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

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ABSTRACT

Reflective abstraction refers to the capacity to recognize, contemplate, and generalize mathematical concepts from prior learning experiences to new contexts. This study seeks to investigate the reflective abstraction process employed by students with disabilities in resolving mathematics problems through a descriptive qualitative methodology. This study included two junior high school pupils with hearing problems who were intentionally recruited. Data were gathered via observations, interviews, and relevant documents pertaining to the mathematical problem-solving process. This reflective abstraction process differs based on the type of disability and the learning experiences of the pupils. Elements such as educator assistance, the utilization of visual aids, and prior learning experiences significantly influence student achievement. This study elucidates the development of understanding among students with disabilities and underscores the significance of adaptive and inclusive learning methodologies to facilitate their assistance. These findings are anticipated to serve as a foundation for the creation of more inclusive educational practices, especially in instruction.

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1. INTRODUCTION

We can explore inquiries pertaining to other fields and examine potential solutions within the realm of mathematics education (Ernest et al., 2016). Mathematics education encompasses the study of mathematics learning, instruction, and research (Balila et al., 2023). Students and adults alike regard mathematics as the most challenging subject (Ningsih et al., 2022). Mathematics is a scientific discipline that encompasses all domains, including education (Maya et al., 2019). Effective mathematics instruction necessitates the utilization of several methodologies and tactics to facilitate student comprehension of the subject matter (Roesken-Winter et al., 2021; Putra et al., 2023). The objective of mathematics education is to instruct pupils in problem-solving techniques. Students will derive greater benefits from mathematics education if they comprehend the concepts in relation to real-life applications (Lutfiyah et al., 2019). The

NCTM asserts that problem solving constitutes one of the standards of classroom mathematics (Piñeiro et al., 2022).

Van de Walle characterizes problem solving as a substantive learning process that fosters an environment conducive to the acquisition of ideas and skills (Putri & Santosa, 2015; Calavia et al., 2021). Students that possess a desire to address self-generated challenges will exhibit heightened motivation and drive (Kaldenberg et al., 2015; Wijnia et al., 2024). Putra et al. (2023) contend that students necessitate the suitable method to proficiently resolve challenges. Polya delineates problem-solving skills as a series of steps or stages, comprising four distinct phases: (1) Comprehending the issue; (2) formulating a problem-solving strategy; (3) executing the problem-solving strategy; and (4) evaluating (Rossydha et al., 2021). In conclusion, educators must enhance their comprehension of kids to augment their problem-solving abilities.

Kërënxhi and Gjoci (2017) asserted that, per Piaget, there exist three tiers of abstraction: empirical abstraction, pseudoempirical abstraction, and reflective abstraction. Reflective abstraction is a construction methodology that employs pre-existing frameworks to generate novel structures. This study will examine this form of reflective abstraction. Reflective abstraction refers to the capacity to generalize, construct models, and comprehend mathematical concepts through critical analysis and reflection (Cetin & Dubinsky, 2017). This form of reflective abstraction generates outcomes based on the subject's viewpoint rather than the item itself. Reflective abstraction emphasizes concepts regarding student behaviors and engagements. Every student encounters varying degrees of difficulty with abstraction. This encompasses challenges in differentiating integers, mathematical symbols, and mathematical propositions.

Rich and Yadav (2020) assert that four layers of abstraction exist. The initial element is recognition, the subsequent is representation, the third is structural abstraction, and the last is structural awareness. In the problem-solving process, the reflective abstraction level is the phase in which the problem-solver focuses on particular concepts. This phase is designated as the exceptional level. Reflective abstraction entails restructuring existing knowledge in light of insights gained from fresh experiences. Consequently, reflective abstraction abilities can assist students in resolving mathematical difficulties (Fuady & Rahardjo, 2019; Sutrisna et al., 2021).

All children ought to obtain a maths education, as mathematics is fundamental for daily living. This encompasses youngsters with unique needs. Children with developmental problems or abnormalities necessitating specialized care are referred to as children with Special Needs (SN) (Kütük et al., 2021). Hopcan et al. (2023) stated that children with special needs differ from typical children due to their distinctive traits and classifications. Lutfiyah et al. (2023) assert that children with special needs (SN) encounter challenges in learning mathematics. Students with special needs acquire mathematical knowledge solely through comprehension of addition, subtraction, and division (Febriyanti & Nugraha, 2017; Polo-Blanco & González López, 2021). Special Schools (SS) are distributed over Indonesia, including Jember Regency. Public SS

Jember is situated in Patrang, Jember Regency. This specialized educational setting is intended to assist individuals with disabilities in enhancing their talents.

