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Students' Learning Obstacle on Function Composition Related to the Ability to Understand Mathematical Concepts

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ABSTRACT

Function composition material is essential in vocational mathematics, yet many students struggle due to low conceptual understanding, especially in solving word problems. Students' difficulties in understanding the concept of story problems stem from their tendency to memorize formulas and their inability to represent visual information in mathematical form. This study used a qualitative method with a hermeneutic phenomenological approach. Using a purposive sampling strategy, the researcher selected 5 out of the 22 eleventh-grade students from SMKN 1 in Kampar Regency for in-depth interviews. The student test instrument included story problems on the conceptual understanding of function composition to identify potential difficulties and learning obstacles students may encounter. Data were triangulated from written tests, student and teacher interviews, and textbook analysis. Results based on Thompson's criteria showed that 45% of students scored 0 (very low understanding), while only 18% scored 4 (complete understanding). Three types of learning obstacles were identified: ontogenic, didactic, and epistemological. These findings highlight the need for a didactic design, such as using Liveworksheet, to improve conceptual understanding.

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INTRODUCTION

The important topic in the mathematics curriculum at the vocational high school level is function composition, as it encompasses many basic algebraic concepts and everyday applications, particularly for vocational subjects. However, many students receive low exam scores because they struggle to grasp algebraic function concepts, such as addition, subtraction, multiplication, division, and the relationships between functions. On the other hand, conceptual understanding allows students to understand the rationale behind a formula, its practical application, and how each mathematical concept meaningfully relates to one another (Fadiana et al., 2021). Constructing mathematical understanding should be through a meaningful learning process, not simply memorizing. Wulansari et al. (2021) argue that students who understand mathematical concepts can apply and adapt mathematical ideas to new situations. Students can construct their own knowledge by connecting existing knowledge, thereby improving their mathematical understanding. Mathematical conceptual understanding is a student's ability to explain, connect, and apply mathematical concepts in various contexts. Conceptual understanding is more than simply knowing information; it is also about being able to interpret that information into various

forms of more meaningful representations (Jatisunda & Nahdi, 2019). Bruner in Wen (2018) stated that the success of mathematics learning is highly dependent on learning that leads to conceptual understanding, namely, the lesson's basic structure. Students who understand concepts can connect new knowledge with prior knowledge, thereby creating a strong cognitive structure. Based on the opinions above, understanding mathematical concepts is important for students as a foundation for building knowledge hierarchically, because with conceptual understanding, students can organize their knowledge to acquire new knowledge. Therefore, students need to concretize mathematical concepts through direct experience or real-world activities to strengthen their understanding (Payadnya et al., 2021). For example, when learning function concepts, students may need to apply these concepts in everyday situations to better understand them, such as solving word problems related to calculating the price of goods paid after deducting a discount.

Story questions are a form of problem to find, namely, searching for, determining, or obtaining a specific value or object that is unknown in the question and fulfilling the conditions or requirements appropriate to the problem. In general, mathematical problems can be story problems. The assessment criteria for measuring students' mathematical understanding in solving story problems, according to Thompson (2008), are presented in Table 1.

Table 1 Mathematical understanding criteria

Score	Criteria
4	The application of mathematical concepts, principles, algorithms, notation, and terms is explained completely and correctly.
3	The use of mathematical concepts, principles, algorithms, notation, and terms is almost complete. The calculations are generally correct but contain a few errors.
2	2 The answer contains incorrect calculations, and the use of concepts and principles in the mathematical problem is incomplete.
1	Most of the answers contain incorrect calculations, and the concepts, algorithms, notation, terms, and principles in the problem are very minimal.
0	The answer does not demonstrate an understanding of the concepts and principles in the mathematical problem.

