

Vocational High School Students' Mathematical Communication: Auditory, Visual, and Kinesthetic Learners

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Abstract. *Mathematical communication skills are essential in activating students' problem-solving abilities and activating excellent cognition. This study aims to analyze the mathematical communication skills conceived by vocational students on financial mathematics material according to auditory, visual, and kinesthetic learning styles. The study used descriptive qualitative with nine samples determined using a purposive sampling technique. Each learning style category comprised three quick, moderate, and slow students comprehending the given materials. The data were collected using a mathematical communication test and a learning style questionnaire. The obtained data were analyzed using Miles and Huberman's model. The results showed that students with an auditory learning style whose ability to comprehend material was quick and slow could complete mathematical communication indicators. In contrast, students with a moderate category could not complete the fourth indicator. Visual learners with quick material comprehension did not formulate situations mathematically, and all the categories did not comply with the fourth indicator. Kinesthetic learners with quick material comprehension could not complete the first and third indicators. The kinesthetic learner with slow comprehension could not fulfill the fourth indicator, while one in the moderate category could complete all mathematical communication indicators.*

Keywords: *learning style, mathematical communication, vocational high school*

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Introduction

Mathematical communication is one of the abilities currently relevant to the 21st-century education model. Low communication skills obstruct the effective transmission of information. Thus, it might lead to misconceptions. Mathematical communication is required in solving problems since it represents the problem and its solvency generation (Sari, Syahputra, & Surya, 2020). Based on the National Council of Teachers of Mathematics (NCTM), mathematical communication refers to the capacity to communicate mathematical concepts orally, in writing, and visually through various media (NCTM, 2000). According to NCTM, there are several indicators of students' mathematical communication skills, encompassing (1) arranging and conveying mathematical thoughts based on information; (2) communicating mathematical reasoning that is understandable to other people; (3) evaluating strategy and results employed as well as their mathematical thinking; and (4) using appropriate mathematical language (NCTM, 2000). According to NCTM (2000), students are considered to have good

communication skills if they can express mathematical ideas orally, in writing, and visually through various media, comprehend, interpret, and evaluate mathematical ideas and conclusions drawn orally or visually, and use mathematical notation and terms to present ideas, describe relationships, and model situations. Thus, mathematical communication indicators cover (1) communicating ideas coherently and clearly to others, (2) organizing mathematical thinking through communication, (3) using mathematical language to express mathematical ideas correctly, and (4) analyzing and evaluating mathematical thinking and strategies.

Communication skills are important as they include the eight skills required for the 21st century: critical thinking, innovation, inquiry, self-direction, perseverance, information utilization, systems thinking, communication, and reflection (OECD, 2018). The need for communication skills is also mentioned in P21 (2019). Regarding the need to face the 21st century, the 4C skills, namely critical thinking, communication, collaboration, and creativity, are compulsory.

Several studies have found that students' mathematical communication is low in junior high school (Tiffany, Surya, Panjaitan, & Syahputra, 2017), senior high schools (Marzuki, Asih, & Wahyudin, 2019), and vocational schools (Radiusman, Yurniwati, Simanjuntak, Sabariyah, & Nurmawanti, 2020). Several factors could cause those low results. One of the factors that influences mathematical communication is the student's learning style (Marzuki et al., 2019). Different learning styles have different abilities in mathematical communication. Teachers need to train mathematical communication skills according to students' learning styles so that abilities can develop optimally. Teacher Kolb (2015) explains that learning style is a person's choice in understanding experiences and transformation processes. Porter and Hernacki (2005) state that students' learning styles consist of visual, auditory, and kinesthetic learning styles, and students might perceive one of them. Teachers can teach according to the student's learning styles so that they can easily obtain lessons and improve their learning outcomes (Gilakjani, 2012; Sheromova, Khuziakhmetov, Kazinets, Sizova, Buslaev, & Borodianskaia, 2020). This study uses three learning styles, namely visual, auditory, and kinesthetic learning styles (Porter & Hernacki, 2005). Researchers undertook this study because of the need for an initial diagnosis of students' learning styles before conducting the teaching and learning process to optimize the learning process (Rogowsky, Calhoun, & Tallal, 2020). Based on Porter and Hernacki (2005), visual learners can learn through visual media such as pictures, posters, videos, and movies. Auditory learners learn through listening to what others say during conversations, group projects, discussions, and oral lectures. Kinesthetic learners can learn through "hands-on" activities. They enjoy engaging in physical activity and interaction.

To the best of the researchers' knowledge, research on mathematical communication skills based on learning styles had been conducted at junior high school (Asgafi, Anwar, Choirudin, Darmayanti, & Usmiyatun, 2023) and senior high school level (Marzuki et al., 2019). However, no study has been undertaken in vocational high schools. The vocational high school level has a big relationship with several learning practices, so many people often attribute vocational high school students to kinesthetic learners (Chavarría-Garza, Santos-Guevara, Morones-Ibarra, & Aquines-Gutiérrez, 2022). However, based on the results of a questionnaire given by authors to students at a vocational high school in Sleman, Indonesia, they had a variety of learning styles, such as auditory, visual, and kinesthetic learning. Therefore, research must reveal students' mathematical communication skills based on their different learning styles in vocational high school. The finding can be a reference for vocational high school teachers in determining appropriate learning strategies for their students.

