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Reflective Abstraction of Students of Middle School with Disabilities in Solving Mathematical Problems

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ABSTRACT

The ability to identify, reflect, and generalize mathematical concepts from previous learning experiences into new situations is known as reflective abstraction. This study intends to examine the reflective abstraction process carried out by students with disabilities in solving mathematical problems. This research is a qualitative study that employs a descriptive approach. This study involved two students with hearing impairments who were purposively selected at the middle school level in Branjangan, Jember. Data were collected through observations, interviews, and supporting documents related to the mathematical problem-solving process. The results of the study show that this reflective abstraction process varies depending on the type of disability and the students' learning experiences. Factors such as teacher support, the use of visual aids, and previous learning experiences play a significant role in student success. This study offers explanations for how students with disabilities develop their understanding and highlights the importance of adaptive and inclusive learning approaches to support them. We hope that these findings will serve as a foundation for the creation of more inclusive learning strategies, especially in teaching.

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1. INTRODUCTION

We can address questions related to various disciplines and study potential solutions in the field of mathematics education (Ernest et al., 2016). Mathematics education is a field of study related to mathematics learning, teaching, and research (Balila et al., 2023). Both students and adults consider mathematics to be the most difficult subject (Ningsih et al., 2022). Because mathematics is a field of science that can cover all fields, including education (Maya et al., 2019). For effective mathematics teaching, various approaches and strategies must be used to help students understand the material (Roesken-Winter et al., 2021; Putra et al. 2023). The goal of mathematics education is to teach students how to solve problems. Students will benefit more from learning mathematics if they can understand the concepts they have learned related to everyday life (Lutfiyah et al., 2019). NCTM states that problem solving is one of the standards of school mathematics (Piñeiro et al., 2022).

Van de Walle describes problem solving as a material learning process that creates an environment in which ideas and skills can be learned (Putri & Santosa, 2015; Calavia et al., 2021). If students have a desire to solve problems that arise from themselves, they will be more motivated and driven (Kaldenberg et al., 2015; Wijnia et al., 2024). Putra et al. (2023) assert that students require the appropriate strategy to effectively solve problems. In other words, Polya describes problem-solving skills as steps or stages of problem-solving, which include four stages: (1) understanding the problem; (2) making a problem-solving plan; (3) implementing the problem-solving plan; and (4) reviewing (Rossydha et al., 2021). In conclusion, teachers must better understand students to improve their problem-solving and problem-solving skills.

Kërënxhi and Gjoci (2017) stated that according to Piaget, there are three levels of abstraction: empirical abstraction, pseudoempirical abstraction, and reflective abstraction. Reflective abstraction is a construction technique that uses existing structures to create new structures. This type of reflective abstraction will be discussed in this study. Reflective abstraction is the ability to generalize, formulate models, and understand mathematical concepts through critical thinking and reflection (Cetin & Dubinsky, 2017). This type of reflective abstraction derives results from the subject's perspective rather than from the object itself. Reflective abstraction focuses on ideas about student actions and activities. Each student faces different levels of difficulty in abstracting. This includes difficulty distinguishing numbers, mathematical symbols, and mathematical propositions.

Rich and Yadav (2020) states that there are four levels of abstraction. The first is recognition, the second is representation, the third is structural abstraction, and the last is structural awareness. In the problem-solving process, the reflective abstraction level is the stage where the problem-solver pays attention to specific concepts. This stage is referred to as the special level. Thus, reflective abstraction means taking what you already know and reorganizing it based on what you learn from new experiences. Therefore, reflective abstraction skills can help students solve mathematical problems (Fuady & Rahardjo, 2019; Sutrisna et al., 2021).