Then classify the percentage based on the scores obtained by the research subjects according to Table 2 (Suswigi & Zanthy, 2019):

Table 2 Percentage of classification

No	Percentage	Classification
1	0 - 34%	Very Low
2	35% - 54%	Low
3	55% - 64%	Currently
4	65% - 84%	Tall
5	85% - 100%	Very high

Students' difficulties in understanding concepts are thought to be related to a lack of mastery of prerequisites, a tendency to memorize formulas without understanding the concepts, and an inability to represent visual information in mathematical forms. Essentially, the structure of mathematical material is highly hierarchical and interconnected (Agusta, 2020). No conceptual stage should be skipped in mathematics learning. Therefore, textbooks are needed to provide a structured framework and comprehensive references. Although a team of experts compiles textbooks, this does not necessarily guarantee quality and accuracy. Poorly designed textbooks can create learning barriers and conceptual misunderstandings. Inaccurate textbook presentation can create learning obstacles (Hendriyanto et al., 2023)

Learning obstacles can describe the limits of a person's ability to master a topic (Prabowo et al., 2022). These learning obstacles can be characterized by the emergence of specific obstacles arising from the *Didactical Design Research* (Nurhayati et al., 2023), these obstacles can be grouped into three types: ontogenic, didactic, and epistemological.

a. Ontogenic obstacles arise when the knowledge provided does not align with the student's level of thinking due to limited mental readiness and cognitive abilities in receiving knowledge.

b. Didactic obstacles arise as a result of the didactic system, such as the stages of presentation, the completeness of the curriculum, and the teacher's presentation methods.

c. Epistemological obstacles arise due to limited student learning experiences. These obstacles arise from students' limited understanding and mastery of a concept, problem, or other topic (Maharani et al., 2022).

Learning resources are one of the learning obstacles that also support the learning process in terms of both type and form. Textbooks are one learning resource that supports the achievement of learning objectives in the curriculum. Textbooks are books designed in accordance with national education standards and follow the applicable curriculum for use in the learning process. Teachers generally rely on textbooks as the primary source in the learning process. Although a team of experts compiles textbooks, they do not necessarily guarantee quality and accuracy in both content and structure. Research by Hendriyanto et al. (2023) shows that, in mathematics textbooks under the 2013 curriculum, knowledge formation occurs only through the development of perceptual and memorization knowledge. Poorly designed textbooks can create learning barriers and lead students to misinterpret concepts.

Based on previous research analyzing students' mathematical conceptual understanding of function composition by Utami_2021et al., (2021) which only used essay questions, this study described students' conceptual understanding of function composition in word problems. The constructivist philosophy of education emphasizes the importance of students in constructing their own knowledge and understanding through interaction with their environment and learning experiences. In mathematics learning, word problems involve words or sequences containing mathematical concepts, which pose a challenge for students, as many receive low scores when solving them. The causes of student errors are not understanding the meaning of the question, not mastering the concepts related to the question, not mastering the steps in solving the question, not mastering the calculation process, not being able to determine the following formula to solve the problem, making mistakes in the previous process, not being able to write the final answer, forgetting factors, and not practicing enough in working on questions (Guillaume et al., 2023). Apart from looking at the questions given, this research also looked at the contents of the printed books used by students.

METHODS

This research employed a qualitative method with a hermeneutic phenomenology approach. Hermeneutic phenomenology is the description and interpretation of a person's experiences and the meanings and significance associated with them (Fardian et al., 2024). In this study, the causes of learning obstacles experienced by students were analyzed based on the students' learning experiences. This approach was used to explore students' learning obstacles in solving function composition story problems related to their ability to understand mathematical concepts. In addition, this approach was chosen to describe in detail the learning obstacles experienced by students.

This study employed a purposive sampling strategy, selecting subjects to inform and understand the main research problem by selecting each of the mathematical understanding

criteria. Data collection techniques in this study employed triangulation (combined), including tests and interviews with students, interviews with teachers, and document analysis in the form of notebooks and printed books.

Data analysis was conducted qualitatively by interpreting all data obtained from observations, interviews, tests, and field notes. Interviews were then conducted to clarify the findings. Conclusions were then drawn based on the analysis, interview results, and field notes. The analysis phase of this study is based on the hermeneutic phenomenology data analysis phase. Data analysis used Paul Ricoeur's hermeneutic circle approach, which includes four stages: naive understanding, explanation, appropriation, and critical comparison (Sungkar, 2023).

