MATHE*dunesa*
Jurnal Ilmiah Pendidikan Matematika *Volume 11 No.3 Tahun 2022*
ISSN :2301-9085

LOW VISION STUDENT ERRORS IN SOLVING AREA AND CIRCUMFERENCE OF PLANE FIGURES PROBLEMS AND ITS ALTERNATIVE SOLUTIONS

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Abstrak

Matematika tidak sedikit menggunakan representasi visual, salah satunya pada materi geometri. Penginderaan visual sangat berperan dalam menangkap informasi matematis berupa objek geometris. Hal ini berimbas pada siswa low vision dalam memahami dan menguasai materi tersebut. Tujuan dari penelitian ini adalah untuk menguraikan kesalahan yang dialami siswa low vision dalam menyelesaikan permasalahan menentukan luas dan keliling bangun datar disertai dengan alternatif solusinya. Penelitian ini merupakan penelitian studi kasus intrinsik dengan pendekatan kualitatif. Subjek pada penelitian kali ini adalah seorang siswa low vision dengan perkembangan kognitif normal. Teknik pengambilan data menggunakan tes dan wawancara. Tes yang digunakan tersusun dari dua masalah kompleks dan dua masalah sederhana. Analisis data untuk menentukan kesalahan siswa dideskripsikan dengan analisa kesalahan Newman. Hasil penelitian menunjukkan siswa tidak mengalami kesulitan dalam membaca, namun mengalami kesalahan utama dalam menentukan langkah penyelesaian untuk suatu masalah (*transformation errors*). Kesalahan dalam memahami konteks (*comprehension errors*) masalah sering terjadi ketika siswa dihadapkan dengan permasalahan kompleks. Kesalahan lain terjadi pada perhitungan (p*rocess skill errors*) dan menuliskan hasil akhir (*encoding errors*). Menindak lanjuti hasil penelitian ini, maka guru dapat merencanakan kegiatan pembelajaran matematika untuk siswa low vision secara umum dengan menggunakan metode dan media yang tepat dan bervariasi.
Kata Kunci: kesalahan siswa, *low vision*, geometri.

Abstract

Mathematics uses a lot of visual representations, one of which is geometry. In capturing mathematical information, visual sensing plays a very important role. This has an impact on low vision students in understanding and mastering the material. This study is interested to describe errors experienced by a low vision student in solving the problem of determining the area and circumference of plane figures and its alternative solutions. This research was an intrinsic case study research with a qualitative approach. The subject in this study was an individual that is a low vision student with normal cognitive development. Data collection techniques were using tests and interviews. The test used was composed of two complex problems and two simple problems. Data analysis to determine student errors was described by using Newman's error analysis. The results showed that students did not have difficulty in reading, but experienced major errors in determining the completion steps for a problem (transformation errors). Errors in understanding the context (comprehension errors) problems often occur when students are faced with complex problems. Other errors occur in the calculation (process skill errors) and writing the final result (encoding errors). Based on the results of this study, the teacher can plan mathematics learning activities for low vision students in general by using appropriate and varied learning methods and media.
Keywords: student errors, low vision, geometry.

INTRODUCTION

Mathematics is a compulsory subject taught at every school level, including special schools. Mathematics is an abstract and deductive science. Many branches of mathematics require visualization to represent the material. That makes mathematics teaching sometimes need spatial abilities (Riastuti, 2017). One of the basic materials in mathematics that uses a lot of visual representations is geometry, including the material of plane figures. Difficulties in understanding geometric objects will lead to student errors in solving geometric problems.

The demand for spatial ability in understanding mathematics causes visual-impaired students to have difficulty understanding the material due to limited sensing to identify objects (Leo, 2017). Riastuti (2017) in her article uses five factors for measuring students' spatial intelligence, i.e., spatial perception, visualization, mental rotation, spatial relations, and spatial orientation. Riastuti (2017) states that there is a correlation between spatial intelligence and the ability to solve geometric problems. So, if students' spatial intelligence abilities are low, students will tend to experience errors in solving geometric problems. Although eye abnormalities aren't necessarily reducing students' ability to capture and process visual information, visual-impaired students tend to encounter decreased spatial memory (Leo, 2017). Leo (2017) asserts that learning geometry for visual-impaired students will be more difficult because of the reduced understanding of many spatial concepts, especially for congenital visual-impaired students.

