**AL IBTIDA: JURNAL PENDIDIKAN GURU MI (2024) VOL 11 (2): 300 - 319**
DOI: http://dx.doi.org/10.24235/al.ibtida.snj.v11i2.18720

Al Ibtida: Jurnal Pendidikan Guru MI
ISSN: 2442-5133, e-ISSN: 2527-7227
Journal homepage: http://syekhnurjati.ac.id/jurnal/index.php/ibtida
Journal email: alibtida@syekhnurjati.ac.id

# Analysis of Student Errors in Solving Numeracy Literacy Problems of Graph Representation Model in Elementary School

**Intan Sari Rufiana***
*Basic Education Study Program, Postgraduates School,
Universitas Negeri Malang, Indonesia
E-mail: intan.sari.pasca@um.ac.id

**Slamet Arifin****
**Basic Education Study Program, Postgraduates School,
Universitas Negeri Malang, Indonesia
E-mail: slamet.arifin.pasca@um.ac.id

**Mohammad Yusuf Randy*****
***Basic Education Study Program, Postgraduates School,
Universitas Negeri Malang, Indonesia
E-mail: mohammad.yusuf.2321038@students.um.ac.id

**Fierda Nursitasari Amaliya******
****Basic Education Study Program, Postgraduates School,
Universitas Negeri Malang, Indonesia
E-mail: fierda.nursitasari.2321038@students.um.ac.id

Received: August 17th, 2024. Accepted: October 20th, 2024. Published: October 30th, 2024.

## Abstract

This study aims to describe the types of student errors in solving numeracy literacy problems of graph representation models. This study used a mixed methods research design with a sequential exploratory type. The data collection techniques used were tests and interviews. The participants in this study were 30 elementary school students tested and six students selected by purposive sampling to be interviewed. The results showed that students experienced conceptual errors and procedural errors. In conceptual errors, 40% of students make errors in reading data, 43% between data, and 60% of students make errors beyond data. Conceptual errors occur when students cannot understand the context of the problem, cannot read the data, do not master the basic concepts of statistics, and do not understand number patterns. In procedural errors, 63% of students make errors in reading data, 73% of students make errors in reading between data, and 80% of students make errors in reading beyond data. Procedural errors occur when students are wrong in choosing the solution procedure, calculating, and predicting. Therefore, educators need to design appropriate learning strategies to minimize errors made by students in numeracy literacy questions on graph representation models, such as applying contextual learning-based numeracy problems.

**Keywords**: *student errors, graphic literacy, numeracy literacy, elementary school.*

**Abstrak**

Penelitian ini bertujuan untuk mendeskripsikan jenis-jenis kesalahan siswa dalam menyelesaikan soal literasi numerasi model representasi grafik. Penelitian ini menggunakan desain penelitian mixed methods dengan tipe eksploratori sekuensial. Teknik pengumpulan data yang digunakan adalah tes dan wawancara. Partisipan dalam penelitian ini adalah 30 siswa sekolah dasar yang dites dan enam siswa yang dipilih secara purposive sampling untuk diwawancarai. Hasil penelitian menunjukkan bahwa siswa mengalami kesalahan konseptual dan kesalahan prosedural. Pada kesalahan konseptual, 40% siswa melakukan kesalahan dalam membaca data, 43% di antara data, dan 60% siswa melakukan kesalahan di luar data. Kesalahan konseptual terjadi ketika siswa tidak dapat memahami konteks soal, tidak dapat membaca data, tidak menguasai konsep dasar statistika, dan tidak memahami pola bilangan. Pada kesalahan prosedural, 63% siswa melakukan kesalahan dalam membaca data, 73% siswa melakukan kesalahan dalam membaca antar data, dan 80% siswa melakukan kesalahan dalam membaca di luar data. Kesalahan prosedural terjadi ketika siswa salah dalam memilih prosedur penyelesaian, menghitung, dan memprediksi. Oleh karena itu, pendidik perlu merancang strategi pembelajaran yang tepat untuk meminimalisir kesalahan yang dilakukan siswa dalam soal literasi numerasi pada model representasi grafik, seperti menerapkan soal literasi numerasi berbasis pembelajaran kontekstual.

**Kata kunci:** *kesalahan siswa, literasi grafik, literasi numerasi, sekolah dasar.*

## INTRODUCTION

Numeracy is the knowledge and skills needed to handle mathematical challenges in personal and public contexts. It enables individuals to actively engage in society as knowledgeable, thoughtful and contributing members (Bennison, et al., 2020; Thomas et al., 2023). Numeracy is essential for many 21st-century jobs, especially in STEM (Science, Technology, Engineering, and Mathematics), finance, data analysis, and business, which require students to improve their numeracy skills to succeed in a competitive job market (Gal, et al., 2020; Plasman, et al., 2021). However, the numeracy skills of students in Indonesia still need to improve (Asmara & Purnomo, 2023; Cahyana, et al., 2024; Oktradiksa et al., 2023 Ekawati, et al., 2020).

The low numeracy skills in Indonesia can be evidenced by the 2022 *Program for International Student Assessment* (PISA) test results, in which Indonesia received a score of 366. Compared to the average of 472 points in OECD countries, the score of 366 is low, and Indonesia's score has also decreased compared to the previous PISA period in 2018, which scored 379. Therefore, Indonesia was ranked 69 out of 81 countries (OECD, 2023). It is also evidenced by the results of the 2022 National Education Report Card that students have numeracy skills in the medium category with a percentage of achievement of 46.67% at the primary school level and should have a minimum achievement of 71% to be said to have good category numeracy skills (Kemendikbudristek, 2023). This is supported by the results of the 2023 Minimum Competency Assessment (AKM) scores in several elementary school education units in Malang City that one of the problematic materials is analyzing information on graphical representation models (Kemendikbudristek, 2024).

Graphical representation is a way to present data visually using graphs, charts, diagrams, and plots (Mathai, Krishnan, & Sreevalsan-Nair, 2024; Tsagaroulis, 2020). This graphic representation is related to graphic literacy because graphic literacy is the ability to understand graphic representations and emphasizes that graphics are ubiquitous in various data sources (Ozmen, Guven, & Kurak, 2020; Uyanik, Elbir, & Ozmen, 2023). Graph literacy is closely related to numeracy skills because by mastering graph literacy, students can solve numeracy problems with a graph representation model (Tsagaroulis, 2020; Uyanik et al., 2023). In graph literacy, there are three levels that students must master, namely reading data, reading between data, and reading beyond data (Merk, Groß Ophoff, & Kelava, 2023; Zeuch, Förster, & Souvignier, 2017). The higher the level of graphic literacy, the more cognitive complexity students need (Ozmen et al., 2020). This graphic literacy has an essential role in everyday life where having an understanding of graphics allows individuals to make better decisions, understand complex social issues, and keep up with developments in science and technology (Binali, Chang, Chang, & Chang, 2024; Mathai et al., 2024; Tsagaroulis, 2020). However, students' ability to understand graphic representations (graphic literacy) is still relatively low and will be fatal if not followed up (Becker, Knippertz, Ruzika, & Kuhn, 2023; Ivanjek, Susac, Planinic, Andrasevic, & Milin-Sipus, 2016; Ozmen et al., 2020).