In general, this study conducted a test on word problems related to function composition. The purpose of providing story problems was to determine students' understanding and potential learning obstacles regarding the material on the composition of functions. The test was then administered to 22 Grade XI students at SMK Negeri 1 Bangkinang, Kampar Regency. The researcher analyzed students' comprehension of the composition function material using scoring guidelines (Table 1). Then, 5 of the 22 students were selected as research subjects for further analysis.

RESULTS AND DISCUSSION

The research results are presented as student learning outcomes, with data collected using a story-problem instrument to assess students' understanding of mathematical concepts related to function composition. Examples of story problems are listed in Figure 1.

Suatu pabrik kertas dengan bahan dasar kayu (x) memproduksi kertas melalui dua tahap. Tahap pertama menggunakan mesin I menghasilkan bahan kertas setengah jadi (m) dengan mengikuti fungsi m = f(x) = x2 - 3x - 2. Tahap kedua menggunakan mesin II menghasilkan kertas mengikuti fungsi g(m) = 4m + 2 dengan x dan m dalam satuan ton. Jika bahan dasar kayu yang tersedia untuk suatu produksi sebesar 4 ton, tentukan banyak kertas yang dihasilkan?

Figure 1 Story problem

Based on the test results given to students, there were difficulties in completing the questions. To determine the percentage of student achievement for each score, see Table 3.

Table 3 Percentage of students' mathematical concept understanding ability

Score	Criteria	Percentage
4	The application of mathematical concepts, principles, algorithms, notation, and terms is explained completely and correctly.	18%
3	The use of mathematical concepts, principles, algorithms, notation, and terms is almost complete. The calculations are generally correct but contain a few errors.	23%
2	The answer contains incorrect calculations, and the use of concepts and principles in the mathematical problem is incomplete.	9%
1	Most of the answers contain incorrect calculations, and the concepts, algorithms, notation, terms, and principles in the problem are very minimal.	5%
0	The answer does not demonstrate an understanding of the concepts and principles in the mathematical problem.	45%

Based on Table 3, for each criterion for achieving material competence in composition functions, many students still solve the questions incorrectly, and some do not answer because they do not know where to start the formula. The ability of students' understanding based on table 2, in criterion 4: the application of concepts, principles of algorithms,

notations, and mathematical terms is explained thoroughly and correctly, very low (18%), criterion 3: The use of concepts, principles, algorithms, notations, and mathematical terms is almost complete; calculations are generally correct but contain a few errors, very low (23%); criterion 2: Answers contain incorrect calculations, and the use of concepts and principles for mathematical problems is incomplete, very low (9%), criterion 1: Most answers contain incorrect calculations, concepts, algorithms, notations, terms, and principles for the problem are very minimal, very low (5%), and criterion 0: Answers do not show an understanding of concepts and principles for mathematical problems (low, 45%). Almost all students (45%) were in the very low category (score 0), indicating no understanding of function composition concepts. To understand the causes of students' difficulties in solving problems, see the following explanation:

Criterion 4: The application of concepts, algorithmic principles, notation, and mathematical terms is explained thoroughly and correctly. Only 4 students met this criterion. Student answers that meet criterion 4 are listed in Figure 2.