Generally, special education is a form of adaptive education that can adapt to the needs of each student when they cannot adapt to the methods applied to conventional education (Cheng & Lai, 2020). Cheng implies that every student with special needs has different needs. So, to ensure students with special needs receive learning well, it is necessary to maintain variety in learning. That is proven empirically by the many studies on the effect of media or teacher teaching approaches on developing students' abilities with special needs, including visual-impaired students.

Efendi (2017) in his book explains that a child with vision abnormalities does not necessarily qualify as visual-impaired. Children are said to be visual-impaired if they meet certain classifications closely related to the provision of special education services (Efendi, 2017). There are various definitions of the visual-impaired. Visual-impaired can be defined as someone who has a central vision of less than or equal to 6/60 (Efendi, 2017; Ehrlich, 2017). Another definition was a child who is unable to attend regular class despite using optical aids or medication or a child who, if examined more closely, is not possible to use education and teaching facilities like a sighted child. That implies a child who can be assisted by medication programs or optical devices isn't considered a visual-impaired child.

Nisa (2018) defines blindness into three in terms of the eye's ability to catch the image of objects i.e., total blindness, functional blindness, and low vision. This definition of visual impairment is in line with the study of Cruickshank (1980), where the level of visual impairment is viewed from the eye condition regardless of whether the person has comorbidities or other congenital diseases. Nisa (2018) defines that a person who is totally blind can't see at all or has no residual vision, while low vision is those who still have a residual vision that is still functioning (e.g., identifying objects with their remaining vision). From the definitions above, low vision can be defined as a condition of eye disability, in terms of the ability to receive an object image. Significantly, it means that the quantity of light the eye received isn't like a normal eye which is characterized by physical changes in the eye, but those eyes can still be used to identify an object.

Students who experience congenital visual impairment or before the age of five years, including low vision students, will experience object identification problems due to poor reception of visual information (Efendi, 2017). That condition is due to the lack of external visual stimulus input into the visual cortex in their brain, (Maurer et al., 2005, p. 145). This condition causes the visual cortex of visual-impaired students better at processing tactical and auditory input (Cruickshank, 1980).

Visual-impaired students' difficulties in learning mathematics are generally due to two factors, linearity and limitation of the character set that can be formed by combining braille letters, Karshmer (2002, pp. 1–2). Karshmer argues that visual-impaired students can still understand simple equations by using their linear representation, but the higher the problem complexity, the more difficult students to understand the linear representation. The level of complexity in learning is relative and can be caused by the difference between the learning objectives and the level of student understanding or how far the student's ZPD zone is, Shabani (2010, p. 238). The formation of new understanding for students can be obtained through the receipt of information visually. This is reinforced by the results of Safitri's research (2017, p. 12) which states that the use of visual media can assist students in constructing an understanding of certain materials. Receiving information visually will be less optimal for visual-impaired students, especially in the low vision category. These deficiencies have an impact on slow concept formation in visual-impaired students, including low vision, difficulties in understanding the material, to errors in problem-solving.

The conditions experienced by low vision students that can affect learning activities can also have an impact on their performance in understanding geometry material. In general, the factors that lead to material understanding difficulties according to Shah (Dwi & Audina, 2021) were divided into two, internal and external factors. Internal factors in terms of psycho-physical abilities deficiency include the level of cognitive and psychomotor, such as sensing devices. Meanwhile, external factors are more related to the environment around students that doesn't support their learning activities such as the families' treatment, communities, and inadequate conditions of teachers and media. As Nabeel et al (2021) did in their research which examined 100 secondary school students with visual impairments, both total blind and low vision, they had learning difficulties due to external factors, such as the condition of teachers who were less competent in delivering geometry and also the lack of suitable media and also the lack of adequate media in teaching geometry. Difficulties in learning geometry can cause errors in working on geometry problems (Nabeel et al., 2021)This is also supported by student internal factors as written in Ardiantoro's research (2017). He stated that low vision students haven't yet been able to reach level 2, informal deduction (Crowley, 1987), at the Van Hiele thinking level and only up to level 0, visualization (Crowley, 1987), on tactual abilities.