Every child should receive a mathematics education because mathematics is essential for everyday life. This includes children with special needs. Children with developmental disorders or abnormalities that require special care are called children with Special Needs (SN) (Kütük et al., 2021). Hopcan et al. (2023) said that children with special needs are children who are different from ordinary children because they have unique characteristics and types. According to Lutfiyah et al. (2023), children with special needs, also known as SN, have difficulty learning mathematics. SN students learn mathematics only by understanding addition, subtraction, and division (Febriyanti & Nugraha, 2017; Polo-Blanco & González López, 2021). Special Schools (SS) are spread throughout Indonesia, including Jember Regency. Public SS Jember is located in Patrang, Jember Regency. This special learning environment is designed to provide support to students with disabilities so they can develop their skills.

Building upon the explanation above, the researcher is interested in studying the reflective abstraction process used by students with disabilities, especially deaf students, in solving mathematical problems about addition and subtraction in grade VII.

2. METHOD

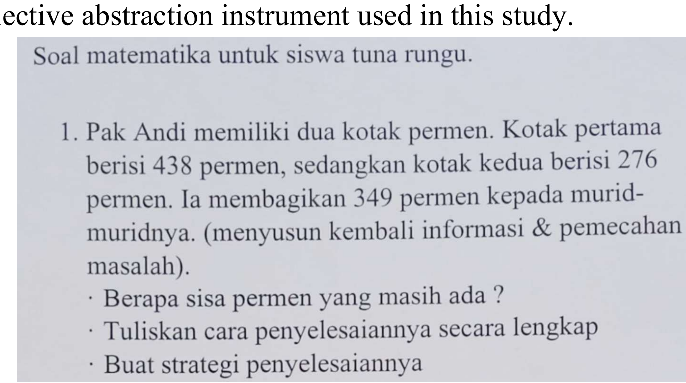
This research employs a qualitative methodology with a descriptive approach. The study was conducted at the public middle school Branjangan Jember. Data sources provided written answers for this study. Two deaf students in grade VII were the data sources for this study. The researcher first discussed the reflective abstraction of the data sources with the mathematics teacher at the school where the test would take place. The purpose of this interview was to determine the students' conditions in solving mathematical problems and whether they had difficulty communicating and interacting with their teachers and friends. After discussing the students' conditions with the mathematics teacher, the researcher administered a test that included specific questions for the students. The researcher interviewed the students to find out how they approached the math problems provided after distributing the test questions. The purpose of this interview was to identify factors that were not visible from the students' written test results.

Discussions with mathematics teachers about the ability of students with disabilities to solve mathematical problems led to the identification of two deaf students in class VII. The following section presents the research indicator code, which can be found in Table 1.

Table 1. Research Indicator Code

Code	Indicator
P1	Introduction
R1	Representation
A1	Structural Abstraction
K1	Structural Awareness

In this study, the following tools were used to explain the reflective abstraction of junior high school students based on their level of reflective abstraction. Figure 1 presents the reflective abstraction instrument used in this study.


Soal matematika untuk siswa tuna rungu.

1. Pak Andi memiliki dua kotak permen. Kotak pertama berisi 438 permen, sedangkan kotak kedua berisi 276 permen. Ia membagikan 349 permen kepada murid-muridnya. (menyusun kembali informasi & pemecahan masalah).
   - Berapa sisa permen yang masih ada ?
   - Tuliskan cara penyelesaiannya secara lengkap
   - Buat strategi penyelesaiannya

Figure 1. Reflective Abstraction Instrument

Additionally, the results of the observations showed that two deaf students were the data sources. Two sources of research data are presented in Table 2 below.

Table 2. Two Sources of Research Data

No	Name Initials	Gender
1.	TY	Female
2.	RF	Male

We provided two data sources for the reflective abstraction test and the interviews. The following is a code to facilitate the presentation of the interview transcripts in Table 3.

Table 3. Research Interview Codes

Code	Description
PTYx	Questions to TY
PRFx	Questions to RF
JTYx	Answers to TY
JRFx	Answers to RF

3. RESULTS AND DISCUSSION

Results

Reflective Abstraction Analysis of TY Data in Solving Mathematical Problems

In this section, we discuss the TY student's work results from Figure 2 on solving mathematical problems.