The low graphic literacy is because students are still inadequate in interpreting and analyzing a graph when faced with using various types of graphic forms, as well as several errors and misunderstandings experienced and made by students when given a data representation presentation (Rufiana, Wahyudi, & Nurhidayah, 2020). Some students think that the graph should start from the zero point, not included in the data, and scaling errors have an impact on students' failure to understand graphical representations (Bragdon, Pandiscio, & Speer, 2019; Ozmen et al., 2020). Students also experience difficulties interpreting graphs and making statistical inferences due to a lack of understanding of the data, leading to errors in solving graph representation model problems (Uyanik et al., 2023; Yılmaz & Ay, 2016). This shows that many errors still occur when solving graph representation model problems.

The errors that occur in students when solving this graph representation model problem will be analyzed using Kastolan's theory. Kastolan's theory is a stage used to understand and analyze how students answer problems in problems, especially AKM Numeration problems (Anggraini, Utomo, & Azmi, 2023; Putri, Juandi, Kurniawan, & Sukri, 2023). Kastolan explained that when students answer a problem in the problem, the students pass through various obstacles in solving the problem, namely conceptual challenges (how students process in understanding the context of the problem) and procedural challenges (how students process in finding answers) (Fujirahayu, Fitrianna, & Zanthy, 2022; Putri et al., 2023). Using this theory is expected to thoroughly analyze student errors in working on graphical representation model problems and then compare with various previous studies that have topics on graphical representation.

Research on mathematical graphic representation has been studied several times, such as understanding graphic literacy at the junior high school level, understanding graphic literacy in high school and university students, and understanding strategies for graphic literacy at each school level (Binali et al., 2024; Mathai et al., 2024; Ozmen et al., 2020). Research by Ozmen et al. (2020) states that students' scores in graphical literacy skills still need to improve because students have difficulty comparing two graphs, determining the appropriate context or type of graph, and realizing errors in the graph. These results indicate that students need help to achieve advanced levels of graph comprehension, such as reading between and beyond data. Then, research by Binali et al. (2024) states statistically significant differences across educational levels regarding graph interpretation competence in scientific and everyday contexts. In addition, students' graph interpretation competence is related to scientific and everyday contexts. Essential factors that predict students' graph interpretation in everyday contexts include age and graph interpretation in scientific literacy. In addition, research by Mathai et al. (2024) stated that students' understanding of graphs is related to significant curricular development in Grades 5 and 9. Understanding bar graphs with nominal data is more accessible than line graphs, which require integrating and interpreting information from two dimensions. The students needed a clear strategy or linear trajectory of understanding but moved back and forth between conventions, groupings of graphical elements and written content in the questions to make meaning.

Research on graphical representation has been carried out several times based on previous research. However, only some studies analyze student errors on graph representation model questions, especially numeracy literacy questions. Therefore, the difference between this research and previous research is that it focuses on student errors in graph representation model problems, focuses on numeracy literacy problems, and focuses on elementary school students. The research aims to describe and illustrate the types of student errors in working on numeracy literacy problems on graph representation models in elementary schools. This research is essential because knowing these errors can be used to find student errors, so later it can be used as a basis for improving learning strategies, learning media, and appropriate assessments.

## METHODS

This study employs a sequential exploratory mix-methods design as described by Creswell and Creswell (2023). The research is conducted in two main phases: the initial phase focuses on quantitative data collection and analysis, while the subsequent phase involves qualitative data collection and analysis. The quantitative phase aims to determine the percentage of student errors in solving numeracy literacy problems, particularly those involving graph representation models. Following this, the qualitative phase explores and describes the types of errors made by students to provide deeper insights into their underlying causes.

The procedures for this research consist of three stages. In the first stage, a written test is administered to 30 sixth-grade students to identify the types and frequencies of errors. The second stage involves purposive sampling to select six students from the initial group based on their test results, representing different categories of errors. These selected students participate in semi-structured interviews aimed at uncovering the reasoning and thought processes behind their errors. In the third stage, data validation is performed using triangulation techniques, including comparing data from written tests with interview findings (technique triangulation) and cross-verifying data among the selected subjects (subject triangulation).

The population in this study includes all sixth-grade students from public elementary schools in Malang, East Java. The sample consists of 30 students selected through stratified random sampling to ensure representation of diverse performance levels. The subjects for the qualitative phase, involving interviews, are six students chosen through purposive sampling from the initial sample based on their performance in the written test. The selected subjects represent varying categories of errors, including conceptual and procedural errors.

The data collection techniques include a written test and semi-structured interviews. The written test is designed to assess students' ability to solve numeracy literacy problems related to graph representations. The test items include a variety of question types, such as interpreting data from graphs and solving related mathematical problems. The semi-structured interviews are guided by a set of open-ended questions, allowing for flexibility to probe deeper into students' thought processes and the specific nature of their errors. All interviews are recorded and transcribed for analysis.

The research instruments consist of a test instrument and an interview guide. The test instrument is a validated set of numeracy literacy problems focusing on graph interpretation and problem-solving. The test questions are adapted and modified from existing standardized assessments and frameworks, ensuring alignment with the study's objectives. The test underwent expert validation to ensure its content validity and was pilot-tested on 10 students from a school outside the research sample to evaluate clarity and reliability. The interview guide includes key questions aimed at eliciting detailed explanations of students' problem-solving strategies and challenges. It was also reviewed by experts and refined based on feedback from the pilot test.

The data analysis techniques differ for the quantitative and qualitative phases. Quantitative data analysis involves calculating the percentage of errors for each error category, guided by the error percentage categories outlined in Fujirahayu et al. (2022). The results are presented in tabular and graphical forms. For qualitative data, analysis follows the framework of Miles, Huberman, and Saldana (2014), involving data reduction, data display, and conclusion drawing. Data reduction includes coding and categorizing interview transcripts to identify recurring themes and patterns related to student errors. The findings from both phases are integrated to provide a comprehensive understanding of the types and causes of errors in solving numeracy literacy problems involving graph representations.

Table 1. Error Percentage Categories

| **Category** | **Percentage** |
|---|---|
| Very Low | 0% − 20% |
| Low | 21% − 40% |
| Medium | 41% − 60% |
| High | 61% − 80% |
| Very High | 81% − 100% |

## RESULTS AND DISCUSSION

### Conceptual Errors on Graph Problems

The conceptual errors made by students on graph questions are as shown in table 2 below.

