E-ISSN: 2579-9258
P-ISSN: 2614-3038

Jurnal Cendekia: Jurnal Pendidikan Matematika
Volume 07, Nomor 02, April - Juli 2023, pp. 1558-1570

Students Error Description and Contributing Factor in Solving TIMSS Geometry Content Domain Problems Based on Their Learning Style

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Abstract

Using Newman Error Analysis (NEA) theory, this study aims to describe the errors made by students when solving TIMSS geometry content domain problems. Six eighth-grade students from a junior high school in Tasikmalaya consists of two students from each of the three learning styles (visual, auditory, and kinesthetic) were used as research subjects in a descriptive qualitative study during the academic year 2019/2020. The data were collected remotely through Zoom and Skype as the research was conducted during the earlier phase of COVID-19 pandemic. Three problems from the geometry content domain of the TIMSS 2015 test, unstructured interviews, and learning style questionnaires developed by the Ministry of Education and Culture of the Republic of Indonesia were the instruments used to collect data. The study results indicate that visual-style subjects made no errors during the reading stage, whereas almost all subjects made errors during the other stages. The most highlighted causes of errors were a lack of concept comprehension and neglecting prerequisite materials related to the required concepts. Mathematics teachers should consider this description when designing instructional strategies to reduce students' problem-solving errors.

Keywords: Geometry content domain, Newman's Error Analysis, students learning style, TIMSS

Abstrak

Penelitian ini bertujuan untuk mendeskripsikan kesalahan yang dilakukan siswa dalam menyelesaikan soal TIMSS domain konten geometri menggunakan teori *Newman Error Analysis* (NEA). Jenis penelitian yang digunakan adalah deskriptif kualitatif dengan subjek penelitian terdiri dari 6 siswa kelas VIII salah satu SMP di Kota Tasikmalaya tahun ajaran 2019/2020 yang masing-masing terdiri dari 2 siswa dengan gaya belajar visual, auditori dan kinestetik. Data dikumpulkan secara daring melalui Zoom dan Skype karena penelitian dilakukan selama masa awal pandemi COVID-19. Tiga soal dari domain konten geometri TIMSS 2015, wawancara tidak terstruktur, dan kuesioner gaya belajar yang dikembangkan oleh Kementerian Pendidikan dan Kebudayaan Republik Indonesia digunakan sebagai instrumen pengumpulan data. Hasil penelitian menunjukkan bahwa subjek dengan gaya visual tidak melakukan kesalahan pada tahap membaca, sedangkan pada tahap lainnya hampir semua subjek melakukan kesalahan. Faktor penyebab kesalahan yang paling disoroti adalah siswa tidak memahami konsep dan siswa lupa akan materi prasyarat terkait konsep yang dibutuhkan. Deskripsi ini harapannya dapat menjadi pertimbangan guru matematika untuk mendesain pembelajaran agar siswa dapat mengurangi kesalahan pada saat menyelesaikan soal.

Kata kunci: Analisis Kesalahan Newman, Domain Konten Geometri, Gaya belajar siswa, TIMSS

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Received 27 March 2023, Accepted 25 May 2023, Published 01 June 2023
DoI: https://doi.org/10.31004/cendekia.v7i2.2326

INTRODUCTION

Trends in International Mathematics and Science Study (TIMSS) is an international assessment program that assesses the mathematical and scientific skills of fourth- and eighth-grade students. The International Association for the Evaluation of Educational Achievement (IEA) conducts TIMSS to provide information on how to enhance mathematics and science education in countries that participate. Two domains are assessed in TIMSS mathematics: the content domain and the cognitive domain (Mullis et al., 2009). The content domain consists of numbers, algebra, geometry, and data & probability. In contrast, the cognitive domain includes knowing, applying, and reasoning. TIMSS was first conducted in 1995 and is conducted every four years. In 1999, Indonesia participated in both levels of TIMSS for the first time. Indonesia was interested in participating in TIMSS because it assesses the quality of students' development according to the curriculum of each participating country. including Indonesia (Widayanti & Kolbi, 2018). However, Indonesia only participated in the fourth grade in TIMSS 2015.The following Figure 1 displays the mathematics results for Indonesia at the eighth-grade level during the TIMSS from 1999 to 2011.