The researcher aims to investigate the reflective abstraction process employed by students with disabilities, particularly deaf students, in resolving mathematics problems related to addition and subtraction in seventh grade.

2. METHOD

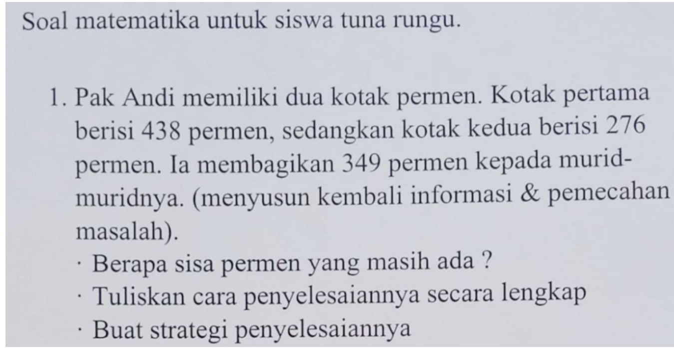
This study utilizes a qualitative methodology characterized by a descriptive approach. The research was carried out at Branjangan Jember Public Middle School. This study utilized written responses from data sources. This study utilized two deaf kids in seventh grade as data sources. The researcher initially examined the reflective abstraction of the data sources with the mathematics instructor at the school where the assessment was scheduled to occur. The objective of this interview was to assess the students' abilities in solving mathematical problems and to evaluate any challenges they faced in communicating and interacting with their teachers and peers. Following a discussion of the students' circumstances with the mathematics instructor, the researcher conducted a test with targeted questions for the students. The researcher conducted interviews with the students to ascertain their methods for tackling the arithmetic problems presented following the distribution of the exam questions. The objective of this interview was to discern factors that were not apparent from the students' written test outcomes.

Conversations with mathematics educators regarding the problem-solving capabilities of kids with impairments resulted in the identification of two deaf pupils in seventh grade. The subsequent section delineates the research indication code, as detailed 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.

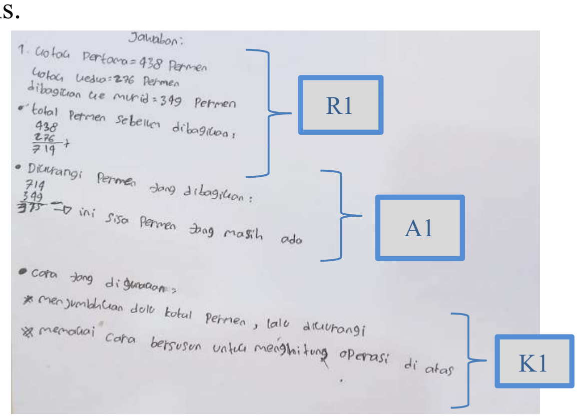


Figure 2. TY Student's Work Results

Source of data TY documented the known facts on the specified problem, as evidenced by the response provided by data source TY in Figure 2. TY demonstrated proficiency in reading and comprehending operational symbols. Subsequently, TY initially recorded the details outlined in the story problem, namely the quantity of candy in the first box, the second box, and the amount of candies distributed. The data source indicated that executing addition operations hierarchically streamlines the process, hence conserving time on both writing and computation. Furthermore, TY computed the aggregate quantity of candies prior to distribution by summing the contents of the first and second boxes in a systematic manner. Subsequently, TY deducted the quantity of candy delivered from the previously computed total and then applied hierarchical subtraction to further reduce the amount of distributed candies.

The data source TY accurately responded to question a. The data source successfully translated and transformed the data into a mathematical model derived from the textual response. As illustrated in Figure 2, TY addressed the problem by initially aggregating the entire number of candies, subsequently deducting them, and finally determining the quantity of candies before to and following distribution through layered addition and subtraction operations. The data source employed nested processes to compute the remaining candies for the hundreds of digits. Through the application of nested processes, the data source successfully resolved problems b and c, thereby delivering accurate answers to questions b and c, which facilitated the right resolution of the overall problem. Subsequently, TY reformulated the newly acquired information regarding the issue and resolved the problem utilizing previously employed replies, so allowing the data source to apply those prior solutions to address the subsequent difficulty. The subsequent results pertain to interviews conducted 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 demonstrated prior resolution of analogous issues (PTY1 & JTY1), retained the memory of these instances, and could recognize the concepts employed in their resolution (PTY4 & JTY4). They also conveyed previously acquired notions applicable to problem-solving.