Table 2. Analysis of Students' Conceptual Errors in Graph Problems

| Literacy Level Graph | Amount | Percentage |
|---|---|---|
| Reading data | 12 | 40% |
| Reading between data | 13 | 43% |
| Reading beyond data | 18 | 60% |

Table 2 shows that the types of conceptual errors are divided into reading data, reading between data, and reading beyond data. In the conceptual error of reading data, 12 out of 30 students (40%) experience errors, which means that the error of reading data is included in the low category. In the conceptual error of reading between data, 13 out of 30 students (43%) experienced errors, meaning that reading errors between data are included in the medium category. In the conceptual error of reading beyond data, 18 out of 30 students (60%) experienced errors, which meant that reading errors beyond data were included in the medium category. This means that the higher the level of the problem, the more students experience conceptual errors in solving numeracy literacy problems with the graph representation model.

- **Conceptual Error in Reading Data**

The following is S-1's answer, which represents conceptual errors in reading the data:

***Question:***

**Read the text below to answer questions 1-3!**

**Dice Game**

One day, four students named Dimas, Anisa, Desi, and Dinda played a dice game with their teacher. They rolled two dice to determine who would get the highest score. Each of them recorded the results of their dice rolls over five rounds. The sum of their dice rolls is presented in the table below:

| Name | Dice Sum (Round 1) | Dice Sum (Round 2) | Dice Sum (Round 3) | Dice Sum (Round 4) | Dice Sum (Round 5) |
|---|---|---|---|---|---|
| Dimas | 6 | 8 | 7 | 9 | 8 |
| Anisa | 8 | 6 | 9 | 7 | 10 |
| Desi | 10 | 7 | 8 | 5 | 6 |
| Dinda | 9 | 7 | 8 | 6 | 7 |

1. Who scored the highest and lowest in the first and last rounds?

Yang mendapat giliran terbanyak adalah Desi karena dimulai dari angka 10
Yang mendapat giliran terendah adalah Dimas karena dimulai dari angka 6

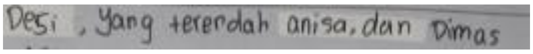
The one who gets the most turns is Desi because it starts from number 10

Figure 1. S-1 Reading Data Answers

The answer was then confirmed with the following interview:

*P* : *How did you answer this question?*
*S-1* : *I looked for the data on the first turn and found that Desi had the most data and Dimas had the lowest data.*
*P* : *Why did you only look for data on one turn?*
*S-1* : *I looked for the most turns.*

The following is S-2's answer, which represents conceptual errors in reading the data:


Desi , Yang terendah anisa, dan Dimas

Desi, the lowest Anisa and Dimas

Figure 2. S-2 Reading Data Answers

The answer was then confirmed with the following interview:

*P* : *How did you answer this question?*
*S-2* : *I looked at the data at the beginning of the turn and found that Desi had the most data, and Anisa and Dimas had the lowest data.*
*P* : *Why did you only look at one of the turns?*
*S-2* : *I thought I was just looking for the data at the beginning.*
*P* : *Why is the lowest data for Anisa and Dimas?*
*S-2* : *Because they have 8 and 6 dice, respectively, and are lower than the other two students.*

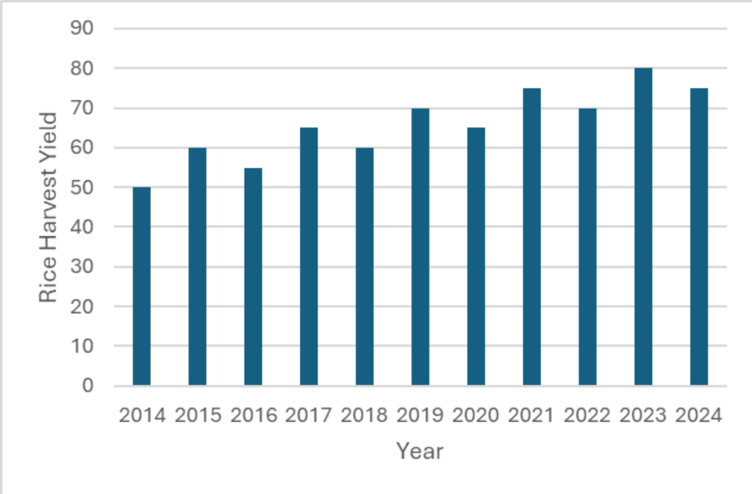
From the students' answers and interview results on Subjects S-1 and S-2, it can be seen that S-1 and S-2 made mistakes in solving the problem to extract information about the highest and lowest number of dice in the first turn, as well as the highest and lowest number of dice in the last turn. In S-1, students did not understand the context of the question order, which should have looked for the highest and lowest data in both turns, not one of the turns. In S-2, students did not understand the question command to find the highest and lowest data in both turns and only explained the highest and lowest data in one of the turns. Then, S-2 cannot read the lowest data, which should only be taken from the student with the smallest score. So, it can be concluded that students make conceptual errors in reading data because they do not understand the context of the problem, cannot read the data, and do not understand the concept of data comparison (highest and lowest data).

- **Conceptual Error in Reading Between Data**

The following is S-3's answer, which represents conceptual errors in reading between the data:

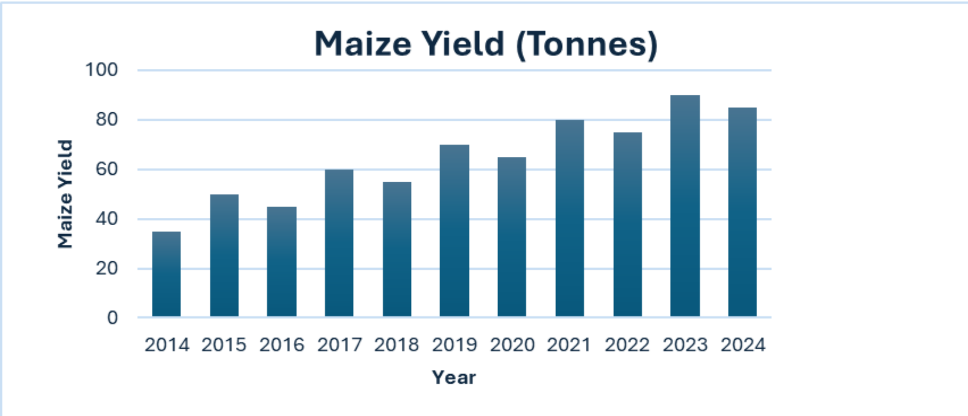
***Question:***

*KUD Tani* Subur *is a cooperative engaged in agricultural production, which produces rice and corn. To prepare for the annual meeting of co-operative members, the treasurer of the co-operative was appointed to record and compare data on rice and corn yields in the last 10 years listed in the following bar chart:*

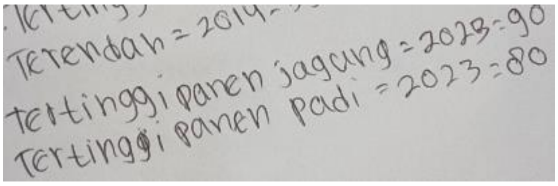



***Rice Harvest Yield in Tonnes***

***Maize Yield in Tonnes***




4. *In which year did the rice yield reach the highest amount and the lowest amount, and what were the amounts?*