The students' errors in this study were described using Newman’s Error Analysis. Prakitipong (2006) and Clements (1980) describe Newman's Error Analysis as an analysis of errors in solving written problems. The outline of the procedure in Newman's Errors Analysis will focus on the students' ability to understand the mathematical context of the problem and the students' ability to carry out the mathematical calculation process in solving the given problem. This research is slightly different from the research conducted by Newman where the research process is not carried out using a hierarchical system (Newman, 1977).

The data obtained from previous studies that have been presented indicating that the condition of low vision students makes it possible for them to experience disturbances in absorbing information visually. This allows low vision students to have difficulty understanding the area and circumference of a plane figure which then leads to errors when solving related topic problems. Researchers are interested in examining the errors experienced by low vision students in solving problems related to the area and circumference of plane figures which were analyzed using Newman's Analysis Error and presented alternative solutions that were linear with research results.

METHOD

This research is an intrinsic case study with a qualitative approach. The reason for choosing this type of research is based on the limited number of research subjects that can be used. In addition, this type of intrinsic case study research can be used to obtain in-depth information about events experienced by students (Parker, 2016). Cousin (2005) defines an intrinsic case study as part of a case study research that focuses on an existing case, either a particular case or an individual. Cousin's (2005) statement confirms that this research type allows individuals to be used as special subjects to describe more general conditions. This is reinforced by the opinion of Pinnegar and Dayne (2006) who states that using an intrinsic case study can help researchers to explore more in-depth information through the analysis process from a smaller number of units which is then used to describe similar conditions in general. Thus, the results obtained from researching a case will then be generalized to describe the problem in general (Cousin, 2005).

This study examines a first-grade secondary school student with a congenital low vision which can be seen from her remaining visual ability and physical changes in her eyeballs. The selected subject are low vision students who had good arithmetic operations skills. The student was selected from three first-grade secondary school blind students, including both legally blind and low vision. After conducting the trial test, the other two students weren't yet proficient in performing arithmetic operations. Thus, considering the lack of numeracy skills and the recommendation of partner teachers, the two students were not selected as research subjects. The research subject doesn’t experience cognitive issues, so the information obtained verbally can be well received. However, congenital defectivity of the subject in her eyes can affect how the student receives spatial information in the form of geometric shapes and how she orients them. The understanding difficulty of the material is also a challenge in organizing this research. The subject had visual impairment and neither optical aids nor medication could restore visual acuity. The reality in the field shows that the student knows little about the area and circumference of squares and rectangles, so the universe of a plane figure is limited to the area and circumference of squares, rectangles, and a combination of both.

Data collection techniques using tests and interviews. The test for one session includes four problems consisting of two simple problems demanding students' conceptual understanding and two complex problems testing students' reasoning. If the problem were made at the same level of problem difficulty, the result couldn't be analyzed in-depth. Then, the researcher decided to break down the level of difficulty, so the analysis could be carried out in-depth and the tendency of what kind of problem model the students could solve. The problems used in the test are made with the advice of the supervisor and get validation from the partner teacher. The following are examples of questions from each type of question:

Figure 1. Example of Complex Problem

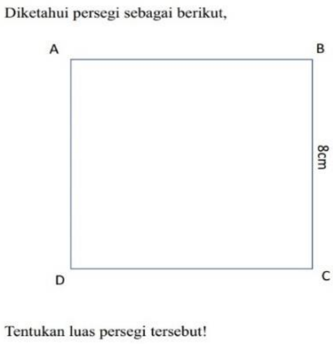

Figure 2. Example of Simple Problem

The interview uses an open-ended interview method with several core questions that represent the five levels of Newman's Error Analysis (Clements, 1980) and with improvisations to add depth of the information in the interview. The following are the core questions used in the interview:

1. Read the questions listed in the text.
2. What is asked in the text.
3. How do you solve the problem.
4. Show what you will do to solve the problem.
5. Write down your answer.