Financial mathematics is one of the important mathematics topics to master because it is closely related to students' economic lives (Moreno, Solórzano, Morales, Villegas, & Sánchez, 2021). Sun, Yuen, Zhang, and Zhang (2020) and Berry, Karlan, and Pradhan (2018) provide examples of how financial education helps avoid issues like having bad credit or defaulting on loans. Expectations do not always match the ideal situation. Students still understand financial mathematics but are limited to using formulas (Ekol & Greenop, 2023).

Financial and mathematical communication are interconnected regarding taking appropriate action in managing finances. Individuals communicate several solutions they have to other people so they can decide appropriately (Van Campenhout, 2015). Communication is also needed regarding financial literacy (Wise, 2013). Therefore, it is necessary to conduct research on mathematical communication, especially in financial mathematics.

Based on the lack of research on mathematical communication in different vocational students' learning styles and the limited available research on mathematical communication on financial mathematics material, this study aims to analyze the vocational students' mathematical communication skills on financial mathematics topics in terms of auditory, visual, and kinesthetic learning styles. It is expected that the results of this study can become a teacher's reference in determining appropriate learning strategies for vocational students with different learning styles.

Method

This study used a qualitative descriptive method at one of the vocational high schools in Depok, Sleman, Indonesia. The subjects of this study were nine students selected from 33 students from a class majoring in Industrial Chemistry. They were selected by using the purposive

sampling technique with the consideration that there were three types of learning styles and three categories in comprehending material for each learning type, which were slow, moderate, and quick. From the nine students, there were three students with an auditory learning style (A1, A2, and A3), three students with a visual learning style (V1, V2, and V3), and three students with a kinesthetic learning style (K1, K2, and K3). Three students from each learning style represented students who could quickly, moderately, and slowly comprehend mathematics material. The selection of students for each learning style was based on the results of the questionnaires, and the selection of students in the categories of quick, moderate, and slow in comprehending math material was based on the results of tests and teacher recommendations.

A learning style questionnaire and a test of students' mathematical communication were the instruments used in this study to gather information on the learning preferences of the participants. Table 1 shows the learning style indicator created by Porter and Hernacki (2005).

Table 1. Indicators of learning styles

Visual	auditorial	Kinesthetic
1. Neat and orderly	1. Easily distracted by noise	1. Speaks slowly, easily distracted by noise
2. Speak fast	2. Move the lips when reading aloud and listening to audio	2. Always physically oriented and moving a lot
3. Good long-term planner and organizer	3. Can repeat and imitate notes	3. learn through practice
4. Be meticulous about details	4. Find difficulties in writing but is great at telling stories	4. Memorizing by walking and looking
5. Concerned about appearance, both in terms of clothing and presentation	5. Speak in a patterned rhythm	5. Use your finger as a pointer when reading
6. Good spellers	6. Usually, an eloquent speaker	6. Use a lot of body cues
7. Remembering what was seen rather than what was heard	7. Learn by listening and remembering what was discussed rather than what was seen.	7. Unable to sit for long periods
8. Remembering by visual associations, usually not bothered by noise	8. Like to talk, likes to discuss and explain something at length	
9. Having trouble remembering verbal instructions unless they are written down and often asks others to repeat them	9. Prefer oral jokes to reading comics.	
10. Quick and assiduous readers, preferring to read rather than be read to		
11. Require a thorough and alert view and purpose before being mentally certain about a problem or project		
12. Doodling meaninglessly while talking on the phone and in meetings.		
13. Forgetting to convey verbal messages to others		
14. Often answer questions with a short yes or no answer		
15. Prefer demonstrations rather than speeches		
16. Prefer art over music		

The learning style questionnaire consisted of twenty statements, with A being the auditory learning style option, B being the visual learning style option, and C being the kinesthetic learning style option. Student learning styles were determined from the greatest number of choices of statements for each learning style.

The mathematical communication task was conducted after the learning style questionnaire was administered. One task about financial mathematics was undertaken. Three graduate students who had done teaching internships at vocational high schools validated the learning style questionnaire and mathematical communication test. Validation results were calculated based on the V-Aiken index. The content validity of the mathematical communication test items was 0.92, and the content validity of the learning style questionnaire was 0.83, which was in the high category according to Aiken (1985). The suggestion from the validator for the learning style questionnaire was to replace inappropriate words, and the suggestion for a mathematical communication test was about writing final savings that do not need to be rounded. Figure 1 shows a math communication task for class 11.

Rina saves IDR 5,550,000.00 in a bank with a compound interest rate of 11% per year. How long does Rina's savings take to become IDR 12,790,184.6?

Figure 1. Financial math problems

Table 2 depicts the indicators of mathematical communication adapted based on NCTM (2000).