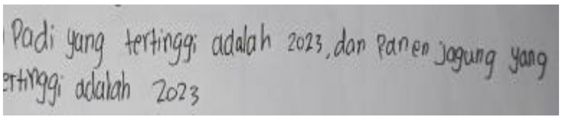

Highest corn harvest = 2023 = 90
Highest rice harvest = 2023 = 80

Figure 3. S-3 Reading Between Data Answers

The answer was then confirmed with the following interview:

| | | |
|---|---|---|
| *P* | : | *How did you answer this question?* |
| *S-3* | : | *I looked for the highest data in each harvest.* |
| *P* | : | *Why did you look for the highest data for each harvest?* |
| *S-3* | : | *I thought the highest total was just looking for the highest harvest in each type.* |
| *P* | : | *Did you have any problems in reading the graph data for each harvest?* |
| *S-3* | : | *Yes, I entered the rice harvest data incorrectly; it should have been corn harvest data.* |

The following is S-2's answer, which represents conceptual errors in reading between the data:




The highest rice harvest is 2023 and the highest corn harvest is 2023

Figure 4. S-2 Reading Between Data Answers

The answer was then confirmed with the following interview:

| | | |
|---|---|---|
| *P* | : | *How did you answer this question?* |
| *S-2* | : | *I looked for the year in each harvest with the highest number.* |
| *P* | : | *Why did you look for the year that had the highest harvest in each harvest?* |
| *S-2* | : | *I understand how to find the highest total harvest by finding the highest harvest data for each harvest.* |
| *P* | : | *Were you able to read the graph data of each harvest smoothly?* |
| *S-2* | : | *There was too much data, which made me careless in reading and writing the harvest data.* |

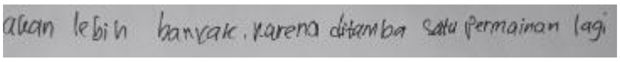
From the students' answers and interview results on Subjects S-3 and S-2, it can be seen that S-3 and S-2 made mistakes in solving the problem of exploring information about the comparison of more than the total amount of rice harvest and corn harvest. In S-3, students did not understand the context of the question command, which should find the total of each harvest and then compare which one is more. After that, S-3 could not read the data on the graph, which made him unable to calculate the total and compare the overall data. In S-2, the student did not understand the context of the question command, which should find the total of each harvest and then compare which one is more. After that, S-2 was not fluent in reading the data on the graph, which made him unable to calculate the total and compare the overall data. So, it can be concluded that students make conceptual errors in reading between data because they do not understand the context of the problem, cannot read the data, and do not understand the concept of comparing overall data.

- **Conceptual Error in Reading Beyond Data**

The following is S-1's answer, which represents conceptual errors in reading beyond the data:

***Question:***

*If the dice game continued for one more round, what might be the score for each student? Explain your reasoning!*



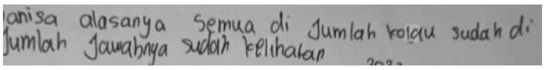

There will be more because one more game is added.

Figure 5. S-1 Reading Beyond Data Answers

The answer was then confirmed with the following interview:

*P : How did you answer this question?*
*S-1 : I guessed each student would get more dice on the next turn.*
*P : Why did you state that each student will get more dice on the next turn?*
*S-1 : I observed that some students get more dice on the next turn.*
*P : Do you understand and observe in the table that there is a number pattern for each student?*
*S-1 : No, sir.*

The following is S-2's answer, which represents conceptual errors in reading beyond the data:




Anisa, the reason is that when you add up the answers, you will see.

Figure 6. S-2 Reading Beyond Data Answers

The answer was then confirmed with the following interview:

*P : How did you answer this question?*
*S-2 : I added all the dice on each student's turn and then found the largest number.*
*P : Why did you add up the dice on each student's turn?*
*S-2 : I add up all the dice to find the number of dice each student will have in the next turn.*
*P : Do you understand and look at the table that there is a number pattern for each student?*
*S-2 : No, sir.*

From the students' answers and interview results on Subjects S-1 and S-2, it can be seen that S-1 and S-2 made mistakes in solving the problem to explore information about predicting dice data in the next turn based on number patterns. In S-1, students did not understand the context of the question command, which should find the number of dice for each student in the next turn using a number pattern. After that, S-1 could not read the data on the graph, which made them unable to find the number pattern and did not understand the concept of the number pattern to predict the following data. In S-1, the student did not understand the context of the problem command, which should have been to find the number of dice in each student in the next turn using number patterns. After that, S-4 could not read the data on the graph, which made them unable to find number patterns and did not understand the concept of number patterns to predict the following data. So, it can be concluded that students made conceptual errors in reading beyond the data because they did not understand the context of the problem, could not read the data, and did not understand the concept of number patterns in predicting the following data.

**Procedural Error on Graph Problem**

The Procedural errors made by students on graph questions are as shown in table 3 below.

Tabel 3. Analysis of Students' Procedural Errors in Graph Problems

| Literacy Level Graph | Amount | Percentage |
|---|---|---|
| Reading data | 19 | 63% |
| Reading between data | 22 | 73% |
| Reading beyond data | 24 | 80% |

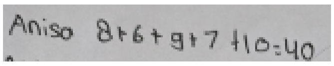
Table 3 shows that the types of procedural errors are divided into procedural reading data, procedural reading between data, and procedural reading beyond data. In the data reading procedural error, there were 19 out of 30 students (63%) experienced errors, which means that data reading errors were included in the high category. In the procedural error of reading between data, 22 out of 30 students (73%) experienced errors, which means that the error of reading between data is included in the high category. In procedural errors reading beyond data, 24 out of 30 students (80%) experienced errors, meaning that reading errors beyond data are included in the high category. This means that the higher the level of the problem, the more students experience procedural errors in solving numeracy literacy problems with the graph representation model.

