognitive Determinants, Gender differences, Students with Mathematical Difficulties.

1 Introduction

Mathematics is an essential ability that everyone needs to support all crucial aspects and foundations in achieving school and life achievements. Even mathematics is the most significant predictor and better predictor than early reading and early attention skills as school success in later [1] and other academic performance [2] The importance

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of having math performance skills in elementary grades will also be related to the performance of mathematics students during middle and high school [3]. It is not surprising that mathematics is a compulsory subject at all levels of the education system. Although not all students are expected to be experts in mathematics subjects, because its application affects daily life, students are required to have basic mathematical abilities.

The importance of mathematical ability is also regulated in the Regulation of the Minister of Education, Culture, Research, and Technology of the Republic of Indonesia Number 5 of 2022 article 6 concerning Graduate Competency Standards at the Basic Education level. It emphasizes that students must demonstrate numeracy skills in reasoning using concepts, procedures, facts, and mathematical tools to solve problems related to themselves and the immediate environment. Indonesian students' obligations in basic mathematics concepts will also be evaluated in the national assessment, namely the minimum competency assessment (AKM). However, the study results show that mathematics is a complex subject experienced by many students at various levels of education [4]. It is confirmed by the results of the PISA Program of International Students Assessment survey that the mathematical ranking of Indonesian students from 2009 to 2015 did not show a significant increase. In 2009 Indonesia was ranked 68th out of 74 countries. In 2012 Indonesia was ranked 64th out of 65 countries with a relatively low level of achievement. While the results of PISA in 2015 showed a slight increase, ranking 63 out of 72 countries. Even the results of three surveys show that the ability of students in Indonesia in mathematics is still deficient compared to other PISA participating countries [5].

MLD are always associated with poor achievement in mathematics. Mathematical difficulties come from factors within students and outside students [6]. External factors include an appreciation of the structure of mathematics, availability or lack of learning resources, teacher quality, curriculum, students themselves, and the value placed on the subject by society [7]. Students' mathematical experience is the result of the interaction between students' knowledge and beliefs that come from parents, environment, and teacher stereotypes. Previous knowledge of mathematical concepts provides the basis for learning the next image. The teacher's central role in learning requires understanding and practicing mathematics' basic conceptual principles [8]. Even interestingly, the factors of gender differences also influence the use of strategies, accuracy, and confidence in mathematics [9]. Previous research has shown that male students perform better in mathematical problems, while female students perform better in mathematical operations [10]. The limitations of previous research are limited to arithmetic operations and problem-solving. We will test the hypothesis in this study. Researchers statistically examined gender differences in math performance and controlled each type separately.

Preliminary studies discussing the identification of students' MLD have also been conducted on April 18 and 19, 2022, for 4th-grade students of the Inclusive Elementary School in Magetan. The results identified 17 students at risk of difficulty learning mathematics. This study's basis is to analyze the types of math difficulty skills, cognitive determinants, and their relation to gender differences in math performance. Analyzing students' mathematical performance allows an understanding of the deficits related to mathematical difficulties and their uniqueness, so it is hoped that readers will also find the article a valuable resource for helping teachers in programming courses develop effective strategies for curriculum design and other intervention programs. It is also in line with the components in the operational curriculum of the education unit in the independent curriculum that in the preparation of learning plans, each student's diagnostic assessment and learning assessment must be written.

Based on the book "Roeper review" in [11] which states that "there is no stand-alone content/material, so it can spontaneously produce generalizable learning," appropriate intervention must be based on learning curriculum content/materials based on students' analysis so that learning support transfer of learning that is right on target. So, in this case, the need for knowledge and understanding of several indicators of mathematical difficulty can later be used as a first step for teachers to design and manage mathematics learning in the classroom [12].

1.1 Matematic Disability or Difficulty?

Mathematical difficulties are one art of specific learning difficulties. Specific difficulties, especially in mathematics, are referred to as MLD (Mathematics Learning Difficulty). It was noted that many students experienced lower performance in mathematics [13] even the prevalence of math difficulties among school-age students reaches 5% - 10% [14]. In fact, about 6% of school-age students with math difficulties have normal intelligence [15]. However, in this case, many students still do not meet the expectations of grade-level mathematics but do not receive an official diagnosis of learning difficulties in mathematics. Even more, students may be identified as having math difficulties but without an official diagnosis of disability [16].