Before organizing the test and interview, the researcher first gave the material to the students for four days to remind them again of the material for the area and circumference of squares and rectangles with the help of partner teachers. The researcher did this because students couldn't recall much about the material, and their understanding of the material was little. Tests and interviews were conducted for five days after the presentation of material to get significant results.

The research was conducted by observing the results of the student's work in solving several problems determining the area and circumference of plane figures and exploring the errors experienced by the student using Newman's Error Analysis. The researcher details the indicators of student errors adopted from the description of Newman's Error Analysis errors by Riatuti (2017) in her article. The indicators of student errors at each level in Newman's Error Analysis (table 1).

Table 1. Indicator of Newman's Error Analysis

Types of level	Error Aspect	Code
Reading Level	Students have difficulty in reading.	RE1
	Students have difficulty understanding the symbols given.	RE2
	Students can't find keywords in the text.	RE3
Comprehension Level	Students can't understand the context of the problem.	CE1
	Students can't explain the question in the text.	CE2
Transformation Level	Students can't determine the appropriate solution steps.	TE1
	Students use inappropriate concepts in solving problems.	TE2
Process Skill Level	Students have a calculation error.	PSE1
	Students experience errors in implementing the problem-solving steps that have been thought of.	PSE2
Encoding Level	Students can't determine the correct solution to the problem.	EE1

The research design for data collection in this study consisted of several stages, i.e: the preparation stage, the implementation stage, and the data management stage. The details of the three stages can be seen in the following flowchart image (Figure 3),

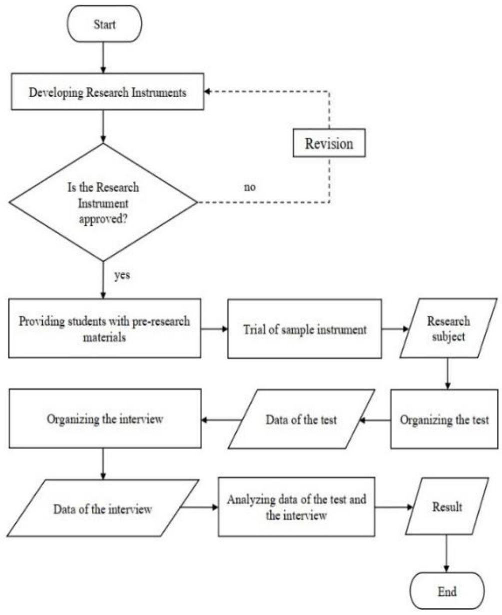

Figure 3. flowchart of research design for data collection

The researcher first conducts a study of the content to be used, discusses it with partner teachers, and asks about students' conditions for the material. After that, data collection was carried out by designing the instrument in advance as shown in the flowchart (figure 3). The researcher then gave material to the three visual-impaired students accompanied by a partner teacher to reintroduce the material for the area and circumference of squares and rectangles. The next step is to try out the sample instrument to get the right subject for this research and continue with a series of data collection.

RESULT

Reading level

The test results showed that the student didn't experience errors at the reading level in both simple and complex problems. The student read the enlarged text by holding it close to their eyes. Although it took a little time, the student could read the text well and sometimes missed information in the text when reading.

Comprehension level

The student begins to show errors at the comprehension level when she is faced with more complex problems. The student could understand some problems by giving them a hint and some aren't. Another factor that is also influential in this case is the reduced level of focus when the student feels stressed. At this level, the student didn't experience errors in simple problems but experienced errors in complex problems. Examples of problems experienced are as follows. The student was given a complex problem in which the student was instructed to write down steps to determine the area of a house's yard (figure 4). Henceforth, in the transcript, "I" stands for the interviewer and "S" for the subject.