- **Procedural Error in Reading Data**

The following is S-4's answer, which represents procedural errors in reading the data:

***Question:***

*2. Who scored the highest and lowest in the first and last rounds?*



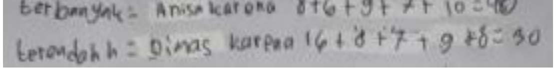
| |
|---|
| Anisa 8+6+9+7+10 = 40 |

Figure 7. S-4 Reading Data Answers

The answer was then confirmed with the following interview:

*P : How did you answer this problem?*
*S-4 : I looked for the highest total number of dice for each student.*
*P : Why are you looking for the highest number of dice?*
*S-4 : Because in the problem, there are words for the largest number of dice.*

The following is S-5's answer, which represents procedural errors in reading the data:



| |
|---|
| Highest = Anisa because 8+6+9+7+10 = 40<br>Lowest = Dimas because 6 +8+7+9+8 = 30 |

Figure 8. S-5 Reading Data Answers

The answer was then confirmed with the following interview:

*P : How did you answer this problem?*
*S-5 : I looked for each student's highest and lowest total number of dice.*
*P : Why did you look for the highest and lowest total number of dice?*
*S-5 : Because the question has the words highest and lowest in the total number dice.*

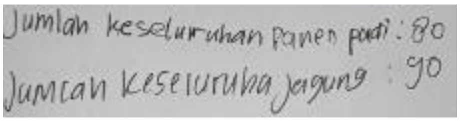
From the students' answers and interview results on Subjects S-4 and S-5, it can be seen that S-4 and S-5 made mistakes in solving the problem to extract information about the highest and lowest number of dice in the first turn and the highest and lowest number of dice in the last turn. In S-4, students were wrong in choosing the procedure to find the sum of the highest and the lowest data in both turns instead of adding up all the dice data to find the highest data because the number of dice was already known in each turn. In S-5, students were wrong in choosing the procedure that should see the highest and lowest data in both turns instead of adding up all the dice data to find the highest and lowest amount because the number of dice was already known in each turn. So, it can be concluded that students make procedural errors in reading data because they make mistakes in choosing procedures that should be limited to reading the number of dice in both turns. Instead, they add up the total dice obtained in all turns.

- **Procedural Error in Reading Between Data**

The following is S-1's answer, which represents procedural errors in reading between the data:

***Question:***

*5. Between the total rice harvest and the total corn harvest, which was higher?*



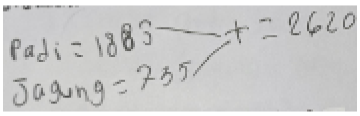

Total rice harvest = 80
Total corn harvest = 90

Figure 9. S-1 Reading Between Data Answers

The answer was then confirmed with the following interview:

*P : How did you answer this question?*
*S-1 : I looked for the total rice harvest and the total corn harvest.*
*P : Why is the total rice harvest 80 and the total corn harvest 90?*
*S-1 : I wrote the total of each crop based on the highest harvest.*

The following is S-5's answer, which represents procedural errors in reading between the data:




Rice = 1885, Corn = 735. 1885 + 735 = 2620

Figure 10. S-5 Reading Between Data Answers

The answer was then confirmed with the following interview:

*P* : *How did you answer this question?*
*S-5* : *I looked for the total rice harvest and the total corn harvest and added the results of the two harvests.*
*P* : *Why is the total rice harvest 1885 and the total corn harvest 735?*
*S-5* : *I calculated the total of each harvest and found that the rice harvest was 1885 and the corn harvest was 735.*
*P* : *Why did you add the two harvests together?*
*S-5* : *Because the question asked for the total number of harvests.*

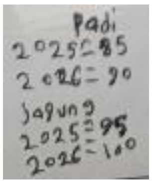
From the students' answers and interview results on Subjects S-1 and S-5, it can be seen that S-1 and S-5 made mistakes in solving the problem of exploring information about the comparison of more than the total number of rice harvests and corn harvests. In S-1, students made mistakes in calculating the total number of each harvest, which should be summed up each year, not just calculating the highest data. In S-5, the student made a mistake in calculating the total amount of each harvest, which should be 725 kg of rice harvest instead of 1885 kg, and the total amount of corn harvest is 710 kg instead of 735 kg. Furthermore, S-5 even calculated the total of the two harvests, which should have been the total compared to find which type of harvest had the most. So, it can be concluded that students made procedural errors in reading between data because they made mistakes in choosing procedures for calculating data and errors in calculating the total data.

- **Procedural Error in Reading Beyond Data**

The following is S-6's answer, which represents procedural errors in reading beyond the data:

***Question:***

*Estimate the rice and corn harvest amounts for 2025 and 2026. Explain your reasoning!*




Rice
2025 = 85
2026 = 90
Corn
2025 = 95
2026 = 100

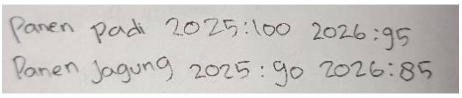
Figure 11. S-6 Reading Beyond Data Answers

The answer was then confirmed with the following interview:

*P* : *How did you answer this question?*
*S-6* : *I looked for the pattern of numbers in each harvest, sir.*
*P* : *How did you find the pattern?*
*S-6* : *I looked at the number of harvests each year for each type of harvest. In the rice and corn harvests, I found the pattern is that in odd years, add 10 to the number of harvests in the previous year, then in even years, add 5 to the number of harvests in the previous year. So, the rice harvest in 2024 is 75,*

*meaning the rice harvest in 2025 is 75 + 10 = 85, and the rice harvest in 2026 is 85 + 5 = 90. The corn harvest in 2024 is 85, meaning the corn harvest in 2025 is 85 + 10 = 95, and the corn harvest in 2026 is 95 + 5 = 100.*

The following is S-2's answer, which represents procedural errors in reading beyond the data:


Panen padi 2025:100 2026:95
Panen jagung 2025:90 2026:85

Rice harvest 2025 = 100 and 2026 = 95
Corn harvest 2025 = 90 and 2026 = 85

Figure 12. S-2 Reading Beyond Data Answers

The answer was then confirmed with the following interview:

*P : How did you answer this question?*

*S-2 : I looked for the pattern of numbers in each harvest, sir.*

*P : How did you find the pattern?*

*S-2 : I looked at the number of harvests each year for each type of harvest. In odd years, rice harvest adds 25 to the previous year's harvest, then subtracts 5 from the previous year's harvest in even years. So, the rice harvest in 2024 is 75, which means the rice harvest 2025 is 75 + 25 = 100, and the rice harvest 2026 is 100 - 5 = 95. In odd years, corn harvest adds 5 to the previous year's harvest, then subtracts 5 from the previous year's harvest in even years. The corn harvest in 2024 is 85, meaning the harvest in 2025 is 85 + 5 = 90, and the corn harvest in 2026 is 90 - 5 = 85.*

From the student answers and interview results on Subjects S-6 and S-2, it can be seen that S-6 and S-2 made mistakes in solving the problem of exploring information about predicting harvest data in the following year based on number patterns. In S-6, students have tried to find number patterns but made mistakes in finding and calculating the following number pattern, which should be the rice harvest in 2025 of 85 and 2026 of 80, and the corn harvest in 2025 of 100 and in 2026 of 95. In S-2, students have tried to find the number pattern but made mistakes in finding and calculating the following number pattern, which should be the rice harvest in 2025 of 85 and 2026 of 80, and the corn harvest in 2025 of 100 and in 2026 of 95. So, it can be concluded that students make procedural errors in reading beyond data due to errors in finding number patterns and calculating the following number pattern to predict data.