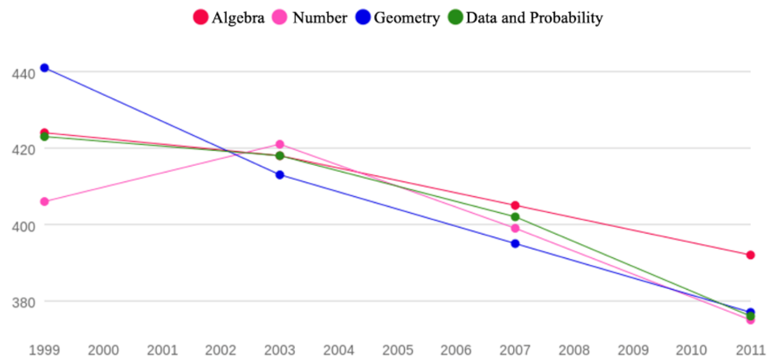

Figure 1. Indonesia eight-grade students' mathematics score in TIMSS

Overall, Indonesia's scores are trending to continue to decline. Even since Indonesia joined TIMSS, Indonesia has not achieved scores above the international average of 500, classifying Indonesia as having a low international benchmark for mathematics scores at the eighth-grade level. If further analyzed, the scores obtained in all content domains continue to decline. The most significant decrease in scores since Indonesia's participation in TIMSS occurred in the geometry content domain (Suwito, 2018). This indicates that the percentage of errors when solving geometry problems is higher than in other content domains. Figure 2 is an example of a TIMSS 2011 geometry content domain problem with the highest percentage of errors made by Indonesian students

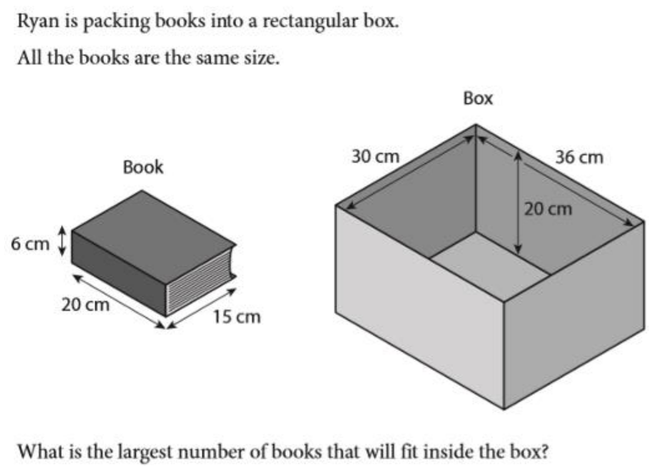

Figure 2. A case of a problem with the greatest error rate by Indonesian student

Of the 5,795 eighth-grade Indonesian students who participated in the TIMSS, 5,157 needed help to solve the problem correctly (Mullis et al., 2012). This result indicates that 89% of TIMSS participants from Indonesia made errors when solving the problem. During a pilot study at a junior high school in Tasikmalaya, 36 of 46 eighth graders made errors while solving the TIMSS problem. It was discovered that 55.26 percent of student errors occurred within the geometry content domain. This is consistent with the fact that students in Indonesia struggle to solve geometry-related problems in general (Asis & Arsyad, 2015).

Students' high error rate on TIMSS geometry content domain problems may indicate that they have not wholly applied their classroom knowledge. The mismatch between the teacher's teaching style and each student's learning style may contribute to this issue (Firdausi & Asikin, 2018). Learning style is the best way a person absorbs, organizes, and processes information or lesson topics. Their learning style highly influences everyone's capacity to absorb and organize information. According to Deporter in Hartati (2013), "Students prefer to learn through sight, sound, or movement, depending on the modality." Thus, three categories of learning styles are based on modality: visual, auditory, and kinesthetic. It should be emphasized that a large percentage of individuals possess all three learning styles, but almost everyone tends to favor one style in the learning process.

Analyzing students' errors when completing TIMSS tasks helps teachers prepare solutions, which is one method to address this issue. Because eighth-grade students in Indonesia have not been able to reach the international average score, particularly in the domain of geometry content, an analysis of the types of errors made by eighth-graders at one of the junior high schools in Tasikmalaya when solving TIMSS geometry content domain problems is conducted using Newman's Error Analysis theory and taking learning styles into account.

METHOD

During the academic school year 2019/2020, this study actively employed descriptive qualitative research using the case study method developed by Creswell (2009) to examine six eighth-grade students from a junior high school in Tasikmalaya. The study focused on three distinct learning styles (visual, auditory, and kinesthetic), with two students from each learning style. Four instruments used to collect data for this study were: (1) learning style questionnaire; (2) problems set; (3) NEA's indicators; and (4) unstructured interviews. Data collection is performed remotely through Zoom and Skype.