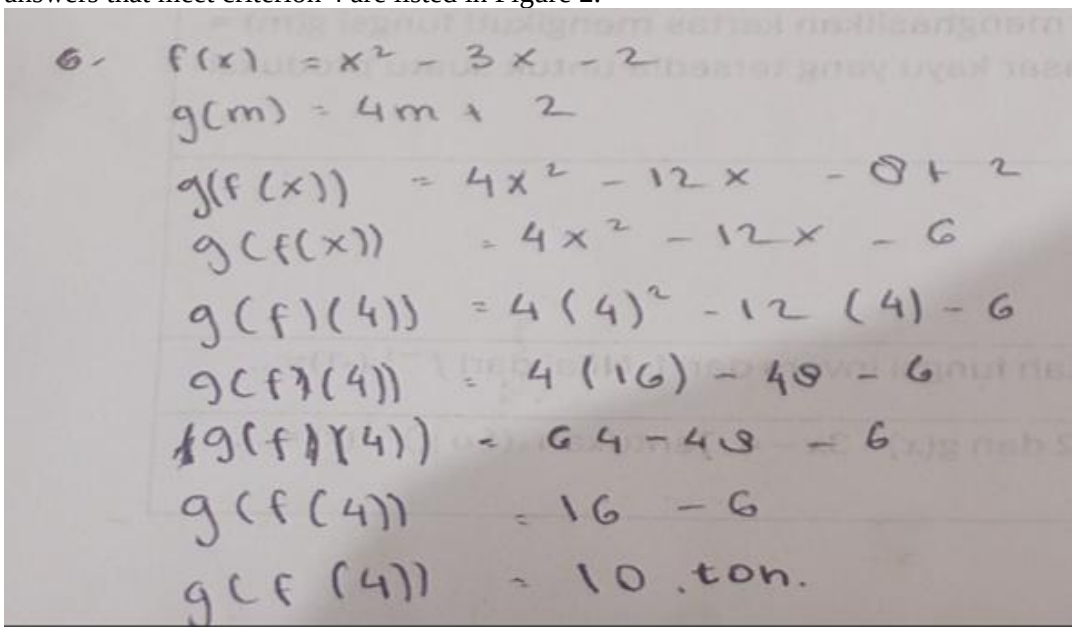

Figure 2 Student answers that meet criterion 4

Based on the students' answers, as shown in Figure 2, students understand the steps for solving the problem: writing the first and second formulas and then combining them via function composition. Each formula is explained in full and correctly, in accordance with the algorithm's notation and principles. To further confirm the students' answers, an interview was conducted with one student who met criterion 4. The student was able to explain the answer process with the correct steps and understood how to solve function composition, even though it was presented as a story problem. This student's initial abilities were also good. When the interview was tested on the prerequisite material, the student answered correctly and precisely. Understanding in this sense does not only mean knowing the network of frames that structures the object of understanding, but, moreover, it involves knowing which frames are essential (for which purpose) (Carl et al., 2021). According to Gestalt theory, the process of recalling memories involves conceptualizing past experiences in the present. This means that students have a good understanding of the concept.

Criterion 3: The use of concepts, principles, algorithms, notations, and mathematical terms is almost complete. The calculations are generally correct but contain a few errors.

Five students meet this criterion. The following is one of the students' answers to criterion 3. Student answers that meet criterion 3 are listed in Figure 3.