Math disability can be referred to as dyscalculia [17]. Meanwhile, a large number of students who struggle with low math performance without a disability diagnosis or in the literature are referred to as Math difficulties. Math difficulty is a term used to represent students with low math performance. It may be due to several reasons, including (a) specific math difficulties are often diagnosed in later elementary grades [18], (b) the design of learning is less effective and not adapted to the characteristics and abilities of students, especially in mathematics subjects [19]. Activities in identifying mathematical difficulties are quite varied [20]. Students are identified as MLD if they have a cutoff score between the 11-25th percentile. Meanwhile, students in the 10 percentile are called math disability or dyscalculia [21].

1.2 Cognitive markers of MLD

Mathematics is a complex ability consisting of various skills that depend on different cognitive processes [22]. Thus, the mathematical difficulty is a heterogeneous disorder [23]. Mathematics is also a broad learning concept that includes measurements, properties, and relationships of quantities expressed in numbers or symbols [24]. Evidence supports the idea that cognitive abilities that will affect elementary school mathematics achievements are related to working memory and students' attention to mathematics [25].

Cognitive mathematics also plays a crucial role in the analytical thinking process of solving problems in everyday life [26]. Cognitive processes also impact the ability to perform basic mathematical operations, namely multi-digit addition and subtraction [27]. The math difficulty subtype should describe impaired cognitive processing [28]. MLD lacks effective strategies or the ability to directly retrieve facts from long-term memory to help complete math tasks [24].

1.3 Type of Mathematics Skills

Based on the 2020 Ministry of Education and Culture policy regarding Minimum Competency Assessment (AKM) in the numeracy section, students must understand numbers, including representation, sequence properties, and operations of various types of numbers (count, fraction, integer, decimal). While the kind of Mathematics Skills in the measurement and geometry subsection include recognizing flat shapes to using volume and surface area in everyday life. In addition, it also assesses students' understanding of measuring length, weight, time, volume, and discharge, as well as units of an area using standard units. Mathematics Skills on data and uncertainty include understanding, interpreting, data presentation, and probability. Algebra covers equations and inequalities, relations and functions (including number patterns), as well as ratios and proportions

However, in some of these aspects, students with math difficulties experience several types of math learning difficulties, such as (a) students have fundamental weaknesses in numbers, number relationships, and number operational [29] (b) students experience poor counting processes, slow search for number results, and inaccurate calculations [30]. (c) students also have difficulty mastering mathematical facts and concepts from the linear representation of numbers and number relationships [31] (d) students have difficulty in mathematics related to problem-solving, especially story-based problems that require understanding skills [26].

1.4 Theoretical Models of Gender and Mathematics Performance

Theoretical models generally begin with the assumption that males outperform females in mathematics. Gender is related to how male and female think, act, and reason [32]. Gender differences are divided into two types, namely attitudes and knowledge. Gender is one of the dimensions that influence the conceptualization process in education. The development of a gender perspective has influenced several disciplines. Even the gender differences between male and female students have different views on solving mathematics [10].

Gender differences in math achievement where there is emerging evidence that male and female students differ in the types of strategies they use to solve math problems. Even in math performance, which is highly dependent on language processing, the risk of impairment also varies by gender. Based on Flannery [33] concluded that language and reading disorders are even twice as common in male students as in female students. We tested the hypothesis in this research. Researchers examined gender differences in arithmetic performance after statistically controlling for the following factors separately, including in the sub-chapters Numbers and Operations, Measurements, Geometry, Data processing, and reasoning. We used the story item sub-material assessment to assess language processing because it measures a vital component of language ability/phonological awareness.

2 Method

This research is essential to know and analyze various mathematical difficulties, cognitive characteristics, and gender differences in Mathematics Performance of students with mathematical difficulties in inclusive elementary schools. This research is also a step before providing an intervention program to develop a universal-based curriculum design for applying mathematics games. This research used a descriptive qualitative method.