The learning style questionnaire used in this study is a complete adaptation of the questionnaire developed by the Ministry of Education and Culture of the Republic of Indonesia for upper primary and junior high school students (Wiedarti, 2018). The questionnaire consists of 14 questions that have been modified to correspond with the level of the students. Option A refers to the tendency towards a visual learning style; Option B refers to the tendency towards an auditory learning style; and Option C refers to the tendency towards a kinesthetic learning style. Based on the preferences of the selected answer options, inferences about the student's learning style tendencies are drawn. After obtaining information about the learning styles of the 48 students in the class, the researcher ranked the scores based on each student's learning style tendencies and then administered the test individually and alternately to each potential subject.

The test consists of three problems with a geometry content domain and reasoning level according to TIMSS 2015 (Mullis et al., 2015). Calculating the area of a triangle under special conditions, applying similarity to two triangles, and calculating the perimeter of a trapezoid were among the problems on the exam. The problems are depicted in Figure 3 below.

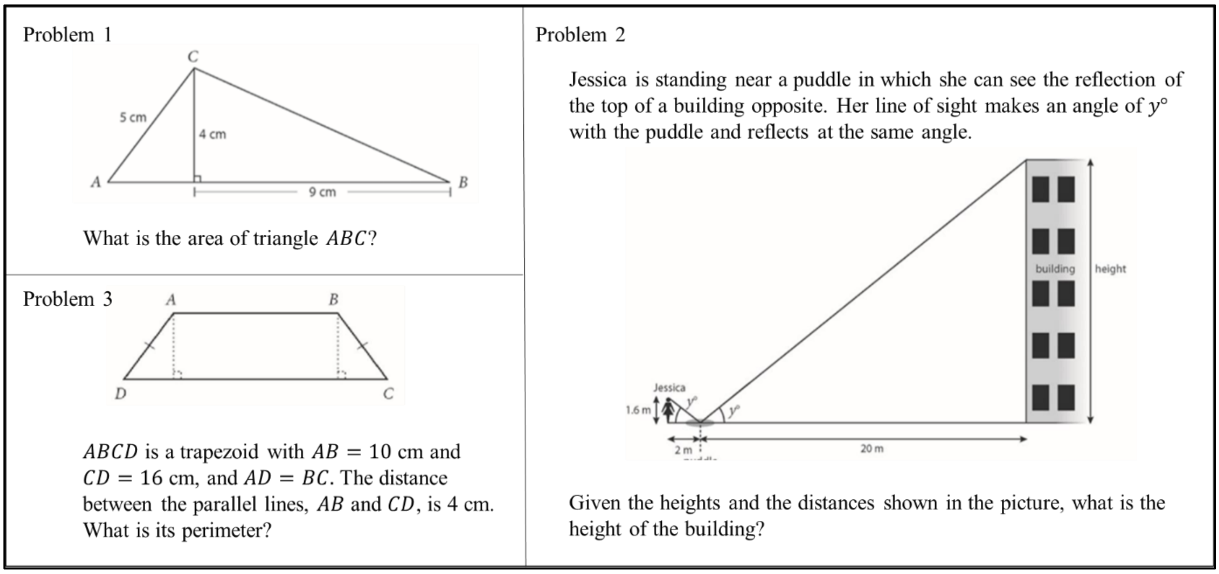

Figure 3. Problems set

The potential subjects are asked to solve three problems using the "think aloud" technique to observe the students' problem-solving strategies (Someren et al., 1994). The results are then analyzed using NEA's indicators. The indicators of NEA are adopted directly from Mukminah & Riana (2020) were selected as the primary reference for analyzing the responses provided by the research subjects. Table 1 presents the evaluation criteria based on Newman's Error Analysis Theory used to analyze the collected data qualitatively.

Table 1. Indicator of Newman Error Analysis

No.	Type of Newman Error	Error Indicators
1.	*Reading Errors*	a. Identifying mathematical information and symbols completely. b. Identifying mathematical information and symbols accurately. c. Misidentifying mathematical information and symbols. d. No answer.
2.	*Comprehension Errors*	a. Writing known and requested information correctly. b. Writing known information but not corresponding to the problem. c. Writing incorrectly known and requested information. d. No answer.
3.	*Transformation Errors*	a. Writing mathematical models completely. b. Writing mathematical models but incomplete. c. Writing mathematical models incorrectly. d. No answer.

4.	*Process Skill Errors*	a. Using correct process and correct answer. b. Using correct process but wrong answer. c. Using wrong process and wrong answer. d. No answer.
5.	*Encoding Errors*	a. Correct conclusion. b. Inaccurate conclusion. c. Wrong conclusion. d. No answer.

After collecting written and verbal responses from the students, the researcher analyzed their errors and conducted a series of interviews regarding their test performance. The interviews aimed to investigate why students made errors while solving the problems (Suyitno, 2018). The available analyses were used to derive conclusions.