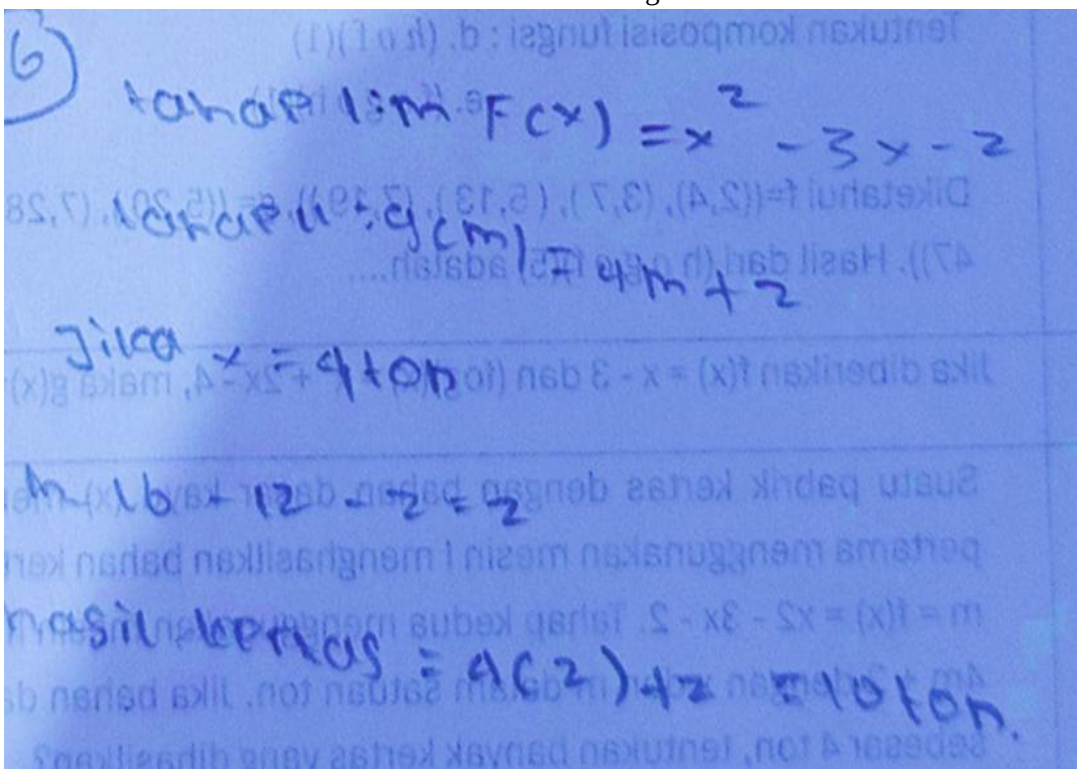

Figure 3 Student answers that meet criterion 3

Figure 3 shows that the final answer is correct and that the use of mathematical concepts, principles, algorithms, notation, and terms is almost complete. The student wrote the formulas used in the correct order, but when entering the variable values, the student did not state whether the result was for m or g(m). When asked in the interview, the student was confused about the difference between m and g(m). The student only completed the problem in the order requested by the question. In the problem, the first formula seen was f(x). The student entered the numbers in the first formula, then the result was entered in the second formula, g(m). For questions asking for the final result, this is not a problem, but if the question asks for the result of the first process, the answer could be incorrect. Therefore, in cases like this, it must be emphasized to students that the formula being asked for must be truly understood, whether it is the combined result of a function composition or just a single function.

Criteria 2: The answer contains incorrect calculations and incomplete application of the principle concept to the math problem. Two students met this criterion. The following is the answer of one student with criterion 2. Student answers that meet criterion 2 are listed in Figure 4.

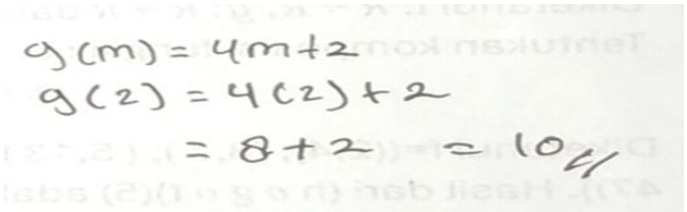

Figure 4 Student answers that meet criterion 2

In Figure 4, the answer contains incorrect calculations and an incomplete application of the principle to the math problem. The student immediately entered the value of m without understanding where it was obtained. They were either guessing or seeing a friend who had already found the value of m and not fully stating the origin of the value. The researcher interviewed students about why the answers they wrote were simply guesses of the number. “Hmmm, I just guessed the numbers by looking at the first formula and then immediately substituting it into the second formula, assuming the only solution was to use the last formula." Clearly, the student did not understand the concept or how to solve function-composition problems. When asked about the function composition story problem, the student laughed and was confused about how to answer.

Criterion 1: Most answers contain incorrect calculations, with very little understanding of concepts, algorithms, notation, terms, and principles related to the problem. Only one student met this criterion. Student answers that meet criterion 1 are shown in Figure 5.