In the study results, students make fewer mistakes at the data reading level because most students already have a basic understanding and can perform simple data analysis on graphs. However, the higher the level of graphic literacy, the more students' mistakes make when solving problems. This is supported by the statements of Ozmen et al. (2020) and Merk et al. (2023) that the higher the level of graph literacy, the more cognitive complexity students need. To reach a higher level of graph literacy, students need to master basic skills in understanding graphs; for example, before being able to read beyond data, students must be able to read data on the graph and read between data on the graph (Guo, Zhang, Wright, & McTigue, 2020; Locoro, Fisher, & Mari, 2021).

The results also showed that most errors made by students in working on numeracy literacy problems with graph representation models were caused more by procedural than conceptual errors. This indicates that students generally understand the basic concepts related to graphs but have difficulty applying the right procedures or solution steps, especially in the context of concrete problems (Ivanjek et al., 2016; Ozmen et al., 2020). Procedural errors occur because students lack familiarity and practice working on contextual problems, are wrong in choosing a solution strategy, and are careless in calculating (Becker et al., 2023; Mathai et al., 2024; Ozmen et al., 2020).

The errors made by students at each level of graphic literacy are similar and related. The causes of students making errors at the three levels of graphic literacy can be divided into two types, namely conceptual errors and procedural errors. Conceptual errors occur when students cannot understand the context of the problem, cannot read data, do not master basic statistical concepts, and do not understand data patterns. Meanwhile, procedural errors occur when students are wrong in choosing a solution procedure, calculating incorrectly, and predicting data. Often, procedural errors made by students in numeracy problems stem from a lack of in-depth understanding of concepts or conceptual errors (Lee & Byun, 2022; Winarso & Toheri, 2021). These conceptual errors become the foundation for subsequent errors in the problem-solving process, especially in graph-type numeracy problems. However, not all procedural errors are caused by wrong concepts, they can occur due to a lack of accuracy or carelessness in working on problems (Granberg, 2016; Lian, Yew, & Meng, 2022).

Conceptual errors occur when students cannot understand the context of the problem, cannot read data, do not master basic statistical concepts, and do not understand number patterns. In numeracy problems, students must understand the context of the problem first before solving the problem. Students who do not understand the context of numerical problems will find it challenging to work on problems (Chinn, 2020; Kolar & Hodnik, 2021). In contextual problems, students are not only required to understand the content on the graph, but students must also relate to concrete situations in everyday life, and this makes students feel difficult to solve problems (Becker et al., 2023; Ivanjek et al., 2016). When reading graphs, students need a basic understanding and analysis of the data on the graph. Reading graphs requires more than just looking at pictures and requires a basic understanding of the types of graphs, the elements in them, and the ability to analyze the data presented (Alper, Riche, Chevalier, Boy, & Sezgin, 2017; Ozmen et al., 2020). Understanding basic statistical concepts is essential for solving various problems in graphic literacy, such as the highest data, lowest data, mode, median, and mean (Aksoy & Bostan, 2021; Shiddieqy, Kartini, & Maimunah, 2024; Tsagaroulis, 2020). Understanding trends and patterns from numerical and graphical data and using statistical analysis of data and linear mathematical relationships is essential for calculating and predicting values in graphical data (Mulligan, 2015; Tsagaroulis, 2020).

Procedural errors occur when students are wrong in choosing a solution procedure, calculating incorrectly, and predicting data. Errors in choosing a solution procedure are often encountered by students when working on graph literacy problems due to several factors, namely, lack of understanding of the keywords contained in the problem, making it difficult for students to determine the proper solution steps, errors in the use of formulas that make students wrong in producing the correct answer, and lack of experience in solving graph-type numeracy problems with a certain level of difficulty can hinder students' ability to choose effective solution strategies (Kolar & Hodnik, 2021; Kop, Janssen, Drijvers, & van Driel, 2020; Lee & Byun, 2022; Nurrahmawati, Sa'dijah, Sudirman, & Muksar, 2021). Errors in choosing a solution procedure indicate students' lack of understanding of basic statistical concepts and the ability to choose appropriate analytical tools (Aksoy & Bostan, 2021; Pallauta, Arteaga, & Garzón-Guerrero, 2021; Shiddieqy et al., 2024). Calculation errors are a frequent source of procedural errors because students make mistakes in the addition, subtraction, multiplication, or division of data (Ozmen et al., 2020; Putri et al., 2023). In addition, errors in reading data on graphs can also lead to calculation errors due to a lack of accuracy, practice, or understanding of number concepts (Setiawan & Sukoco, 2021; Tsagaroulis, 2020). Errors in predicting data often occur when students are too quick to conclude without conducting careful data analysis because they see patterns that are not there or ignore patterns that are there (Mulligan, 2015; Ozmen et al., 2020; Tsagaroulis, 2020).

When reading data in graph literacy, students must read and extract information explicitly given in the graph (Merk et al., 2023; Ozmen et al., 2020). At the data reading stage, students are generally asked to retrieve information directly from the graph, such as looking for specific values, comparing data, or identifying simple trends (Aksoy & Bostan, 2021; Mathai et al., 2024). This narrower focus makes it easier for students to understand what is being asked and find the answer (Tsagaroulis, 2020; Yılmaz & Ay, 2016). Reading graphs essentially requires a basic understanding and analysis of the data on the graph, and students tend to succeed at the reading data stage rather than the reading between data and reading beyond data stages (Börner, Bueckle, & Ginda, 2019; Ozmen et al., 2020; Tsagaroulis, 2020).

At the reading between data stage, students must interpolate or compare information explicitly given in the graph (Merk et al., 2023; Ozmen et al., 2020). When reading between data, students only need to take information that is directly visible on the graph; then at the stage of reading between data, students are required to carry out a more in-depth analysis (Jungjohann, Gebhardt, & Scheer, 2022; Zeuch et al., 2017). Students do not just read numbers but must also be able to interpret the relationship between data, and students also need to compare data from various categories or variables (Binali et al., 2024; Boote & Boote, 2017). However, at this stage, students have difficulty distinguishing between two graphs because they think that the graph should start from zero and have difficulty understanding scaling, leading to student failure (Bragdon et al., 2019; Yılmaz & Ay, 2016). These errors are related to insufficient mathematical knowledge and misreading axes or scaling (Ozmen et al., 2020; Uyanik et al., 2023).

When reading beyond data, students must predict and extract information not explicitly encoded in the graph (Merk et al., 2023; Ozmen et al., 2020). In the reading data and reading between data stages, students focus on information that is directly visible or can be calculated from the graph, so at the reading beyond data stage, students are invited to think more critically and creatively to predict data patterns (D'Ignazio, 2017; Jungjohann et al., 2022). Students may have more challenges since this level requires making inferences and predictions about unknown cases (Ozmen et al., 2020). If students are not successful in determining what kind of information and trend patterns can be obtained from the graph, then students will fail to find information that exists beyond data (Tsagaroulis, 2020; Yılmaz &

Ay, 2016). Students are required to go beyond the information provided on the graph and make more in-depth interpretations, which means students should be able to predict future trends based on existing data patterns, identify the causes behind a phenomenon shown in the graph, or even relate the data in the graph to a broader context (Börner et al., 2019; Jungjohann et al., 2022).