RESULT AND DISCUSSION

The results of identifying students' errors when solving TIMSS problems were labeled as V1 and V2 for students with a visual learning style, A1 and A2 for students with an auditory learning style, and K1 and K2 for students with a kinesthetic learning style as described in Table 2.

Table 2. Identification of Student Error

Question	Type of Error					Full Mark
	Reading	*Comprehension*	*Transformation*	*Process Skill*	*Encoding*	
1	A1, K2	V1, V2, A1, K2	A1, K1, K2	A1, K1, K2	V1, A1, K1,	A2
2	A1, K1	V1, A1, K1	V1, V2, A1, K1, K2	V1, V2, A1, A2, K1, K2	V1, V2, A1, A2, K1, K2	-
3	A2	V1, A1, A2	V1, V2, A1, K1	V1, V2, A1, A2, K1	V1, V2, A1, A2, K1, K2	-

Students with a visual learning style made no errors during the reading phase, as shown in the table. In contrast, those with a kinesthetic learning style committed fewer errors during the comprehension phase. At the transformation, process skill, and encoding stages, it was obvious that every student made errors. The description of errors in this written work is presented based on students' learning style tendencies, with a descriptive account beginning from errors in the reading stage, comprehension, transformation, skill process, up to the writing of conclusions.

Description of errors made by students with visual learning style.

The absence of errors made by subjects with visual learning styles during the reading stage indicates that these subjects were able to recognize all mathematical information and symbols in each question. Furthermore, students with visual learning styles made few errors during the comprehension phase. As seen in Figure 4, only V1 made the primary error at this stage for all questions, whereas V2 only made a comprehension process error for the first question.

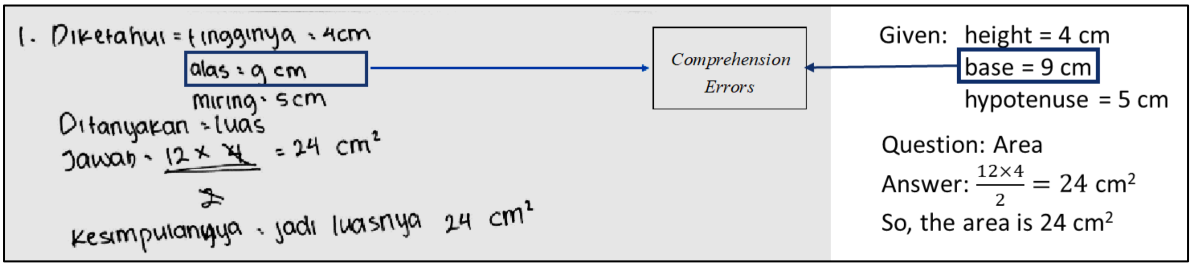

Figure 4. The response of the V2 on problem 1

Based on V2's work, the student made a mistake when recording the provided information, as the triangle's base was not 9 cm. The students seem unable to comprehend that the given part should correspond to the problem's conditions; in this case, some parts of the base still need to be discovered. The results of subjects with visual learning styles tended to be written precisely and systematically from what was known and what was asked to the conclusion, resulting in minimal errors at the comprehension stage. It is consistent with De Porter's in (Puspita & Firdaus, 2017) theory, which explains that students with visual learning styles are careful and detail-oriented when approaching a problem. Additionally, V1 also made a comprehension error in all problems and argued that they just forgot to write down what was the question because they were not used to doing so when solving math problems at school. It is obvious from the following interview excerpt.

R : "*Why didn't you write the question part?*"

V1 : "*Oh, I forgot. But the answer is correct, right?*"

R : "*Yes, it is correct. Typically, you don't write the question part when you solve the problem?*"

V1 : "*No, I don't. Usually providing the correct answer is enough.*"

The frequency of errors made by subjects with visual learning styles tended to increase during the transformation stage. Transformation errors were discovered in problems 2 and 3 for both V1 and V2. According to the study's findings by Solfitri & Roza (2015), these mistakes included improper analogy use, a lack of understanding of the material's concept, and insufficient information utilization. It is noticeable in the results of V1 in Figure 5, where the student incorrectly wrote the required mathematical model.

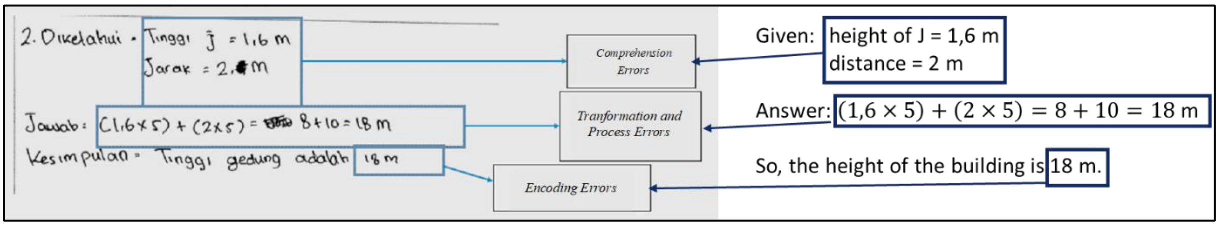

Figure 5. The response of the V1 on problem 2

The student's work further explored during the interview.