The accompanying teacher was subsequently interviewed regarding supplementary problem-solving strategies and the difficulties encountered when addressing the issues. Due to the hearing disability of the TY data source, the interview proceeded with the accompanying teacher of the deaf student in grade VIIC. The supervising teacher illustrated supplementary techniques employed by the students to resolve the issues.

These methods involved employing visual aids, including images of confectionery (PTY5 & JTY5). The supervising educator subsequently addressed the problem-solving methodology. The teacher indicated that the data source contained numerous scribbles due to occasional lapses in recalling the subsequent step. The supervising instructor obtained this insight from the interview transcript with the deaf pupil.

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.

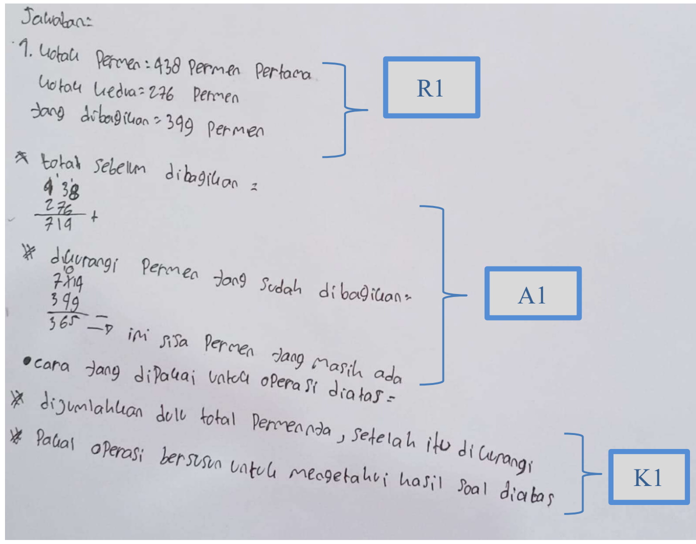


Figure 3. RF Student Work Results

The RF data source documented the pertinent facts regarding the issue, as illustrated in their response in Figure 3. They demonstrated proficiency in reading and comprehending operational symbols. Subsequently, students initially recorded the known variables in the narrative problem: the quantity of candy in the first box, the quantity of candies in the second box, and the quantity of candies distributed. They elucidated that employing layered addition streamlines the process as it necessitates reduced time for both writing and computation. Subsequently, they computed the aggregate quantity of sweets prior to distribution by summing the number of candies in the first box with those in the second box. They subsequently deducted the quantity of candy supplied from the previously computed total prior to distribution, employing layered subtraction for the calculation. They accurately resolved problem a.

In their written response, they exhibited their capacity to convert and manipulate facts into mathematical models. The RF data source addressed the issue by initially aggregating the total number of candy, as illustrated in Figure 3, subsequently performing subtraction, and finally computing the quantity of candies before and after distribution through layered addition and subtraction processes. The data source employed nested processes to compute the remaining candies for the hundreds of digits. Through the application of nested processes, the data source effectively resolved difficulties b and c, hence facilitating the accurate resolution of the overall problem. Moreover, the RF data source reformulated the newly acquired information regarding the issue by employing their prior solutions, hence enabling the data source to utilize these earlier answers for subsequent problems. We provide the findings of our interview with the RF data source herein.

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.

The interview results revealed that the RF data sources indicated prior resolution of analogous issues (PRF1 & JRF1). The data sources referenced previously resolved issues. Consequently, the RF data sources successfully identified concepts to address the issues (PRF5 & JRF5). Previously acquired notions were conveyed via the data sources and may be employed to address the issues.

The RF data sources were thereafter inquired about supplementary problem-solving techniques and any challenges encountered during the procedure. The RF data sources elucidated supplementary approaches (PRF6 & JRF6), in contrast to the TY data source, which had communication difficulties throughout the interview. The RF data sources reported challenges in resolving the issue, particularly due to lapses in recalling subsequent procedures, as seen by the following excerpt from the interview transcript.

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 retrieve prior activities pertinent to the current issue. The data source indicates whether the current issue varies from prior issues. Moreover, the data source delineates the variables that distinguish this issue from prior ones. Furthermore, the data source may discern a range of notions, including visualization ideas, mental imagery of objects, numerical representations for computations, and the implementation of stacking processes. The data source determines the stacking operation concept employed to address the issue. This corresponds with the perspective of Verschaffel et al. (2020) that pupils will exhibit fundamental concepts when faced with issues.