Table 2. Indicators of mathematical communication

Mathematical communication indicator	Description
Communicate ideas coherently and clearly to others	Convey the information of the problems
Organize mathematical thinking through communication	Explain the strategy for solving math problems
Using mathematical language to express mathematical ideas correctly	Use mathematical notation and symbols to present ideas related to the problem
Analyze and evaluate the mathematical thinking and strategies of others	Evaluating the strategy and results obtained in real-life

As for data collection techniques, the researchers gave a learning style questionnaire to 33 students to determine which students had auditory, visual, and kinesthetic learning styles. After obtaining the data on student learning styles, researchers chose three auditory students with quick, moderate, and slow mathematics comprehension, three visual students with quick, moderate, and slow mathematical comprehension, and three kinesthetic students with quick, moderate, and slow mathematical comprehension. Then, each subject was given a mathematical communication ability test on the financial mathematics topic they had learned. The test was carried out for 10 minutes.

The Milles and Huberman methodology (Miles, Huberman, & Saldana, 2014), which comprised data reduction, data presentation, verification, and decision-making, served as the foundation for the qualitative descriptive analysis used in this study. The stages encompassed (a) the data reduction stage, in which the responses of the nine research subjects were each verified using the indicators of mathematical communication; (b) data presentation, which was to present the data; and (c) drawing conclusions, which was to conclude from the results of the verification.

Results and Discussion

The findings of the questionnaire analysis of the learning styles of vocational high school students majoring in Industrial Chemistry obtained groupings of student learning styles. Based on the test results, 17 students had a visual learning style, five had an auditory learning style, and 11 had a kinesthetic learning style. Then, nine subjects were selected based on three types of learning styles, with three subjects for each type of learning divided into quick, moderate, and slow abilities in comprehending mathematics material based on test scores and observations. Table 3 conveys the research subjects used in the present study.

Table 3. Subjects' qualifications

Subject code	Learning style	Students' absorption in mathematics
V1	Visual	Quick
V2		Moderate
V3		Slow
A1	Auditorial	Quick
A2		Moderate
A3		Slow
K1	Kinesthetic	Quick
K2		Moderate
K3		Slow

One task was given to find out the mathematical communication skills of vocational high school students in financial mathematics. Students took this test, and researchers analyzed the data using student work suitable for auditory, visual, and kinesthetic learning. Table 4 displays the summary results of students' mathematical communication skills based on learning styles.

Table 4. Summary of subjects' results based on mathematical communication test

Mathematical communication indicator	Description	Subjects								
		V1	V2	V3	A1	A2	A3	K1	K2	K3
Communicate ideas coherently and clearly to others	Convey the information of the problems		✓	✓	✓	✓	✓		✓	✓
Organize mathematical thinking through communication	Explain the strategy for solving math problems	✓	✓	✓	✓	✓	✓	✓	✓	✓
Use mathematical language to express mathematical ideas correctly	Use mathematical notation and symbols to present ideas related to the problem	✓	✓	✓	✓	✓	✓		✓	✓
Analyze and evaluate the mathematical thinking and strategies of others	Analyze and evaluate the strategy and results obtained in real-life				✓		✓	✓	✓	

Students' Mathematical Communication Skills in Auditory Learning Style

Student A1 can correctly fulfill all mathematical communication indicators with the correct calculation results. A1 could convey the information of the problems by writing down what was known and asked. A1 could explain the strategy for finding solutions. A1 could use the correct notation to represent the information. Then, A1 could analyze and evaluate the appropriate results

in real life, by changing the year it initially obtained from decimal form to an integer to be eight years. Here is the interview excerpt between A1 and Researcher (R).

- R : What are your steps in working on this problem?
 A1 : I first wrote down the information in the question and what was asked. Then, I looked for a strategy that suited what was asked and the information provided.
 R : What about the answers you found?
 A1 : I found a year with a result of 8.0867. Because the interest was every year and there were no years in decimal form, I rounded 8.0867 to the nearest year, which was 8.

	Known = $P = 5,550,000$ $r = 11\% = 0.11$ $A = 12,790,184.6$ Answer = $A = P \left(1 + \frac{r}{n}\right)^{(nt)}$ $12,790,184.6 = 5,550,000 \left(1 + \frac{0.11}{n}\right)^{(1t)}$ $\frac{12,790,184.6}{5,550,000} = \left(1 + \frac{0.11}{n}\right)^{(1t)}$ $2.31 = (1.11)^{(t)}$ $\log 1.11 (2.31) = t$ $t = 6.39$ So, it takes about 6.4 years for Rina's savings to become Rp. 12,790,184.6 at a compound interest rate of 11% per year
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Figure 2. The answer of student A2

Regarding Figure 2, student A2 could write down the situation mathematically precisely. For the second indicator, A2 could explain the strategy used but was less precise in calculations. A2 could not use a calculator to calculate the logarithm in code **A**. The logarithm calculation was not quite right. For the third indicator, A2 could use the correct notation to represent the information. However, for the fourth indicator, the answer chosen did not make sense because the year for the solution to the task was not round, that was 6.4 years in code **B**. A2 could analyze and evaluate the results. Here is the interview excerpt between A2 and Researcher (R).

- R : How do you solve that problem?
 A2 : I first write down what was known and what was asked. Then, I looked for the compound interest formula, entered the information in the formula, and calculated it.
 R : What did you use to calculate? and what did you find?
 A2 : I used a calculator ma'am and I found 6.39 years. I rounded it to 6.4 years.