## CONCLUSION

This study highlights significant conceptual and procedural challenges faced by students in solving numeracy literacy problems involving graph representations. Conceptual errors, such as difficulties in understanding problem contexts and interpreting data, and procedural errors, including incorrect solution strategies and miscalculations, underscore the need for targeted educational interventions. These findings emphasize the importance of designing innovative and contextually relevant learning strategies to address these gaps. By fostering better comprehension of data interpretation and problem-solving techniques, educators can enhance students' numeracy literacy skills and reduce error rates, ultimately contributing to more effective learning outcomes in elementary education.

## ACKNOWLEDGEMENT (*OPTIONAL*)

This research is funded by a Decentralized Research grant from the Graduate School of the State University of Malang for the 2024 fiscal year.

## REFERENCES

Aksoy, E. Ç., & Bostan, M. I. (2021). Seventh Graders' Statistical Literacy: An Investigation on Bar and Line Graphs. *International Journal of Science and Mathematics Education*, *19*(2), 397–418. https://doi.org/10.1007/s10763-020-10052-2

Alper, B., Riche, N. H., Chevalier, F., Boy, J., & Sezgin, M. (2017). Visualization Literacy at Elementary School. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, 5485–5497. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3025453.3025877

Anggraini, N., Utomo, D. P., & Azmi, R. D. (2023). Analysis of Student Errors in Solving Minimum Competency Assessment Problems Based on Kastolan Theory. *Kalamatika: Jurnal Pendidikan Matematika*, *8*(1), 1–10. https://doi.org/10.22236/KALAMATIKA.vol8no1.2023pp1-10

Asmara, S. D., & Purnomo, Y. W. (2023). Context of Data and Uncertainty: One of the Challenges for Numeracy Provision in Elementary School Teacher Education. *Acta Scientiae*, *25*(6), 235–271. https://doi.org/10.17648/acta.scientiae.7276

Becker, S., Knippertz, L., Ruzika, S., & Kuhn, J. (2023). Persistence, context, and visual strategy of graph understanding: Gaze patterns reveal student difficulties in interpreting graphs. *Physical Review Physics Education Research*, *19*(2), 020142. https://doi.org/10.1103/PhysRevPhysEducRes.19.020142

Bennison, A., Goos, M., & Geiger, V. (2020). Utilising a research-informed instructional design approach to develop an online resource to support teacher professional learning on embedding numeracy across the curriculum. *ZDM*, *52*(5), 1017–1031. https://doi.org/10.1007/s11858-020-01140-2

Binali, T., Chang, C.-H., Chang, Y.-J., & Chang, H.-Y. (2024). High School and College Students' Graph-Interpretation Competence in Scientific and Daily Contexts of Data

Visualization. *Science & Education*, *33*(3), 763–785. https://doi.org/10.1007/s11191-022-00406-3

Boote, S. K., & Boote, D. N. (2017). Leaping from Discrete to Continuous Independent Variables: Sixth Graders' Science Line Graph Interpretations. *The Elementary School Journal*, *117*(3), 455–484. https://doi.org/10.1086/690204

Börner, K., Bueckle, A., & Ginda, M. (2019). Data visualization literacy: Definitions, conceptual frameworks, exercises, and assessments. *Proceedings of the National Academy of Sciences*, *116*(6), 1857–1864. https://doi.org/10.1073/pnas.1807180116

Bragdon, D., Pandiscio, E., & Speer, N. (2019). University students' graph interpretation and comprehension abilities. *Investigations in Mathematics Learning*, *11*(4), 275–290. https://doi.org/10.1080/19477503.2018.1480862

Cahyana, U., Lestari, I., Irwanto, I., & Suroso, J. (2024). Development of a mobile learning network for science with augmented reality and its impact on students' literacy and numeracy. *International Journal of Innovative Research and Scientific Studies*, *7*(2), 576–586. https://doi.org/10.53894/ijirss.v7i2.2685

Chinn, S. (2020). *The Trouble with Maths: A Practical Guide to Helping Learners with Numeracy Difficulties* (4th ed.). London: Routledge. https://doi.org/10.4324/9781003017714

Creswell, J. W., & Creswell, J. D. (2023). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. Sage Publication: London.

D'Ignazio, C. (2017). Creative data literacy: Bridging the gap between the data-haves and data-have nots. *Information Design Journal*, *23*(1), 6–18. https://doi.org/10.1075/idj.23.1.03dig

Ekawati, R., Susanti, S., & Chen, J.-C. (2020). Primary Students' Mathematical Literacy: A Case Study. *Infinity Journal*, *9*(1), 49–58. https://doi.org/10.22460/infinity.v9i1.p49-58

Fujirahayu, A. R., Fitrianna, A. Y., & Zanthy, L. S. (2022). Analisis Kesalahan Siswa dalam Menyelesaikan Soal Operasi bentuk Aljabar berdasarkan Teori Kastolan. *JPMI (Jurnal Pembelajaran Matematika Inovatif)*, *5*(6), 1813–1820. https://doi.org/10.22460/jpmi.v5i6.11203

Gal, I., Grotlüschen, A., Tout, D., & Kaiser, G. (2020). Numeracy, adult education, and vulnerable adults: A critical view of a neglected field. *ZDM*, *52*(3), 377–394. https://doi.org/10.1007/s11858-020-01155-9

Granberg, C. (2016). Discovering and addressing errors during mathematics problem-solving—A productive struggle? *The Journal of Mathematical Behavior*, *42*, 33–48. https://doi.org/10.1016/j.jmathb.2016.02.002

Guo, D., Zhang, S., Wright, K. L., & McTigue, E. M. (2020). Do You Get the Picture? A Meta-Analysis of the Effect of Graphics on Reading Comprehension. *AERA Open*, *6*(1), 2332858420901696. https://doi.org/10.1177/2332858420901696

Ivanjek, L., Susac, A., Planinic, M., Andrasevic, A., & Milin-Sipus, Z. (2016). Student reasoning about graphs in different contexts. *Physical Review Physics Education Research*, *12*(1), 010106. https://doi.org/10.1103/PhysRevPhysEducRes.12.010106

Jungjohann, J., Gebhardt, M., & Scheer, D. (2022). Understanding and improving teachers' graph literacy for data-based decision-making via video intervention. *Frontiers in Education*, *7*(919152). https://doi.org/10.3389/feduc.2022.919152

Kemendikbudristek. (2023). Rapor Pendidikan 2022. Retrieved February 15, 2024, from Pusat Standar & Kebijakan Pendidikan website: https://pskp.kemdikbud.go.id/rapor_pendidikan