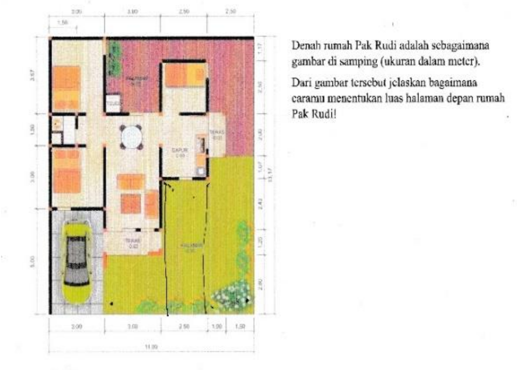

Figure 4. Students dividing the house's yard into some plane figures

I : "Try to read the following text first and pay attention to what is asked in it" – Reading level

S : (reading the whole question)

I : "done reading it? What is asked in the text?" – Comprehension level

S : "I don't understand what is meant, sir" – **An error occurred at this level, CE1**

I : "Try to find out what information is contained in the text" – Directing students to understand the given text

S : "There is a house plan and asked to determine the area of the garden"

I : "Well, from the picture there is a garden of that size. How do you determine the area?" – Transformation Level

S : "I don't know, sir"

I : "So we use the combined area, remember? So, if you see, we can break the shape of the garden into smaller squares or rectangles. Then, to determine the total area, what do we do?

S : "I don't know, sir"

The student at this level can convey what is asked in the question. The error that occurred was that the student doesn't understand the context of the problem given, CE1. The teacher gave direction to the student by directing her to the concept of a combined area. The teacher then gave instructions by dividing the part of the yard of a house into smaller figures. Despite the teacher's assistance, the student couldn't solve the problem and only followed the direction of the teacher, and she divided the yard of a house into several rectangles without knowing the concept she was using.

Transformation level

The main error experienced by the student in this study was at the transformation level. The test results show the student can determine and explain the steps necessary to solve a simple problem. The student has difficulty in this aspect when she is asked to solve more complex problems independently, and she can only solve the problem if she gets guidance from the teacher.

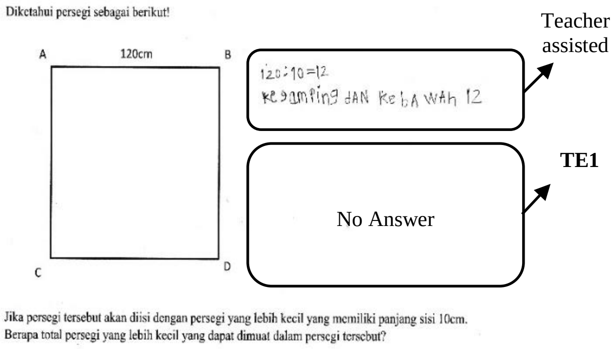

Figure 5. Example of student's transformation error

The student is assisted to determine the elements used to solve problems. Problems that the student can solve independently did not show TE2 category errors. The problem that often arises when the student can't solve the problem is TE1. Researchers guided the student to find elements that could be used to solve problems, but sometimes she couldn't take advantage of the information (Figure 5). With the teacher's assistance, the student could calculate one of the elements that could be used to find the number of small squares that could be inserted into the larger square. However, the student couldn't continue the process in the same way because they didn't understand the concepts used to solve the problem. This indicates the inability of students to solve problems independently for some problems.

Process skill level

The student also experiences errors at the process skill level, both in simple and complex problems, but errors that happen at this stage do not occur often. The errors happen not because of the inability of students to count, but it caused of her psychological condition.

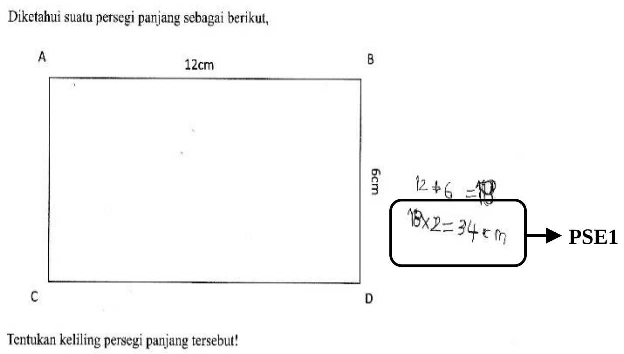

Figure 6. Example of student's calculation error

The student knew the concepts used to solve the given problem (figure 6), and she could work on it independently, but she had a calculation error in this problem, PSE1. The student in this phase did not show any errors in performing calculations in the early minutes. Count errors start to occur when the test time has run long enough. The students lose focus, causing them to be less careful in solving a problem. This error is purely the student's fault because when interviewed the student was convinced of the results of her work.