In connection with Figure 3, A3 could write down the information mathematically but was less precise in identifying mathematical aspects of problems located in real-world contexts and identifying significant variables because the initial savings known to be incorrect were IDR 5,500,000.00. The initial savings should be IDR 5,550,000.00. So, for the third indicator, A3 could use the right notation but less precise. For the second indicator, A3 could explain the strategy but was less precise in calculations. A3 could not use a calculator to calculate the

logarithm in code C. For the fourth indicator, A3 could analyze and evaluate the solution in the real world, but the answer was incorrect because the logarithm calculation was not quite right. Automatically, the selected answer was also not quite right, and the name in the conclusion was false. It must be "Rina," not "Andri," on code D. Here is the interview excerpt between A3 and Researcher (R).

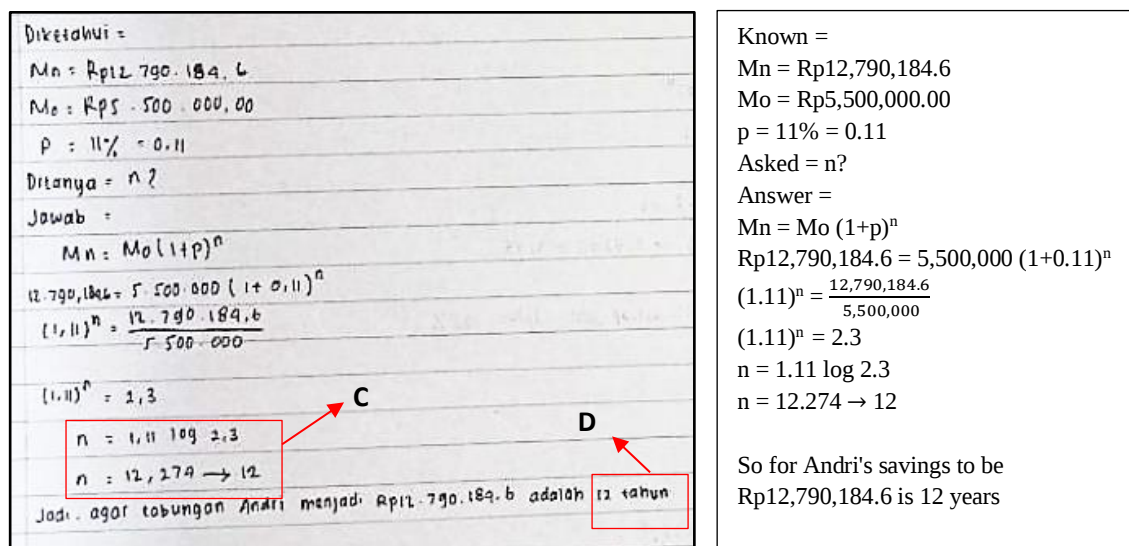


Figure 3. The answer of student A3

- R : How do you solve that problem?
 A3 : Writing down what was known and what was asked, looking for the formula, entering what was known, calculating it, and getting the result.
 R : What did you use to calculate? and what are the results?
 A3 : I used a calculator and got the result of 12.274 years. Then I rounded it up because there was no decimal in years, so it got 12 years.

Students' Mathematical Communication Skills in Visual Learning Style

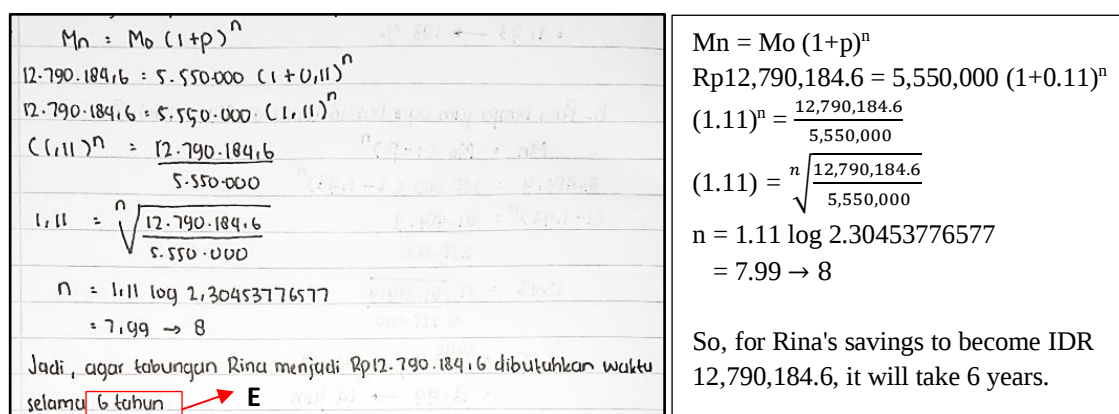


Figure 4. The answer of student V1

Regarding Figure 4, V1 did not convey the situation mathematically in the first indicator. V1 immediately wrote down the strategy without writing any information about the problem. For the second indicator, V1 could explain the strategy to find the right solution. Although V1 did not convey the situation mathematically, V1 could use the correct notation to find the solution. Thus,

he fulfilled the third indicator. However, for the fourth indicator, even though V1 could analyze the solution in the real world, V1 did not check or evaluate what had been written in the conclusion. V1 wrote the inaccurate conclusion of six years, shown in code E. Here is the interview excerpt between V1 and Researcher (R).