2.1 Partisipant

The MLD sample consisted of 17 students (seven boys and ten girls) in grade 4 Inclusive Elementary School in Magetan, Indonesia. 17 students were obtained from non-clinical samples. Namely, students were labeled as MLD if they performed one standard deviation below the average norm score (score below 50) using test questions with a level of difficulty below the material/curriculum being studied. In this case, students in Grade 4 inclusive elementary schools were identified using math problems with a grade 3 difficulty level.

2.2 Research procedure

The research procedure includes 1) schools permission to participate in research, 2) information to parents of children through class teachers, 3) identification of students with math difficulties in grade 3 of the Inclusive Elementary School and was carried out on April 18, 2022, and found 17 students identified with math difficulties, 4) Assessment of curriculum/materials on students with math difficulties on April 19, 2022, using a test instrument totaling 30 questions which were completed in 1 session and lasted for 120 minutes. The item questions are based on the [34] national curriculum standard with six sub-chapters of mathematics material that have been validated by math class teachers and expert lecturers, e) data analysis and conclusion drawing.

2.3 Cognitive processing tasks

The test analysis process was adapted from the BSNP 2020 assessment textbook, which integrates aspects of elementary school grade 4 math skills with the method of giving test items totaling 30 questions with a processing time of 120 minutes.

The following are some cognitive processing tasks for students with MLD (a) Counting operations on whole numbers: this test consists of 4 item test questions (b) Fractions: This test consists of 5-item test questions, (c) Measurement: this test consists of

6 test items (d) Angles and flat shapes (geometry): this test consists of 6 test items (e) Area, perimeter, and volume (geometry): This test consists of 4 item test questions. (f) Data processing: this test consists of 5 items.

3 Result and Discusion

3.1 Type of Mathematics Skills

Table 1. Percentage of analysis of teaching material difficulties in 17 MLD students

Learning focus	Material Indicators	Number of question items (17 students)	Number of correct answers	Number of wrong answers	Percentage of difficulty
Numbers and Operations	Counting operations	68	22	46	67,6%
	Fractions	85	35	50	58,8%
Measurement and Geometry	Measurement	102	18	84	82,3%
	Corner, Two-dimensional Figure, Geometry	102	43	59	57,8%
	Area, Perimeter, and Volume Geometry	68	13	55	80,8%
Data processing and reasoning	Data processing and story questions	85	28	57	67%

Based on the table above, it can be concluded that students with MLD who work on test analysis questions using the lower curriculum, namely grade 3 elementary school, still get scores below 50. The operationalization and limit values used to define MLD have varied substantially [35]. It also matches Geary's research in determining the cutoff of percentile scores. Some cutoffs apply pretty strict standards, namely, the 10th percentile [36], while others are lighter at the 40th percentile [37].

The profile of the type of mathematical skill on the task of counting operations on 17 MLD students got 67.6% difficulty, this is in accordance with previous research that students' mathematical difficulties are also related to difficulties in several aspects of numbers, number relationships, and number operations [29]. Even students also experience a poor calculation process, slow search for number results, and inaccurate calculations so that getting wrong answers is always more than right answers [30]. Other findings also relate to fractions. Fraction knowledge refers to understanding part-whole relationships, interpreting fractional measurements, and math problems involving the sum of fractions. In this study, it was found that 17 MLD students who had difficulty in fractional problems reached 58.8%. It is in accordance with research Fuchs [38] that fractional material is also one of the difficulties for MLD students.

Another finding on the type of mathematical difficulty related to Measurement, even the difficulty reached 82.35% in this study, the measurement material found the highest difficulty in analyzing the mathematical difficulty of MLD students. Students have difficulty mastering mathematical facts and concepts from the linear representation of numbers and number relationships [31]. The linear representation of Measurement includes measurement of time in hours, measurements of days, months, and years, measurements in units of length, and measurements in weight units. Another finding on the type of mathematical difficulty is related to geometry. In the Corner sub-material, Two-dimensional Figures, MLD students have difficulty reaching 57.8%, while in Area, Perimeter, and Volume Geometry, it reaches 80.8%. Geometry involves problem-solving and reasoning about shapes, sizes, and angles. It is also in accordance with Dobbin's research [39] that students with MLD have difficulty in geometry material. Other findings in this study include data processing and story questions, and the difficulty reaches 67%. It is also supported by Phonapichat's research that MLD students experience difficulties in mathematics related to problem-solving, especially story-based problems that require understanding skills [26].