The TY data source can convert and reformulate issue data into mathematical models at the representation level. Montenegro et al. (2018) assert that, at the representation level, students can articulate their reasoning using mathematical symbols, visuals, or tables pertinent to the topic. Prior research suggests that the data source can express their concepts using mathematical symbols, offering established information regarding the variable issue.

At the structural abstraction level, the TY data source can document the outcomes of prior representations and address the issue. The data source can employ layered operations to determine the results of addition and subtraction from their efforts. Moreover, the data source can resolve complex issues by analyzing the problem iteratively for comprehension. This conclusion aligns with the perspective of Sterner et al. (2019), which asserts that at the structural abstraction level, students address problems by utilizing the outcomes of prior representations.

At the structural awareness level, the data source (TY) can furnish justifications for the previously executed problem-solving process. The data source substantiates its response by employing the principle of nested operations, commencing with a record of existing knowledge regarding the issue. Moreover, the response from the data source functions as an instrument for addressing later issues. The data source can leverage existing technologies to address novel challenges. Students' structural awareness, as seen by Greeno (2017) and Ulia et al. (2021), facilitates their comprehension of the solutions they have derived.

Reflective Abstraction of RF Data Sources in Solving Mathematical Problems

At the recognition level, the RF can retrieve prior activities pertinent to the issue at hand. It signifies whether the present issue diverges from prior issues. Moreover, the data source delineates variables that distinguish this issue from prior ones. Moreover, the data source can discern a variety of concepts employed, encompassing visualization—such as envisioning an image or object—and the utilization of numerical representations for computations and stacking operations. Students select stacking operations to resolve difficulties. This corresponds with Cevikbas and Kaiser's (2022) assertion that kids exhibit fundamental notions when faced with challenges.

At the representation level, the RF data source can convert and modify issue data into mathematical models. Hatisaru (2020) asserts that students can articulate their reasoning at the representation level through the use of mathematical symbols, visuals, or tables pertinent to the topic presented. Prior study suggests that the data source may articulate its reasoning through mathematical symbols, encapsulating established knowledge on the variable issue.

At the structural abstraction level, the RF data source can document the outcomes of prior representations and address issues. The RF data source can employ nested processes to determine the results of addition and subtraction. Moreover, the data source can resolve complex issues by analyzing the situation repeatedly for comprehension. Djasuli et al. (2017) and Bachtiar & Susanah (2021) assert that students resolve difficulties through structural abstraction derived from prior representations.

The RF data source can provide rationales for the previously executed problem-solving process at the structural awareness level. The data source presents rationale for students' responses through the use of nested operations, commencing with the documentation of known information regarding the problem. Moreover, the RF data source can utilize the resultant solution to address the subsequent issue. The data source can employ previously utilized strategies to address new challenges. Greeno (2017) discovered that pupils at the structural awareness level facilitate comprehension of the rationale underlying their responses.

Deaf children in this group have a sophisticated level of reflective abstraction, enabling them to engage in independent and reflective mathematical thinking. This illustrates that with appropriate strategies and assistance, deaf kids may cultivate advanced mathematical reasoning abilities.

4. CONCLUSION

The study's findings indicate that deaf students can employ concepts, regardless of their prior usage, to address challenges at the recognition level. Moreover, deaf pupils can remember the types of difficulties they have previously resolved, which differ from the challenges they are presently addressing. Students employ mathematical models to record information on response sheets at the representation level. At the level of structural abstraction, deaf students are capable of problem-solving and devising innovative methods. They can also tackle the root of challenges by repeatedly studying the issue. Deaf pupils can articulate their problem-solving process at the structural awareness level. Moreover, students can implement their solutions to subsequent challenges.

Deaf pupils that comprehend and utilize Polya's problem-solving indications, and exhibit advancement at the reflective abstraction stages, possess significant potential in resolving story-based mathematical issues. Moreover, students may grasp the topic thoroughly, discern critical information inside the narrative, and select the suitable mathematical operation. They can devise and implement a rational solution strategy utilizing suitable visual representations, such images or mathematical symbols. At the level of abstraction, these kids have attained: Recognition: Relating the problem context to practical experiences. Representation: The creation of visual representations or symbols to enhance comprehension of problems. Structural Abstraction: Capable of generalizing the framework of diverse problems into mathematical symbolic representation. Structural Awareness: Exhibiting conceptual comprehension, specifically the ability to elucidate the rationale behind a given technique, rather than only detailing the method of solution.

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