- R : How do you solve this problem?
 V1 : I looked for what was known and what was asked, then looked for the compound interest formula and entered what was known.
 R : What results did you get?
 V1 : I got 7.99 years; then I rounded it to 8.
 R : Why did your conclusion say 6?
 V1 : Sorry, I did not check the answer again.

Regarding the results conveyed by V2, the errors made were the same as those for A2. To convey the information mathematically, V2 could what information is known and asked exactly. V2 also could explain the strategy to find the results, and V2 could use the correct notation. However, for the fourth indicator, V2 did not analyze and evaluate the result in the real world. Here is the interview excerpt between V2 and Researcher (R).

- R : What is your strategy for solving this problem?
 V2 : Write down the available information and know what was asked. Then, I looked for the appropriate formula, calculated it, and got the result.
 R : What are the results? What tool did you use to calculate?
 V2 : I found 6.4 years using a calculator.

	Known = in the bank = Rp5,550,000 compound interest rate = 11% per year Asked = how many years for the savings to be Rp12,790,124.6 Answer: $M_n = M_o (1+p)^n$ $12,790,184.6 = 5,550,000 (1+0.11)^n$ $12,790,184.6 = 5,550,000 (1.11)^n$ $(1.11)^n = \frac{12,790,184.6}{5,550,000}$ $(1.11)^n = \sqrt[n]{\frac{12,790,184.6}{5,550,000}}$ $n = 1.11 \log \frac{12,790,184.6}{5,550,000} = 0.00000142137$
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Figure 5. The answer of student V3

The results of V3's work depicted in Figure 5 showed that V3 could convey the information mathematically and correctly for the first indicator. V3 wrote down what was known and asked completely. In addition, V3 could explain the strategy to find solutions and use the right notation. However, V3 could not fulfill the fourth indicator. V3 could not use the logarithm calculator as in code F and did not pass on the answer. Here is the interview excerpt between V3 and Researcher (R).

- R : What is your strategy for solving this problem?

- V3 : Write down the available information and know what was asked. Then I looked for the appropriate formula, entered what was known, and calculated it.
- R : What results did you get?
- V3 : Sorry, I did not find the results. I don't know what's wrong with my strategy.

Students' Mathematical Communication Skills in Kinesthetic Learning Style

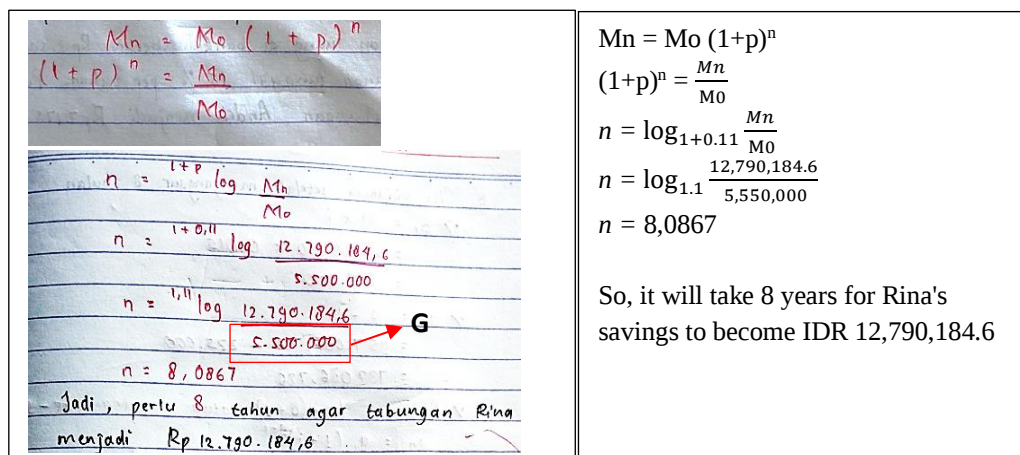


Figure 6. The answer of student K1

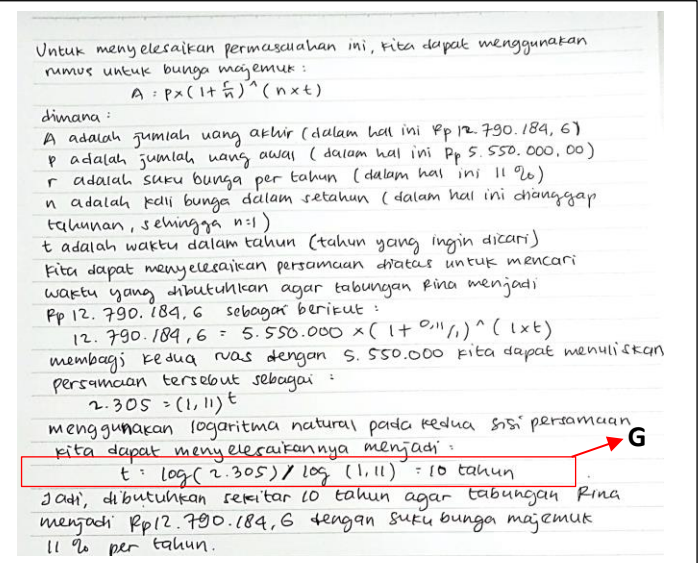
K1 did not convey the information mathematically, as V1 did in the first indicator. K1 immediately wrote down the strategy without writing any information about the problem. For the second indicator, K1 could explain the right strategy to find the right solution. However, the information used was less precise for initial savings. K1 wrote down the initial savings. IDR 5,500,000.00, which should have been IDR 5,550,000.00 as shown in code G. So, K1 used the correct notation but was less precise. However, the result was 8 years, which was appropriate in the real-world context obtained from rounding decimals. Therefore, K1 fulfilled the fourth indicator. Here is the interview excerpt between K1 and Researcher (R).