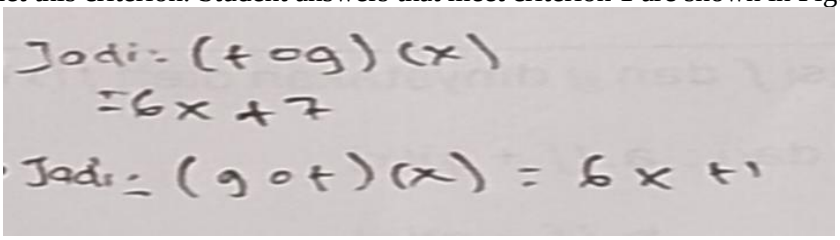

Figure 5 Student’s answers that meet criterion 1

Most of the answers contained incorrect calculations, concepts, algorithms, notations, terms, and principles related to the problem. Students assumed the function $f(g(x)) = g(f(x))$ so that the resulting formulas were the same. The researcher interviewed the student: “Why is your answer like that?” The student answered, "I think the function can be reversed like addition." An analysis of the solution to the problem shows that students' conceptual understanding of function composition was minimal. Students answered without writing down any formulas in the problem. After the interview, when asked what was asked for in the problem and why they did not write what was known and asked, they assumed the first function was f(x) and the second was g(m), as stated in the problem. Then the student said the problem asked to determine the number of sheets of paper produced and focused only on the final result, not the problem as a whole. The student did not know which function was the first and which was the second. The student was unable to determine the function and could not create a mathematical model of the story problem.

Criterion 0: Answers do not demonstrate an understanding of the concepts and principles of the math problem. Ten students met this criterion. Their answers were inconsistent with the problem and appeared haphazard, with some failing to answer the story problem. Student answers meeting this criterion. The students' answers that meet criteria 0 are shown in Figure 6.

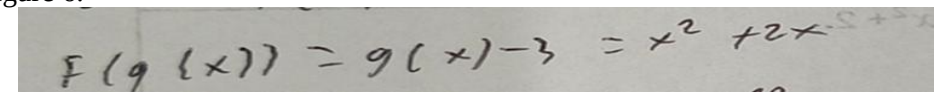

Figure 6 Student’s answers that meet criterion 0

Figure 6 shows that the answers do not demonstrate an understanding of the concepts and principles of the math problem; almost half of the students fall into this category. The answer sheet shows that the required formula does not relate to the question. The use of function composition is also incorrect and inappropriate, indicating that the students do not understand the concepts and principles of the math problem. After the interview, the students stated that they did not understand and did not know which formula to use to solve

the problem. Because they forgot, they made up what was known about the problem. They did not understand what the problem meant and were confused when determining which formula to use. Cognitive learning theory supports active learning, in which individuals are actively engaged in efforts to make sense of their experiences and develop understanding. Then, to further analyze students' learning obstacles, they were asked to review their math notes while studying function composition. The composition of the function notes are shown in Figure 7.