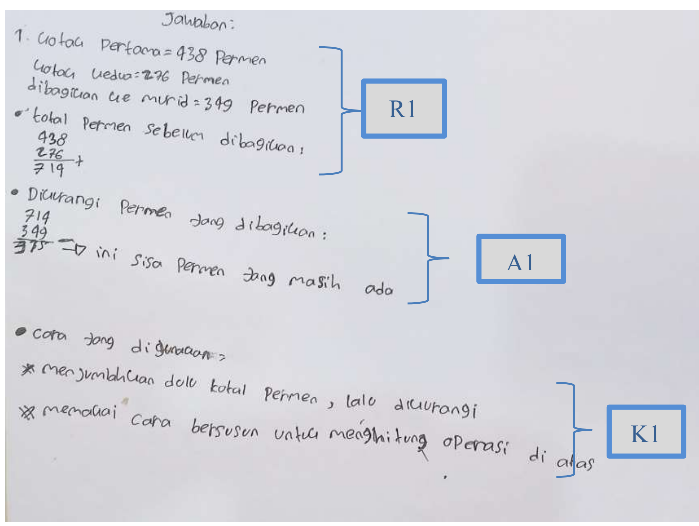


Figure 2. TY Student's Work Results

Data source TY wrote down known information about the given problem, as shown by the answer given by data source TY in Figure 2. TY was also able to read and understand operational symbols well. Next, TY first wrote down the points contained in the story problem, namely the number of candies in the first box, the second box, and the number of candies distributed. The data source explained that performing addition operations in a hierarchical manner simplifies the process, saving time on writing and calculating. Additionally, TY calculated the total number of candies before distribution, namely the number of candies in the first box and the number of candies in the second box, by adding them in a hierarchical manner. After that, TY subtracted the number of candies distributed from the previously calculated total number of candies before distribution and then subtracted the number of candies distributed using hierarchical subtraction.

Data source TY correctly answered question a. The data source was able to translate and transform the data into a mathematical model based on the written answer. As shown in Figure 2, TY solved the problem by first adding up the total number of candies, then subtracting them, then calculating the number of candies before they were distributed and after they were distributed using nested addition and subtraction operations. The data source used nested operations to calculate the remaining candies for the hundreds of digits. By using nested operations, the data source was able to solve problems b and c correctly and provide the correct answers to questions b and c, thus enabling the data source to solve the problem correctly. Next, TY rewrote the new information they learned about the problem, then solved the problem using the answers they had used previously, thus enabling the data source to use the answers they had used before to solve the next problem. The following are the results of interviews from data source TY.

PTY1 : Have you ever solved a problem like this before?
JTY1 : I've done it, sis
PTY2 : Are you having problems working on the questions?
JTY2 : At first, I was a little confused in examining the contents of the questions, but after that I tried to remember it again.
PTY3 : What do you remember from this question?
JTY3 : Calculating addition and subtraction in sequence
PTY4 : Can you restate what is known in the question?
JTY4 : What is known in that question, sis, is that you add up the total number of candies first, then subtract them, so you add up the total number of candies before they are distributed, then subtract the candies that have been distributed.

The TY data sources indicated that they had solved similar problems before (PTY1 & JTY1), remembered them, and could identify the concepts used to solve them (PTY4 & JTY4). They also shared concepts they had previously learned that they could use to solve the problems.

The accompanying teacher was then interviewed about additional problem-solving methods and challenges they faced when solving the problems. Because the TY data source had a hearing impairment, the interview continued with the accompanying teacher of the deaf student in grade VIIC. The accompanying teacher demonstrated additional methods the students used to solve the problems. These practices included using visual aids, such as pictures of candy (PTY5 & JTY5). The accompanying teacher then discussed the problem-solving process. According to the accompanying teacher, the data source had many scribbles because they sometimes forgot the next step. The accompanying teacher received this revelation from the transcript of the interview with the deaf student.

PTY5: Is there another method that TY data sources typically use to solve problems like this, ma'am?