- R : How do you solve that problem?
- K1 : Find existing information and look for what was asked, then look for a formula according to the existing information, enter the information into the formula, calculate it, and find a solution.
- R : What did you get?
- K1 : I got 8.0867 years, but because the interest was given per year and there were no decimal years, I rounded it up to 8 years.

Regarding K2, it could fulfill all indicators of mathematical communication, which are being able to convey the information mathematically, explain the strategy to find solutions and analyze and evaluate the results obtained in the real world. The results obtained were also correct; that was 8 eight years. Here is the interview excerpt between K2 and Researcher (R).

- R : What are your steps in solving this problem?
- K2 : I wrote down what was known and asked, then looked for a formula corresponding to what was known and asked, calculated it, and finally found the answer.
- R : What answer did you find?

- K2 : I found 8 years, which I got from rounding.
 R : Why rounded?
 K2 : Because I don't think there is a decimal in years.



Untuk menyelesaikan permasalahan ini, kita dapat menggunakan rumus untuk bunga majemuk :

$$A = P \times \left(1 + \frac{r}{n}\right)^{(n \times t)}$$

dimana :

A adalah jumlah uang akhir (dalam hal ini Rp 12.790.184,6)
 P adalah jumlah uang awal (dalam hal ini Rp 5.550.000,00)
 r adalah suku bunga per tahun (dalam hal ini 11%)
 n adalah kali bunga dalam setahun (dalam hal ini dianggap tahunan, sehingga n=1)
 t adalah waktu dalam tahun (tahun yang ingin dicari)

Kita dapat menyelesaikan persamaan diatas untuk mencari waktu yang dibutuhkan agar tabungan Rina menjadi Rp 12.790.184,6 sebagai berikut :

$$12.790.184,6 = 5.550.000 \times \left(1 + \frac{0,11}{1}\right)^{(1 \times t)}$$

membagi kedua ruas dengan 5.550.000 kita dapat menuliskan persamaan tersebut sebagai :

$$2.305 = (1,11)^t$$

menggunakan logaritma natural pada kedua sisi persamaan kita dapat menyelesaikannya menjadi :

$$t = \log(2.305) / \log(1,11) = 10 \text{ tahun}$$

Jadi, dibutuhkan sekitar 10 tahun agar tabungan Rina menjadi Rp 12.790.184,6 dengan suku bunga majemuk 11% per tahun.

To solve this problem, we can use the formula for compound interest:
 $A = P \left(1 + \frac{r}{n}\right)^{(nt)}$
 Where:
 A is the final amount of money (in this case, IDR 12,790,184.6)
 P is the initial amount of money (in this case, IDR 5,550,000.00)
 r is the interest rate per year (in this case, 11%)
 n is the number of times the interest in a year (in this case, it is considered annual so that n = 1)
 t is the time of year (the year you want to find)
 we can solve the equation above to find the time needed for Rina's savings to become IDR 12,790,184.6 as follows:
 $12,790,184.6 = 5,550,000 \left(1 + \frac{0.11}{1}\right)^{(1t)}$
 dividing both sides by 5,550,000, we can write the equation as:
 $2.305 = (1.11)^t$
 Using the natural logarithm on both sides of the equation, we can solve this as:
 $t = \log(2.305) / \log(1.11) = 10 \text{ years}$
 so it takes about 10 years for Rina's savings to become IDR 12,790,184.6 with a compound interest rate of 11% per year

Figure 7. The answer of student K3

Regarding Figure 7, K3 could convey the information mathematically and correctly, explain the strategy, and use the correct notation. However, there was an error in the logarithm calculation in code H. Automatically, logarithmic calculations caused errors in analyzing and evaluating solutions in the real world. Here is the interview excerpt between K3 and Researcher (R).

- R : What are your steps in solving this problem?
 K3 : I wrote what was known and knew what was asked, wrote a solution plan using the compound interest formula, and explained the letter examples I used in the calculations. After that, I entered whatever was known into the formula and then calculated it. Finally, I got the result.
 R : Are you sure the method you are using is correct?

K3 : Honestly, ma'am, I forgot how to calculate logarithms, so I am unsure whether my answer is right or wrong.

Based on the results of the vocational high school students' learning style questionnaire, there was an unexpected result that the most common learning style was a visual learning style with 17 students, followed by a kinesthetic learning style with 11 students, and an auditory learning style with five people. It is similar to Baltaci, Yildiz, and Özcakir (2016) and Gilakjani (2012) in that students mostly used a visual learning style. Based on the study results, two out of three students with visual and auditory learning styles were less familiar with non-routine questions, such as calculating logarithms. In contrast to students with a kinesthetic learning style, one out of three students miscalculated logarithms. The following discussed each subject used in the present study for more details.