R : "*What was the question asked about?*"

V1 : "*It asked about the height of the building; oh yeah, I forgot.*"

R : "*Can you elaborate on why you decided using this approach?*"

V1 : "*Because the height was comparable to the building, eh, because the height was comparable to the window glass. So, that's why.*"

R : "*So, do you think that the height was the same as the height of one window?*"

V1 : "*Yes.*"

R : "*Okay, and why you add two times five here*?"

V1 : "*Because there was a gap between the windows, there was like the ledge.*"

R : "*Oh, I get it. What's the grand total then?*"

V1 : "*Eighteen meters.*"

R : "*Do you understand the main idea?*"

V1 : "*No.*"

Students made errors in the subsequent stage, the process stage, due to errors in this stage. When students make errors when modeling the provided problem, they will also make errors when solving it. It cannot be denied, and as shown in Figure 6, it will result in subjects making errors during the encoding stage.

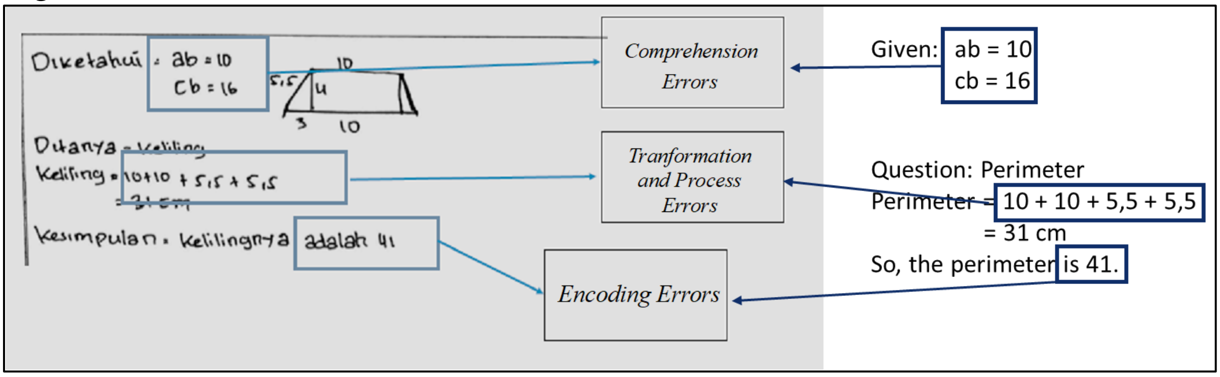

Figure 6. The response of the V1 on problem 3

Interestingly, V1 made an error in the coding phase due to negligence, which is a curious occurrence. Although the student obtained a process result of 31 centimeters, the written conclusion contained 41 without units. During the interview, the student instantaneously recognized an error in their work, and at the same time, they realized the correct response. The researcher concludes that the student comprehends the necessary concepts to solve the problem.

Description of errors made by students with auditory learning style.

During the reading stage, errors committed by subjects with an auditory learning style are more frequent than those with other learning styles. One of the errors made by A1 during the reading stage is illustrated in Figure 7.

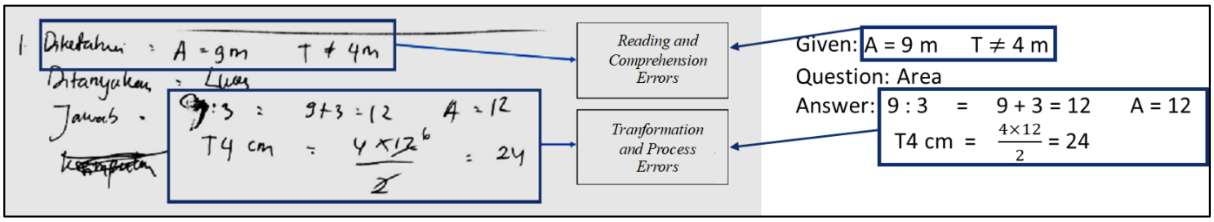

Figure 7. The response of the A1 on problem 1

The student made an error in recognizing the mathematical information and symbols in the question, resulting in the known value being written in meters rather than centimeters. On the other hand, A2 also made an error in identifying the problem's value. This work further explored during the interview.