I : "Next, try to solve the following problem. Please read the text first then find the information in it!" – Reading level

S : (reading the whole question)

I : "done reading it? What is asked in the text?" – Comprehension level

S : "We are asked to determine the circumference."

I : "Then? Can you find more information in the text?"

S : "12 and 6"

I : "What are 12 and 6?"

S : "the length and width"

I : "Then, what should we do?" – Transformation level

S : "Determine the circumference"

I : "How do we determine the circumference?"

S : "Add up the length and width, then multiply it by two"

S : "(students solve the given problem)" – A miscalculation occurred in this section, **PSE1**

I : "Are you sure about your answer?"

S : "Yes, sir"

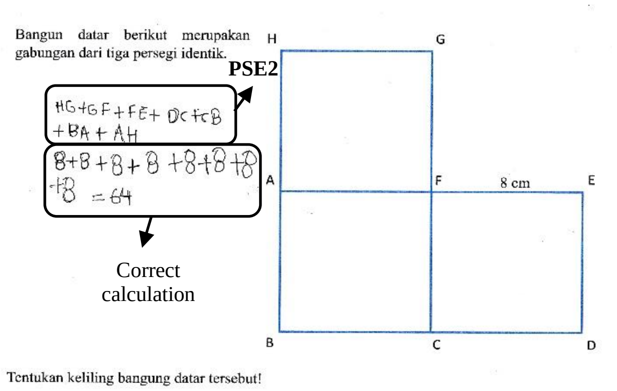

Figure 7. Example of student's problem-solving implementation error

The student on some problems can solve problems with the help of directions even though the writing of the completion steps is not quite right. As in the following problem (figure 7), the student can determine the solution steps to determine the circumference of the combined three identical squares. The student got the correct results, but the student experienced errors because she wasn't careful in writing the answers, PSE2.

Encoding level

The student also experiences errors in encoding level. The majority of student errors are due to a lack of thoroughness and patience. The results of student work indicate the correct answer, but the student often doesn't include or provide the correct notation for the circumference and area units if they are not guided, EE1. This occurs in both simple (figure 8) and complex (figure 9) problems. Errors at the encoding level can also be caused by students' lack of understanding of the material.

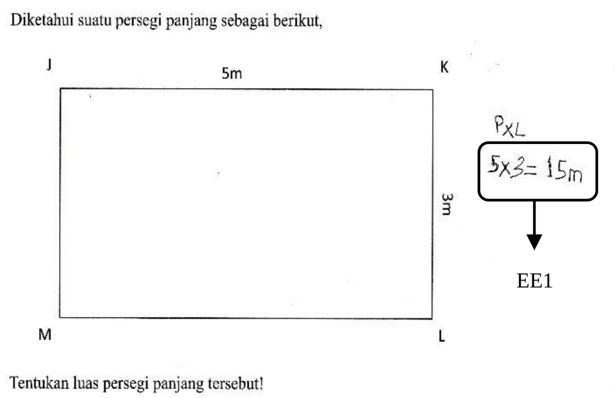

Figure 8. Example of student's encoding error in simple problem

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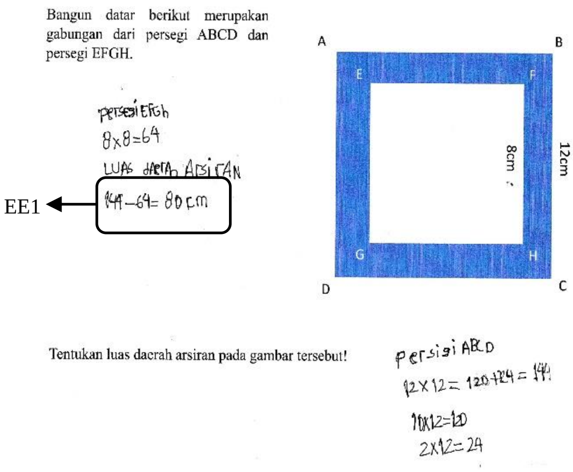