Students with an auditory learning style who could accept material quickly and slowly, as represented by A1 and A3, could fulfill all indicators of mathematical communication with the correct answers. That result was in line with Pratiwi, Inganah, and Putri (2020), who showed that the auditorial learning style gave good, long, and detailed answers to address the questions. It was different with students with moderate auditory learning styles receiving material represented by A2. He was less able to analyze and evaluate the results. Reinforced by Baiduri, Khusna, and Solikhah (2021), auditory learning style students did not re-check their answers.

Students with visual learning styles had diverse mathematical communication skills. Students who could quickly accept material, as represented by V1, did not fulfill the indicators of conveying situations mathematically because they immediately wrote strategies to find solutions. This was contrary to Rivai, Lestari, Munir, and Anas (2023) that students with a visual learning style could write the information mathematically. This could happen because students with a visual learning style took a long time to understand information by reading. In addition, subjects V1, V2, and V3 did not evaluate answers. It was the same result with Sakinah and Avip (2021) that students with a visual learning style were lacking in interpreting solutions to the real world. Machromah, Ishartono, Mirandhani, Muhroji, Samsudin, Basry, and Ernitasari (2021) also stated that students with a visual learning style did not check the results obtained.

Students with a kinesthetic learning style who could accept material quickly, as represented by S1, did not formulate situations mathematically but could use correct notation even with less precision. So, S1 just fulfilled the second and fourth indicators. That result was similar to Sholihah, Riyadi, and Triyanto's (2020) study that kinesthetic learners could express and evaluate mathematical theory but not for other indicators. Students who comprehended material at a moderate level, as represented by S2, could complete all indicators with appropriate answers. Students could solve the problem correctly using their strategy (Pratiwi et al., 2020). Meanwhile,

students with slow comprehension, as represented by S3, only had errors in calculating logarithms, which caused errors in analyzing and evaluating solutions to the real world. Kurniawati, Suyitno, and Mulyono (2021) stated that kinesthetic learners could not explain the solution to daily problems.

Conclusion

Based on the results and discussion, auditory students who can comprehend material quickly and slowly can complete mathematical communication indicators. However, a student who has slow comprehension carries some calculation errors. A student who has a moderate comprehension level cannot evaluate answers, so they cannot fulfill the fourth indicator. Students with visual learning styles for quick material comprehension do not formulate situations mathematically, and all the categories do not fulfill the fourth indicator since they cannot evaluate the result and strategy. Meanwhile, students with kinesthetic learning styles for quick material comprehension do not fulfill the first and third indicators. Kinesthetic students with slow comprehension cannot meet the fourth indicator, while the one in the moderate category can complete mathematical communication indicators. Based on the study results, it is expected that teachers can emphasize understanding concepts, using calculators, and evaluating the answers obtained for students with auditory, visual, and kinesthetic learning styles. Students should also be accustomed to writing down the information of the problem. The present study is limited to examining vocational high school students in one major with limited subjects. For further research, it is advisable to examine the mathematical communication of vocational high school students in terms of different cognitive and affective skills in dissimilar fields.

References

- Aiken, L. R. (1985). Three coefficients for analyzing the reliability and validity of ratings. In *Educational and Psychological Measurements*, 45(1), 131–142.
- Asgafi, A., Anwar, M. S., Choirudin, Darmayanti, R., & Usmiyatun. (2023). Analysis of students mathematical communication ability on student learning styles. *AMCA Journal of Science and Technology*, 3(2), 36–39. <https://doi.org/10.1088/1742-6596/1157/3/032124>
- Baiduri, B., Khusna, A. H., & Solikhah, M. (2021). The process of students' mathematical connection in solving mathematical problems regarding learning styles. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, 12(6), 1451–1466. <https://doi.org/10.17762/turcomat.v12i6.2684>
- Baltaci, S., Yildiz, A., & Özçakir, B. (2016). The relationship between metacognitive awareness levels, learning styles, genders and mathematics grades of fifth graders. *Journal of Education and Learning*, 5(4), 78. <https://doi.org/10.5539/jel.v5n4p78>
- Berry, J., Karlan, D., & Pradhan, M. (2018). The impact of financial education for youth in Ghana. *World Development*, 102, 71–89. <https://doi.org/10.1016/j.worlddev.2017.09.011>