JTY5: For another method, students have been taught to use visualization using pictures, but that method is used for addition and subtraction of small numbers, ma'am. Previously, students would scribble. I believe the teacher uses this method to incorporate visual aids, such as pictures of candy or real objects. Then, the symbols can be shown with hands or number cards. To show subtraction, they can pick up objects.

PTY6: Do students experience difficulties solving problems this way, ma'am?

JTY6: For deaf students, because they have limited communication skills, such as speaking or asking questions to their teachers and peers, when working on problems involving hundreds, like the one above, it seems they are having difficulties, ma'am. Using visual aids or pictures, as the teacher has taught them, is easier for addition and subtraction operations down to tens, ma'am, as previously learned.

PTY7: So, how do you overcome these difficulties, ma'am?

JTY7: By using short and clear verbal language, using visual displays, and repeating the material at the end of the class for addition and subtraction material with hundreds of nominals, it is easier for deaf students to use stacked operations, Miss, such as when students work on the questions above, and in the previous meeting students had been taught to use stacked operations.

Next, excerpts from interview transcripts from TY's data sources are presented. The data sources provide rationale for the methods used to solve the problems. They tend to use the concept of nested addition and subtraction operations rather than using visual aids or visualizations.

PTY8: Well, the supervising teacher said there was another way, so why did you use this method?

JTY8: Because, if you use that method, it's hard to imagine and calculate, because the problem above is in the hundreds, so it's not easy to find the result, bro.

1. Understanding the Problem: The TY data source is able to understand the meaning of the word problem and identify important information.
2. Planning a Solution: The TY data source demonstrates logical planning strategies, such as selecting the appropriate mathematical operation (addition/subtraction).
3. Executing the Plan: The TY data source can calculate correctly using pictorial and symbolic representations.\
4. Rechecking: The TY data source demonstrates reflection by evaluating their own answers.

The results of the study show that reflective abstraction in TY data sources develops gradually and is greatly influenced by the ability to understand language (including sign language) as well as the concrete experience of the data source.

Reflective Abstraction Analysis of RF Data in Solving Mathematical Problems

In this section, we discuss the RF student's work results from Figure 3 on solving mathematical problems.

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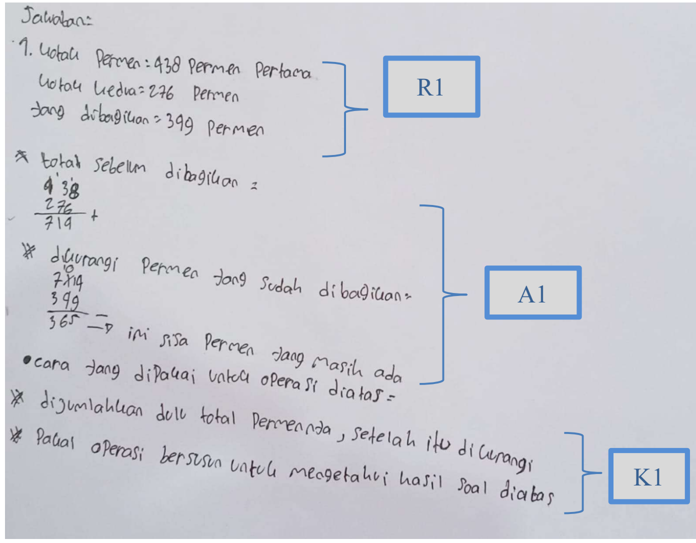

Figure 3. RF Student Work Results

The RF data source wrote down the known information about the problem, as shown in their answer in Figure 3. They were also able to read and understand operational symbols well. Next, they first wrote down the known points in the story problem: the number of candies in the first box, the number of candies in the second box, and the number of candies distributed. They explained that using nested addition simplifies the work because it requires less time to write and calculate. Next, they calculated the total number of candies before distribution: the number of candies in the first box and the number of candies in the second box, by adding them together. They then subtracted the number of candies distributed from the previously calculated total before distribution and then subtracted the number of candies distributed using nested subtraction. They correctly answered problem a.