R : "*What are the given values?*"

A1 : "*The base on the right side is nine cm, and the height is four cm.*"

R : "*Are they in meters or centimeters?*"

A1 : "*Centimeters, I wrote it wrong.*"

R : "*Why did you make a mistake in writing?*"

A1 : "*I didn't see it. I didn't notice the 'cm' for the unit of measurement, that's why I wrote meters.*"

R : "*The question was about the area. What does nine divided by three means?*"

A1 : "*Well, if you look at the picture, it's like one third from the right side.*"

R : "*Oh, so the base on the right side becomes three?*"

A1 : "*Yes.*"

It is obvious that the subject believes that they forgot or ignored the details. On the other hand, they admitted a lack of conceptual understanding. This was observed as A1 attempted to calculate the length of the base of the small right triangle, given that one of the sides was 4 cm and the hypotenuse was 5 cm. The student erroneously attempted to determine the length by dividing the length of the other side by three, assuming it was three times shorter, instead of using the Pythagorean theorem. Further, Subiyono et al., (2015) explained students with an auditory learning style are more likely to recall what they hear than what they read. Due to the fatal errors made at this stage, subjects with an auditory learning style tend to make errors until the conclusion is written. Figure 8 displays some of the outcomes of A2's efforts.

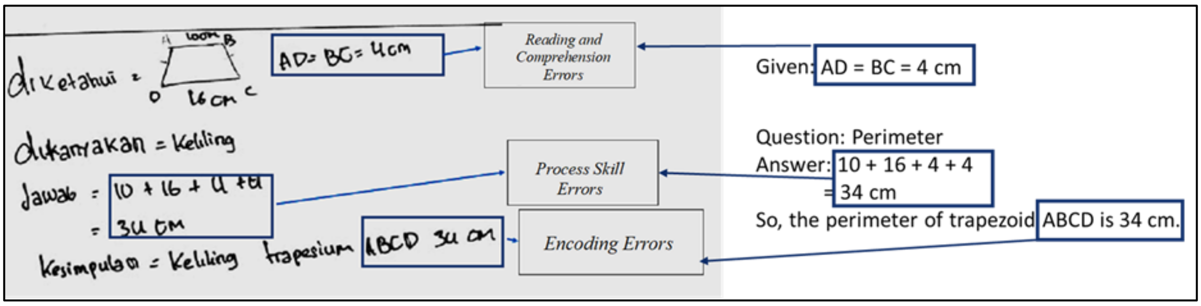

Figure 8. The response of the A2 on problem 3

This work further explored during the interview.

R : "*Do you think your answer is correct?*"

A2 : "*I think so.*"

R : "*What side are four centimeters long?*"

A2 : "*The length of AD and BC which have the same long.*"

R : "*Are you sure the length of both AD and BC are four centimeters?*"

A2 : "*Sure.*"

R : "*Let's take a look to the problem 3.*"

A2 : "*Oh okay, Sir, Oh my God! I was wrong. It should be the height of trapezoid.*"

R : "*Yes, alright. Four centimeters is the height of the trapezoid. Why did you make a mistake?*

A2 : "*I thought the hypotenuse side was four centimeters long. Yes, there was a misunderstanding.*"

According to the results of the interview, the student stated that the student thought the length of the hypotenuse was 4 cm, which is misunderstood. However, neither the text nor the figure contains any information regarding the length of the hypotenuse. The researcher hypothesizes that this is due to their hearing-based learning optimization tendencies instead of their vision-based tendencies. Despite this, A2 made no errors in response to problem 1. This is another hypothesis related to A2's comprehension of the concept, which enables the student to comprehend the test material well.

Simple technical problems most likely caused the errors that occurred. Figure 9 shows that additional investigation into the second problem also confirmed this.