- Chavarría-Garza, W. X., Santos-Guevara, A., Morones-Ibarra, J. R., & Aquines-Gutiérrez, O. (2022). Assessment of multiple intelligences in first-year engineering students in Northeast Mexico. *Sustainability (Switzerland)*, 14(8). <https://doi.org/10.3390/su14084631>
- Ekol, G., & Greenop, S. (2023). Teacher interventions using guided discovery and mathematical modelling in grade 10 financial mathematics. *The European Educational Researcher*, 6(2), 35–53. <https://doi.org/10.31757/euer.623>
- Gilakjani, A. P. (2012). A match or mismatch between learning styles of the learners and teaching styles of the teachers. *International Journal of Modern Education and Computer Science*, 4(11), 51–60. <https://doi.org/10.5815/ijmecs.2012.11.05>
- Kolb, D. A. (2015). *Experiential learning: Experience as the source of learning and development*. Pearson Education Inc.
- Kurniawati, F., Suyitno, H., & Mulyono. (2021). Mathematical communication ability in terms of student learning styles in inquiry based learning assisted by module. *Unnes Journal of Mathematics Education Research*, 10(2), 202–210. <https://journal.unnes.ac.id/sju/index.php/ujmer/article/view/48989>
- Machromah, I. U., Ishartono, N., Mirandhani, A., Muhroji, Samsudin, M., Basry, W., & Ernitasari. (2021). PISA problems solving of students with a visual learning styles. *Journal of Physics: Conference Series*, 1720(1). <https://doi.org/10.1088/1742-6596/1720/1/012010>
- Marzuki, Asih, E. C. M., & Wahyudin. (2019). Creative thinking ability based on learning styles reviewed from mathematical communication skills. *Journal of Physics: Conference Series*, 1315(1). <https://doi.org/10.1088/1742-6596/1315/1/012066>
- Miles, M. M., Huberman, A. M., & Saldana, J. (2014). Qualitative data analysis. In *A methods sourcebook*. A methods sourcebook.
- Moreno, L. A. H., Solórzano, J. G. L., Morales, M. T. T., Villegas, O. O. V., & Sánchez, V. G. C. (2021). Effects of using mobile augmented reality for simple interest computation in a financial mathematics course. *PeerJ Computer Science*, 7, 1–33. <https://doi.org/10.7717/peerj-cs.618>
- NCTM. (2000). *Principles standards and for school mathematics*. Key Curriculum Press.
- OECD. (2018). *PISA 2022 mathematics framework*. https://pisa2022-maths.oecd.org/files/PISA_2022_Mathematics_Framework_Draft.pdf
- P21. (2019). *Framework for 21st century learning*. P21 Partnership for 21st Century Learning. http://static.battelleforkids.org/documents/p21/P21_framework_0816_2pgs.pdf%0Ahttp://www.p21.org/our-work/p21-framework
- Porter, B. De, & Hernacki, M. (2005). *Quantum learning* (A. Abdurrahman & S. Meutia (eds.)). Kaifa.
- Pratiwi, I. C., Inganah, S., & Putri, O. R. U. (2020). Analysis on written mathematical communication skills at system of linear equations in two variables (SLETV) material viewed from student learning styles. *Mathematics Education Journal*, 3(2), 119–129. <https://doi.org/10.22219/mej.v3i2.11069>
- Radiusman, R., Yurniawati, Y., Simanjuntak, M., Sabariyah, R. J., & Nurmawanti, I. (2020). Students' vocational high school misconception reviewed from written mathematical communication ability. *Indonesian Journal of Science and Mathematics Education*, 3(2), 133–143. <https://doi.org/10.24042/ij sme.v3i2.6075>
- Rivai, A., Lestari, A., Munir, N. P., & Anas, A. (2023). Students' mathematical literacy in solving pisa problems observed by learning styles. *Jurnal Pendidikan Matematika*, 17(1), 121–134.

- Rogowsky, B. A., Calhoun, B. M., & Tallal, P. (2020). Providing instruction based on students' learning style preferences does not improve learning. *Frontiers in Psychology*, 11(164), 1-7. <https://doi.org/10.3389/fpsyg.2020.00164>
- Sakinah, M., & Avip, P. B. (2021). An analysis of students' mathematical literacy skills assessed from students' learning style. *Journal of Physics: Conference Series*, 1882(1). <https://doi.org/10.1088/1742-6596/1882/1/012075>
- Sari, L., Syahputra, E., & Surya, E. (2020). Development of autograph-based learning tools to improve mathematical communication skills students in vocational high school. *International Journal of Multicultural and Multireligious Understanding*, 7(8), 326-335. <https://doi.org/10.18415/ijmmu.v7i8.1880>
- Sheromova, T. S., Khuziakhmetov, A. N., Kazinets, V. A., Sizova, Z. M., Buslaev, S. I., & Borodianskaia, E. A. (2020). Learning styles and development of cognitive skills in mathematics learning. *Eurasia Journal of Mathematics, Science and Technology Education*, 16(11), 1-13. <https://doi.org/10.29333/EJMSTE/8538>
- Sholihah, A. N., Riyadi, & Triyanto. (2020). Students' mathematical communication abilities in solving geometry problems viewed from learning styles. *Journal of Physics: Conference Series*, 1538(1), 012102. <https://doi.org/10.1088/1742-6596/1538/1/012102>
- Sun, H., Yuen, D., Zhang, J., & Zhang, X. (2020). Is knowledge powerful? Evidence from financial education and earnings quality. *Research in International Business and Finance*, 52, 1-20. <https://doi.org/10.1016/j.ribaf.2019.101179>
- Tiffany, F., Surya, E., Panjaitan, A., & Syahputra, E. (2017). Analysis mathematical communication skills of student at the grade IX junior high school. *Ijariie-Issn*, 3(2), 2160-2164. www.noveltyjournals.com
- Van Campenhout, G. (2015). Revaluing the role of parents as financial socialization agents in youth financial literacy programs. *Journal of Consumer Affairs*, 49(1), 186-222. <https://doi.org/10.1111/joca.12064>
- Wise, S. (2013). The impact of financial literacy on new venture survival. *International Journal of Business and Management*, 8(23), 30-39. <https://doi.org/10.5539/ijbm.v8n23p30>