In their written answer, they demonstrated their ability to translate and transform data into mathematical models. The RF data source solved the problem by first adding, as shown in Figure 3, the total number of candies, then subtracting, then calculating the number of candies before and after distribution using nested addition and subtraction operations. The data source used nested operations to calculate the remaining candies for the hundreds of digits. By using nested operations, the data source was able to correctly solve problems b and c, thus enabling the data source to solve the problem properly. Furthermore, the RF data source rewrote the new information they learned about the problem using their previous solutions, allowing the data source to use their previous solutions for the next problem. We present the results of our interview with the RF data source here.

PRF1 : Have you ever done this problem before?
JRF1 : Already
PRF2 : What do you remember?
JRF2 : The story problem above uses stacked operations because the nominal value is hundreds, so it's easier.
PRF3 : Is the method the same as before?

JRF3 : Yes, same
PRF4 : What's the same??
JRF4 : First write down what is known in the problem and then use nested operations to calculate it.
PRF5 : Can you explain again what is known in the question?
JRF5 : What is known in the question is the number of boxes of candy in the first place, then the total number of boxes of candy in the second place, and the number of candies distributed.

Based on the interview results, it was discovered that the RF data sources reported having solved similar problems before (PRF1 & JRF1). The data sources recalled previously solved problems. Thus, the RF data sources were able to identify ideas to use to solve the problems (PRF5 & JRF5). Previously learned concepts were communicated through the data sources and could be used to solve the problems.

The RF data sources were then asked about additional problem-solving methods and any issues that arose during the process. The RF data sources were able to explain additional methods (PRF6 & JRF6), unlike the TY data source, which experienced communication issues during the interview. The RF data sources also indicated that they had difficulty solving the problem, specifically due to forgetting the next steps, as shown in the following interview transcript excerpt.

PRF6: Did you use a new method to solve this problem? JRF6: I don't think there's a new method, because the previous method I used for this problem would be difficult, because the numbers involved hundreds.
PRF7: Did you have any difficulties solving the problem?
JRF7: Yes, I was a bit confused about the meaning of the problem. So it took me a while to solve it.
PRF8: How did you overcome that difficulty?
JRF8: I read the problem several times, carefully studied the contents, and then tried to work on what I knew first.

Next, we present excerpts from RF data sources that provide arguments for problem solving.

PRF9: Is there a different approach?
JRF9: I don't think there is another way, because the previous method I used, which involved visualization using images or real objects, was for addition and subtraction operations involving small amounts, and I believe it would be difficult to use for problems like the one above, where the amounts are in the hundreds.

The interview results indicate that the RF data source can provide reasons for problem solving. The evidence indicates that the data source can provide arguments about problem-solving methods. Research data reveals that deaf students use reflective abstraction to solve mathematical problems.

1. Understanding the Problem: The RF data source can understand the meaning of the word problem and identify important information.

2. Planning a Solution: The RF data source demonstrates logical planning strategies, such as selecting the appropriate mathematical operation (addition/subtraction).
3. Executing the Plan: The RF data source can calculate correctly using pictorial and symbolic representations.
4. Rechecking: The RF data source demonstrates reflection by evaluating their own answers.

The results of the study indicate that reflective abstraction in the RF data source develops gradually and is strongly influenced by the ability to understand language (including sign language) and the students' concrete experiences.

Discussion

Reflective Abstraction of TY Data Sources in Solving Mathematical Problems

At the recognition level, the TY data source can recall previous actions related to the current problem. The data source indicates if the current problem differs from previous problems. Furthermore, the data source states what factors make this problem different from previous problems. Additionally, the data source can identify various ideas, which include visualization concepts, imagining images or objects, using numerical images for calculations, and applying stacking operations. The data source selects the stacking operation concept used to solve the problem. This aligns with Verschaffel et al.'s (2020) opinion that students will demonstrate basic concepts when they encounter problems.

At the representation level, the TY data source is able to translate and transform problem data into mathematical models. According to Montenegro et al. (2018), at the representation level, students can convey their thinking through mathematical symbols, images, or tables relevant to the problem. Previous research indicates that the data source can convey their ideas in mathematical symbols, providing known data about the variable problem.