Kemendikbudristek. (2024). Rapor Pendidikan 2023. Retrieved February 15, 2024, from Pusat Standar & Kebijakan Pendidikan website: https://pskp.kemdikbud.go.id/rapor_pendidikan

Kolar, V. M., & Hodnik, T. (2021). Mathematical Literacy from the Perspective of Solving Contextual Problems. *Mathematical Literacy from the Perspective of Solving Contextual Problems*, *10*(1), 467–483. https://doi.org/10.12973/eu-jer.10.1.467

Kop, P. M. G. M., Janssen, F. J. J. M., Drijvers, P. H. M., & van Driel, J. H. (2020). The relation between graphing formulas by hand and students' symbol sense. *Educational Studies in Mathematics*, *105*(2), 137–161. https://doi.org/10.1007/s10649-020-09970-3

Lee, S., & Byun, T. (2022). Understanding high school students' errors in solving genetic problems. *International Journal of Science Education*, *44*(7), 1143–1164. https://doi.org/10.1080/09500693.2022.2068205

Lian, L. H., Yew, W. T., & Meng, C. C. (2022). Assessing Lower Secondary School Students' Common Errors in Statistics. *Pertanika Journal of Social Sciences and Humanities*, *30*(3), 1427–1450. https://doi.org/10.47836/pjssh.30.3.26

Locoro, A., Fisher, W. P., & Mari, L. (2021). Visual Information Literacy: Definition, Construct Modeling and Assessment. *IEEE Access*, *9*, 71053–71071. https://doi.org/10.1109/ACCESS.2021.3078429

Mathai, S., Krishnan, P., & Sreevalsan-Nair, J. (2024). Understanding Graphical Literacy Using School Students' Comprehension Strategies. *Contemporary Education Dialogue*, 09731849241242855. https://doi.org/10.1177/09731849241242855

Merk, S., Groß Ophoff, J., & Kelava, A. (2023). Rich data, poor information? Teachers' perceptions of mean differences in graphical feedback from statewide tests. *Learning and Instruction*, *84*, 101717. https://doi.org/10.1016/j.learninstruc.2022.101717

Miles, M. B., Huberman, A. M., & Saldana, J. (2014). *Qualitative Data Analysis: A Methods Sourcebook*. Los Angeles: SAGE Publications.

Mulligan, J. (2015). Moving beyond basic numeracy: Data modeling in the early years of schooling. *ZDM*, *47*(4), 653–663. https://doi.org/10.1007/s11858-015-0687-2

Nurrahmawati, Sa'dijah, C., Sudirman, & Muksar, M. (2021). Assessing Students' Errors in Mathematical Translation: From Symbolic to Verbal and Graphic Representations. *International Journal of Evaluation and Research in Education*, *10*(1), 115–125. https://doi.org/10.11591/ijere.v10i1.20819

Oktradiksa, A., Mujahidun, & Hunt, C. (2023). A literacy and numeracy model to enhance the independent learning education for Islamic elementary school teachers. Al Ibtida: Jurnal Pendidikan Guru MI, 10(1), 106-114. https://doi.org/10.24235/al.ibtida.snj.v10i1.12345

OECD. (2023). *PISA 2022 Results (Volume I): The State of Learning and Equity in Education*. Paris: OECD Publishing. Retrieved from https://www.oecd.org/publication/pisa-2022-results/

Ozmen, Z. M., Guven, B., & Kurak, Y. (2020). Determining the Graphical Literacy Levels of the 8th Grade Students. *Eurasian Journal of Educational Research*, *20*(86), 269–292. https://doi.org/10.14689/ejer.2020.86.13

Pallauta, J. D., Arteaga, P., & Garzón-Guerrero, J. A. (2021). Secondary School Students' Construction and Interpretation of Statistical Tables. *Mathematics*, *9*(24), 3197. https://doi.org/10.3390/math9243197

Plasman, J., Gottfried, M., Williams, D., Ippolito, M., & Owens, A. (2021). Parents' Occupations and Students' Success in STEM Fields: A Systematic Review and Narrative Synthesis. *Adolescent Research Review*, *6*(1), 33–44. https://doi.org/10.1007/s40894-020-00136-z

Putri, C. K., Juandi, D., Kurniawan, S., & Sukri, S. (2023). High School Students' Errors in Solving Statistical Literacy Test Similar to Minimum Competency Assessment. *Edumatica : Jurnal Pendidikan Matematika*, *13*(2), 83–93. https://doi.org/10.22437/edumatica.v13i02.26153

Rufiana, I. S., Wahyudi, W., & Nurhidayah, D. A. (2020). Misinterpretasi Mahasiswa pada Representasi Histogram dan Box Plot. *ANARGYA: Jurnal Ilmiah Pendidikan Matematika*, *3*(2), 82–87. https://doi.org/10.24176/anargya.v3i2.5324

Setiawan, E. P., & Sukoco, H. (2021). Exploring First Year University Students' Statistical Literacy: A Case On Describing and Visualizing Data. *Journal on Mathematics Education*, *12*(3), 427–448. https://doi.org/10.22342/jme.12.3.13202.427-448

Shiddieqy, A. F. A., Kartini, & Maimunah. (2024). An Analysis of Student Errors in Solving Higher Order Thinking Skills Problems on Number Patterns Using Newman's Theory. *JURNAL ABSIS: Jurnal Pendidikan Matematika Dan Matematika*, *7*(1), 154–165. https://doi.org/10.30606/absis.v7i1.2718

Thomas, A., Tazouti, Y., Hoareau, L., Luxembourger, C., Hubert, B., & Jarlégan, A. (2023). Early Numeracy Assessment In French preschool: Structural analysis and links with children's characteristics. *International Journal of Early Years Education*, *31*(4), 1018–1035. https://doi.org/10.1080/09669760.2021.1938518

Tsagaroulis, P. (2020). *Data visualization, numeracy and graph literacy: Seeing and thinking of data presented as tables or charts.* (Dissertation). Chicago School of Professional Psychology, Chicago.

Uyanik, S., Elbir, D., & Ozmen, Z. M. (2023). Determining the graphical literacy levels of the middle school mathematics teachers. *Pedagogical Research*, *8*(2), em0158. https://doi.org/10.29333/pr/13003

Winarso, W., & Toheri, T. (2021). An Analysis of Students' Error in Learning Mathematical Problem Solving: The Perspective of David Kolb's Theory. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, *12*(1), 139–150. https://doi.org/10.16949/turkbilmat.753899

Yılmaz, N., & Ay, Z. S. (2016). Investigation of 8th Grade Students' Knowledge and Skills about Histogram. *Elementary Education Online*, *15*(4), 1280–1298. https://doi.org/10.17051/io.2016.66174

Zeuch, N., Förster, N., & Souvignier, E. (2017). Assessing Teachers' Competencies to Read and Interpret Graphs from Learning Progress Assessment: Results from Tests and Interviews. *Learning Disabilities Research & Practice*, *32*(1), 61–70. https://doi.org/10.1111/ldrp.12126