3.2 Cognitive determinant

Developing cognitive abilities, which can be referred to as thinking skills, is one of the goals of learning mathematics achievement. Cognitive abilities should be given more attention to learning mathematics through learning activities and assessment [40]. We use seven mathematical cognitive abilities as a reference for assessment instruments based on [41] including aspects of mathematics, mathematical concepts, numbers operations, working memory, executive function, phenology/reading accuracy, and non-verbal problem-solving.

The level of students' mathematical cognitive abilities can be known based on the analysis of the measured scores that have been tested. The analysis of the cognitive abilities of students with math difficulties in grade 3 inclusive elementary schools shows that the overall average of students' mathematical cognitive abilities is 31.72. the results found details of difficulties in mathematical aspects and concepts, which include Counting operations, Fractions, Measurement, Geometry, Data processing, and story questions using material and difficulty 1 level below the level of learning material in class. So it can be concluded that the cognitive determinant aspect of students with math difficulties is also related to working memory. These results are in accordance with Swanson's research that mathematics is more closely associated with working memory problems and problem-solving [42]. Students with math difficulties also showed difficulty in recalling auditory and visual stimuli. Research suggests this difficulty stems from deficits in working memory [43] or the ability to retain information for short periods while engaged in cognitively demanding tasks. This deficit in working memory is shown in activities such as remembering math facts on grade 2 questions for grade 3 students where they should have mastered the basic concepts of the material.

Working memory is also closely related to the executive function component in Mathematics and problem solving [44]. Correlational studies also provide convincing evidence of the relationship between executive function skills and mathematics, which may be stronger than the relationship between executive function skills and other areas of academic performance [45]. It considers the strategies used by students aged 10-12 or grades 4-6 when solving math problems and executive function roles. Of course, this is closely related to showing students decide on strategies to solve math problems. In the results of the analysis of the problem, it was found that the results of poor mathematical performance, so in this case, the cognitive determinants of students, especially in the executive function, were also disturbed in the strategies used, especially in mathematical calculations. Executive function is generally defined as a process that controls, directs, or coordinates other cognitive processes [46]. As students; knowledge of mathematics develops, the types of strategies they use will also develop to use numerical strategy manipulatives to cognitive representations to retrieve the right answer. Suppose analyzed, during the problem-solving process and in the storage also retrieval of partial results. In that case, inhabitation can suppress inappropriate strategies (e.g., addition when subtraction is required) or stronger number representation in fractions problems. When the exact numbers are combined in fractions, a larger denominator represents a smaller quantity – understanding of fractions may require inhabitation of the large-number mapping that applies to integers). Obstacles also occur in geometry questions that get the most wrong answers; students find it difficult to decide on a concept strategy if the questions are packaged in data processing and story questions.

Suppose it is related to students' cognitive determinants on understanding and strategies in problem-solving story problems, of course. In that case, it is also related to the accuracy of phonological processing of a combination of reading difficulties and non-verbal problem-solving. In the research process, it was found that students with math difficulties also had difficulty in reading/dyslexia based on the identification of the teacher, which amounted to 3 children with the lowest score getting a score of 6.6 (male students), 13.3 (female students), and 16.6 (female students). It is also consistent with Wilson's study that the comorbidity rate for students with math difficulties with reading disabilities has been reported to be around 40% [47]. In fact, recent studies by Koponen have been approximately 30% to 70% [48]. MLD students accompanied by RD faced difficulties with verbal comprehension. Problem-solving in story problems is a complex activity that requires not only mathematical skills but also text comprehension skills to understand the purpose and structure of the problem, so it will be closely related to students' mathematical results if students have difficulty in reading.

3.3 Gender differences

There is evidence that gender differences in math achievement already exist when children enter primary school [9]. The results of the descriptive analysis of the percentage of students' mathematical ability scores based on gender differences are presented in the table below.