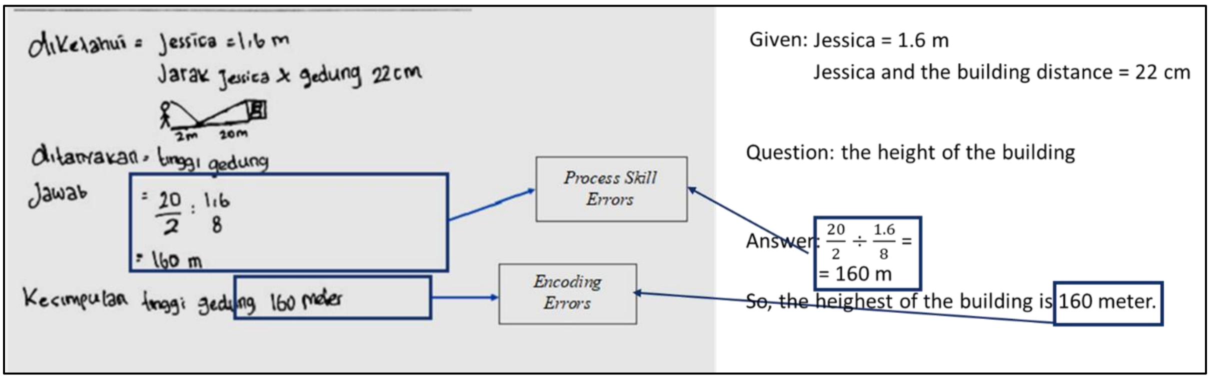

Figure 9. The response of the A2 on problem 2

The student made an error only during the calculation procedure, specifically when calculating the result to determine the building's height. The student committed no errors from reading to writing the model required to solve the problem. Due to mistaken calculations, the student made an error while writing the conclusion.

Description of errors made by students with kinesthetics learning style.

In contrast to other levels, students with kinesthetic learning styles tend to make fewer mistakes in the reading and comprehension stages. The only problem where K1 made reading and comprehension mistakes was problem number 2, where the subject misread the sentence in the question and believed it to be an unknown element when, in fact, it was a known element. Their work is shown in Figure 10 below.

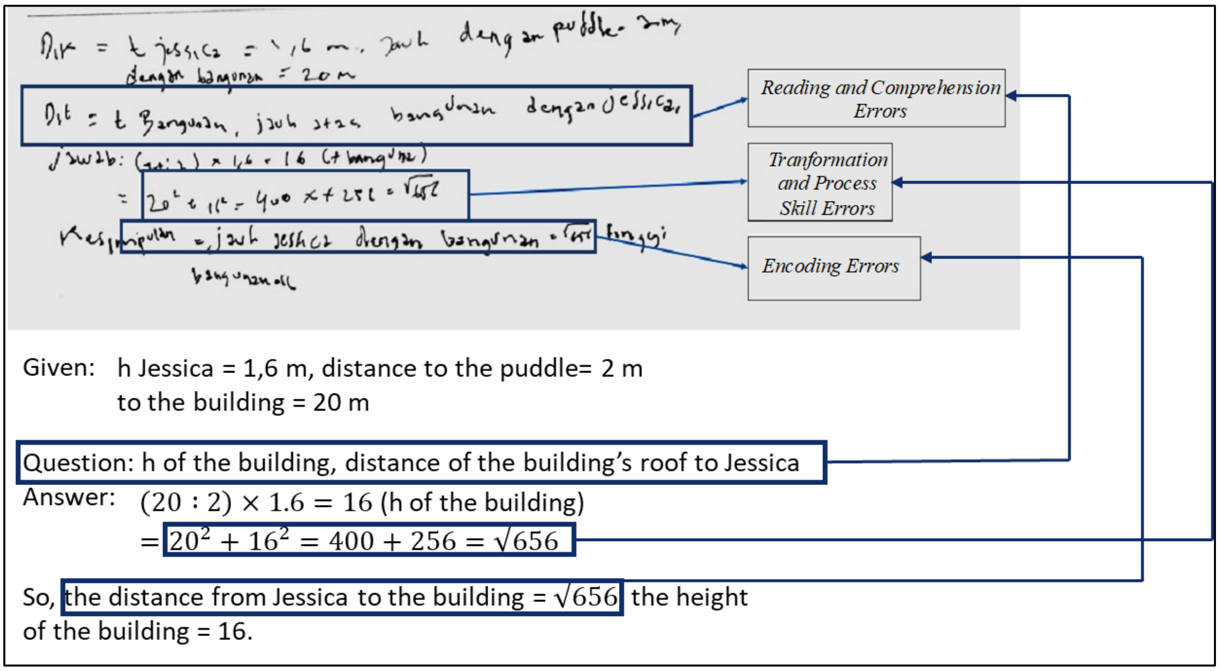

Figure 10. The response of the K1 on problem 2

The student identified mathematical symbols and information in the problem incorrectly. The problem was about the building's height, but the student noted the distance between the building's roof and Jessika as the known variable. Next, the researcher verified that the subject did not comprehend the problem, or the concept required to solve it. An interview with the subject confirmed this: "*I was just speculating and trying to do the calculations for the problem*."