Figure 9. Example of student's encoding error in complex problem

DISCUSSION

From the data of the tests and the interviews, the main problem experienced by students was based on a lack of understanding of the area and circumference of squares and rectangles which caused them to experience errors. From the research, the student can be justified that she experienced the main error at the third level, transformation errors. This is in line with Riastuti's research (2017), where students with visual impairments experienced the most errors at the transformation, process skill, and encoding levels.

These mistakes can be fixed by using a variety of learning methods. This is in line with the opinion of Efendi (2017) in his book regarding the importance of students with disabilities being given different teaching strategies and approaches. The following is a learning method that can be used as a reference:

- The use of Bruner's learning theory in the enactive and rhythmic stages. This was stated by Utami (2015). Students are taught to recognize the concept of a material assisted by concrete media rather than using learning that emphasizes the use of symbols. The same thing in Utami's research was experienced by Ruhimat (2010). Teaching blind students can be assisted with rhythmic movements so that students are not pressured in learning and can make learning more meaningful.
- The use of the SQRQCQ method. The step in the SQRQCQ method is Survey-question-read-question-compute-question. This method was applied by Yundasari (2015) in his research. This method is like a procedure that helps students in solving problems. So by familiarizing students with this method, students are formed habits in solving problems, at least in understanding the context of the problem and finding important information in the text.
- Use of the Van Hiele Method. The Van Hiele method itself is a method in teaching geometry consisting of five stages of learning in Crowley's (1987) writings. This was applied by Indriani (2019) in her research on blind students. In Indriani's research, the learning stages used include visualization where students learn the shape of a plane figure as it is without recognizing the elements and properties of the figures, analysis where students begin to analyze the properties of the shape, and abstraction where students connect the properties of the shape which is known. Indriani's research shows that this method combined with a tactile and linguistic approach can help students develop their understanding of geometry.

The use of learning media in learning assistance that can support the needs of students is very much needed in special education, especially for low vision students (Efendi, 2017; Spindler, 2006). The media created for low vision student learning assistance are generally tactile-based media. There is a finding that the use of a Digital Handled Magnifier and loupe can help low vision students in increasing understanding of the material (Khaeroh et al., 2020). The researcher also found much research on the development of learning media technology for low vision students in the last decade. Like the research conducted by Leo (2017), he examined the effectiveness of the use of tactile graphics presented using a programmable pin-array tactile display on students with various age ranges and levels of visual impairment. The result is that both students with total blindness and low vision experience an increase in their ability to work on spatial problems.

CONCLUSION

The student experiences errors in solving problems related to the area and circumference of plane figures which in this study are limited to squares and rectangles. The errors that occur vary, but the student generally experiences errors when faced with complex problems. Another thing that influences the student to make mistakes is her psychological condition. The student easily feels bored and depressed so she loses focus and has difficulty absorbing information in the text. The student in the study did not experience errors in reading. The student experienced errors at the comprehension level because they did not understand the context of the problem, CE1, but students were still able to understand what was asked in the text. The main errors that the student experiences in the research series are transformation errors, and errors occur because she cannot determine appropriate steps to solve the given problem, TE1. Errors at this level occur due to the student's lack of understanding of the area and circumference of squares and rectangles. Other errors experienced by the student are process skill errors and encoding errors. The student at the process skill level experienced errors in both the calculation, PSE1, and the application of the problem-solving step, PSE2. At the encoding level, the student experienced errors in writing answers in the form of not including notation in the answers. Errors at this level occur because students are less careful in the work process.

The solution to reducing the student's difficulties in understanding the material and the errors she experienced is to plan to learn using relevant and innovative methods or approaches, so the learning process can become meaningful. Another thing that can be done is by procuring supportive learning media. Tactile and auditory-based media are recommended because they are more effectively used in the learning activities of low vision students.

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