Table 2. Students' math scores by gender differences

Gender	Number	Min score	Max score	Mean	Standar deviation
Male	7	6.6	46.6	34.24	14.49
Female	10	13.3	40	29.97	9.30

Based on table 2, the results of the descriptive analysis of the percentage of students' mathematical ability scores based on gender differences, the average score of male students is higher than the average score of female students. In fact, the highest score is also obtained by male students, so it can be concluded that male students are better than female students at picking up answers accurately. In accordance with Zhu's previous research [49] male students have been shown to outperform female students in solving mathematical problems. Male students' mathematical problem-solving gains have been attributed to their superior spatial abilities. However, based on the analysis results, male students also found the lowest scores compared to female students. In the following, a descriptive analysis of the percentage of each Type of Mathematics ability based on gender differences will be presented to find out which aspects are the most dominant based on gender differences.

Table 3. Type of Mathematics Ability based on gender differences

Type of Mathematic Ability	Correct answers		Persentage	
	Male	Female	Male	Female
Counting operations	9	13	40.9%	59.0%
Fractions	16	19	45.7%	54.2%
Measurement	8	10	44.4%	55.5%
Corner, Two-dimensional Figure, Geometry	23	20	53.4%	46.5%
Area, Perimeter, and Volume Geometry	9	7	56.2%	43.7%
Data processing and story questions	11	17	39.2%	60.7%

Based on table 3, the results of the descriptive analysis of the percentage of each Type of Mathematics Ability obtained aspects of Counting operations, fractions, and Measurement of female students are higher than male students. In accordance with previous research [50], female students generally outperformed male students in arithmetic or counting operations.

While in the Types of Mathematics Ability on geometry questions, male students are superior to female students. Geometry involves problem-solving and reasoning about the geometric properties of a shape that do not change when the image is rotated or altered, so students' thinking skills should be improved when working with geometric constructions. These properties include points, lines, planes, angles, various shapes, and dimensions. Geometry material encourages students' logical thinking and engages them in rigorous analytical thinking. These results are in accordance with research [51] that male students get superior results in learning geometry than female students. This is influenced by the view that geometry is a difficult math problem and affects the decrease in interest of female students, resulting in ignoring questions or answering inaccurately. In story questions, the analysis results show that female students are superior to male students. Word problem solving is a complex activity that requires not only mathematical skills but also text comprehension skills to understand the narrative of the problem, focus on relevant information and ignore irrelevant information, compose number sentences, and also solve missing numbers to find the answer. The multistep nature of word problem solving and the requirements for processing mathematical and linguistics information. These results are consistent with the study of Flannery [33] that language and reading disorders are twice as common in male students as in female students. Superiority in language processing explains their superiority in arithmetic. Girls' superiority in arithmetic is most likely due to their superiority in language processing rather than superiority in basic numerical processing or specific cognitive abilities.

4 Conclusions

The current results support the view that mathematical earning difficulty is a heterogeneous disorder. The research's findings based on the type of mathematical difficulty showed that the operations of counting whole numbers were difficulty 67.7%, fractions 58.8%, measurements 82.3%, angles, flat shapes, 57.7% area, circumference, and volume 80.8%, data processing and story questions 67%. The research findings on the cognitive abilities of the determinants of students with mathematical difficulties showed difficulties in mathematical aspects, mathematical concepts, operating numbers, working memory, executive function, phonological processing accuracy, non-verbal problem solving, and a combination of reading difficulties. It is also related to the finding of mathematical ability based on the gender differences that male students get a higher average score than female students and are more dominant in arithmetic operations and story problems. Further studies related to the study of the type of mathematical ability, cognitive determinant, and gender differences in the mathematical performance of students with math difficulties. It still needs to be done using a broader sample, but still needs to be done to reveal whether gender differences (male and female) have the potential to affect students learning outcomes. It has implications for how to intervene using curriculum design, pedagogy, and digital tools that are appropriate and tailored for each student in different subtypes so that students can engage and express mathematical ideas optimally. Readers will also find helpful article resources for helping teachers know differences in student abilities to determine the appropriate intervention program and curriculum design for mathematical learning difficulties students.

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