At the structural abstraction level, the TY data source is able to write down the results of previous representations and solve the problem. The data source can use nested operations to ascertain the outcomes of addition and subtraction as a result of their labor. Furthermore, the data source can overcome difficult problems by reading the problem repeatedly to understand it. This conclusion is in line with the opinion of Sterner et al. (2019), which states that at the structural abstraction level, students solve problems given by using the results of previous representations.

At the structural awareness level, the data source (TY) is able to provide arguments for the problem-solving process already carried out. The data source supports its answer by using the concept of nested operations, starting with a record of what is already known about the problem. Furthermore, the data source's answer serves as a tool for solving subsequent problems. The data source can use existing solutions to solve new problems. Students' structural awareness, as noted by Greeno (2017) and Ulia et al. (2021), helps them understand the answers they have worked out.

Reflective Abstraction of RF Data Sources in Solving Mathematical Problems

At the recognition level, the RF can recall previous actions related to the problem at hand. It indicates whether the current problem differs from previous problems. Furthermore, the data source identifies factors that differentiate this problem from previous ones. Furthermore, the data source can identify various ideas used, which range from visualization—such as imagining an image or object—to using numerical images for calculations and stacking operations. Students choose stacking operations to solve problems. This aligns with Cevikbas and Kaiser's (2022) opinion that students demonstrate basic concepts when they encounter problems.

At the representation level, the RF data source can translate and transform problem data into mathematical models. According to Hatisaru (2020), students can express their thinking at the representation level using mathematical symbols, images, or tables relevant to the problem at hand. Previous research indicates that the data source could convey its thinking in mathematical symbols, representing known information about the variable problem.

At the structural abstraction level, the RF data source can write down the results of previous representations and solve problems. The RF data source can use nested operations to ascertain the outcomes of addition and subtraction as a result of their efforts. Furthermore, the data source can overcome difficult problems by reading the problem repeatedly to understand it. According to Djasuli et al. (2017) and Bachtiar & Susanah (2021), students solve problems based on previous representations by using structural abstraction.

The RF data source can offer justifications for the previously completed problem-solving procedure at the structural awareness level. The data source provides arguments for students' responses by using the concept of nested operations, starting with writing down what is known about the problem. Furthermore, the RF data source can use the resulting solution to solve the next problem. The data source can use previously used solutions to solve new problems. Greeno (2017) found that students at the structural awareness level assist in understanding the reasoning behind their answers.

With these abilities, deaf students in this category have demonstrated a mature form of reflective abstraction and are able to think mathematically independently and reflectively. This demonstrates that with the right approach and support, deaf students can develop higher-level mathematical thinking skills.

4. CONCLUSION

The study's conclusions show that deaf students can use concepts, whether used or not, to solve problems at the recognition level. Furthermore, deaf students can recall types of problems they have previously solved, which are different from the problems they are currently solving. At the representation level, students use mathematical models to write information on answer sheets. At the structural abstraction level, deaf students can solve problems and create new ways to do so. They are also able to address the source of difficulties by reading about the problem repeatedly. At the structural awareness level, deaf students can provide arguments about their problem-solving process. Furthermore, students can apply their solutions to subsequent problems.

Deaf students who can understand and apply Polya's problem-solving indicators and demonstrate progress at the reflective abstraction levels have strong potential in solving story-based math problems. Furthermore, students can understand the problem comprehensively, identify important information in the story problem, and choose the appropriate mathematical operation. They are able to plan and execute a logical solution strategy using appropriate visual representations, such as pictures or mathematical symbols. At the abstraction level, these students have achieved: Recognition: Connecting the problem context to real-life experiences. Representation: Creating visual images or symbols to facilitate problem understanding. Structural Abstraction: Able to generalize the structure of various problems into mathematical symbolic form. Structural Awareness: Demonstrating conceptual understanding, namely being able to explain why a particular strategy is used, not just how to solve it.

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