The first problem, where the subject neglected to record the requested element and misunderstood the question, was the only one in which K2 made a reading and comprehension error. This error is shown in Figure 11 below.Figure 11. The response of the K2 on problem 1

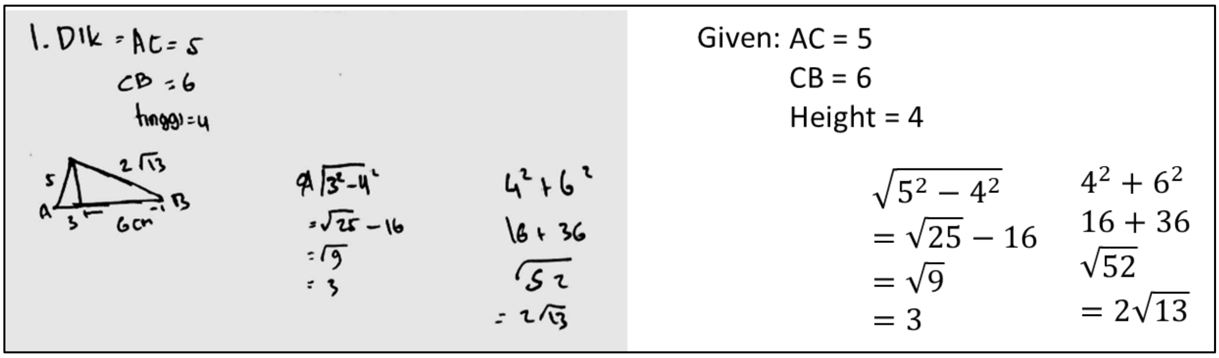

Figure 11. The response of the K2 on problem 1

The student's work further explored during the interview.

R : "*Okay, for the first problem, what is it about?*"

K2 : "*Triangle.*"

R : "*What are you looking for?*"

K2 : "*The hypotenuse.*"

R : "*Is that so? Let's look to the problem 1.*"

K2 : "*Wait a minute… Oh. The question is about the Area of the triangle, right?*"

R : "*Yes, correct. You asked for find the area of the ABC triangle.*"

The student needed to write down what was being asked and understand the known element in the problem but mistake the length of AB for 9 centimeters when it was not. Students with a kinesthetic learning style conduct numerous experiments on how to solve problems, even though they may not completely comprehend the problem or the required concept. This is consistent with De Porter's assertion in Puspita & Firdaus (2017) that individuals with a kinesthetic learning style tend to experiment with new things and learn through practice.

Description of Factors Causing Students' Errors

This study identified possible error-causing factors by interviewing participants about their problem-solving strategies. The researcher acknowledges this method's limitations and the significance of conducting interviews with teachers involved in the school's teaching and learning processes. This would provide valuable information that could be used to verify the students' responses and conditions. In addition, the data capture process during the pandemic's earliest phases is a limitation of this study. Before the pandemic, all tested topics were taught in a face-to-face setting, despite the online data collection.

Students' impulsive attempts to record what they already know, their inability to recognize the information and mathematical symbols in the problem, and their failure to understand the problem's purpose are the three leading causes of errors in the reading phase. These factors were identified as contributing factors to students' errors in solving the given problems. According to a study by Firdausi & Asikin (2018), errors in the comprehension phase of the problem were caused by (1) students not understanding what is being asked; (2) students not focusing and not writing down what is being asked; (3) students making errors in writing units; and (4) students not writing down what is known and what is being asked. Errors in the transformation phase were due to (1) students not comprehending the material concepts; (2) students racing to record unnecessary information, and (3) students not comprehending the question. Errors in the skill process were the result of (1) students hurrying and making errors in addition; (2) students making errors in selecting the mathematical model; and (3) students making errors in dividing decimal numbers. Students' errors in earlier stages led to errors in summarizing and concluding during the answer writing phase.

CONCLUSION

Based on the description of the six subjects' errors in completing the TIMSS geometry content domain, the following conclusions can be drawn: (1) subjects with auditory and kinesthetic learning styles made errors in the reading stage because they misidentified mathematical information and symbols in the problems they were asked. All subjects committed errors in the comprehension phase because students incorrectly recorded what was known or asked about. All subjects except A2 committed errors during the transformation phase because students made errors when writing mathematical models. All research subjects committed errors at the process skills stage because they used the incorrect process or obtained the incorrect answer. All students made errors in encoding or writing their answers because they incorrectly recorded or did not record their conclusions; and (2) in general, not understanding the concept of the material and prerequisite concepts, rushing calculations, not understanding the meaning of the question, and guessing when solving problems are the causes of student errors. Errors in one stage can be influenced by errors in the previous stage.

Mathematics teachers at secondary school can use this error description when designing learning activities to reduce errors in geometry question answers.

ACKNOWLEDGE

The authors acknowledge and thank Dr. Yudi Soeharyadi of FMIPA Institut Teknologi Bandung for fruitful discussions leading to improvement of the article.

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