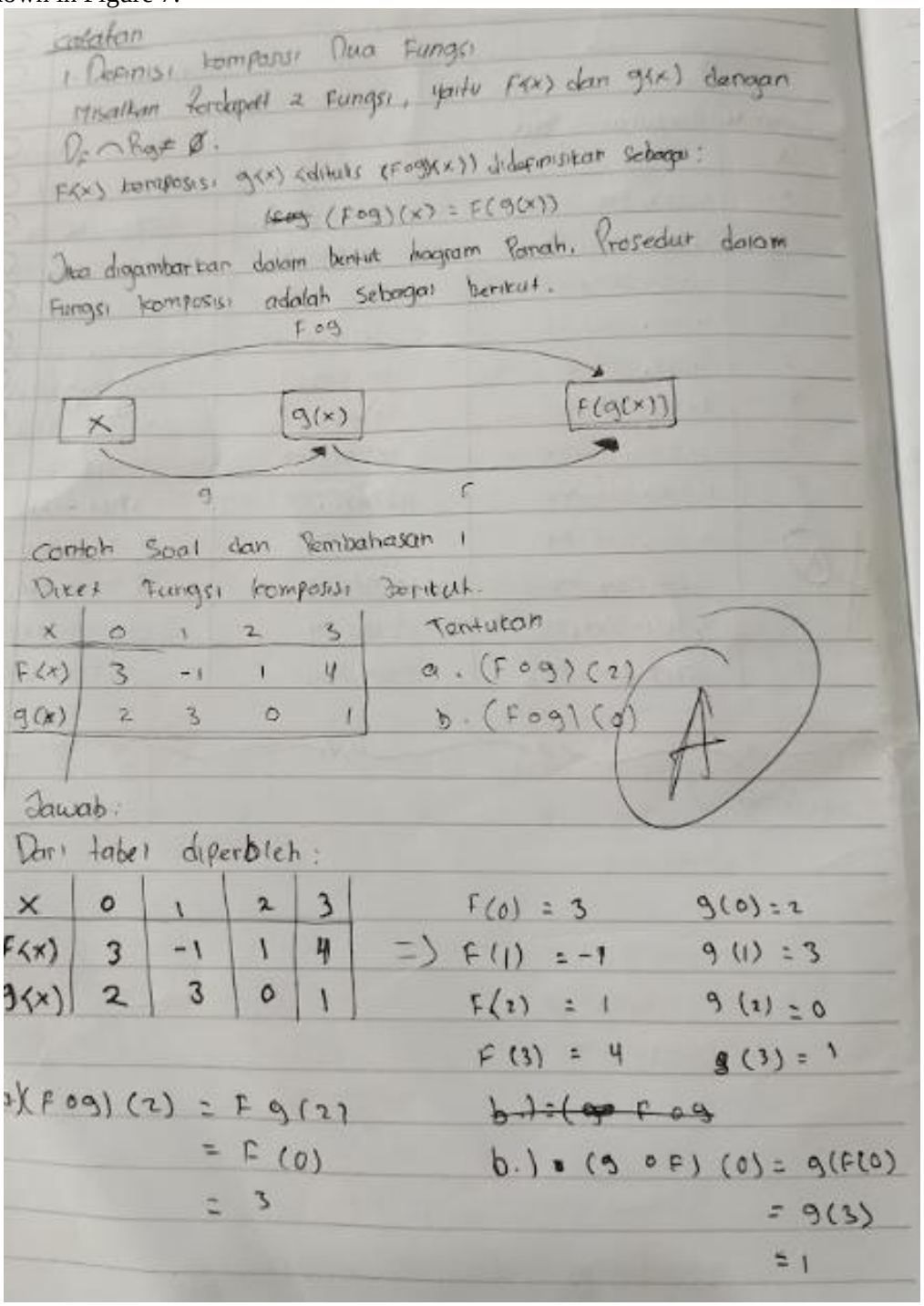

Figure 7 Function composition notes

After reviewing the students' notes in Figure 7, student notes show limited examples and no story problem practice. During interviews with students, they mostly look at the material in printed books and work through the problems. Then, after checking the story problems in the printed books published by the curriculum and book center, they are presented in Figure 8.

"The amount of paper required to print x copies of a mathematics module is expressed by the function $k(x) = 250(x + 1)$ sheets. The printing cost required for k sheets is $b(k) = 400k + 20,000$ (in rupiah). If today's expenditure for printing x copies of the module is Rp10,120,000.00, determine the number of module copies printed."

Jumlah kertas yang diperlukan untuk mencetak x eksemplar modul matematika dinyatakan dalam fungsi $k(x) = 250(x + 1)$ lembar. Biaya pencetakan yang diperlukan untuk k lembar adalah $b(k) = 400k + 20.000$ (dalam rupiah). Jika pengeluaran hari ini untuk mencetak x eksemplar modul adalah Rp10.120.000,00 tentukan banyak eksemplar modul yang dicetak.

Figure 8 Function composition practice questions

The story problem in Figure 8 could be categorized as difficult for vocational high school students. The questions directly use large numbers and complex function formulas that many students do not understand, leading many to fail the exercise. Textbook exercise with large numbers and incomplete worked examples, potentially causing didactic obstacles.

Students who meet criterion 4 align with Ghifari et al. (2022), who stated that understanding the initial concepts of algebra is crucial for students to build the basic knowledge needed at the next level. Algebra allows one to understand various rules, symbols, and how the system operates. Algebra is a prerequisite for studying the composition of functions and so on. Students were unable to define functions and create mathematical models for the word problems. Sari & Afriansyah (2022) stated that when working on word problems, students were unable to interpret the problems into a mathematical form that would determine the function. Therefore, these students' answers did not meet the criteria for presenting concepts in various mathematical representations. Students do not understand what the question means and are confused about which formula to use. Lestari et al. (2018) stated that students can read the question but do not understand what it asks, are not thorough in their understanding, and are confused when determining which formula to use, leading to students' answers not matching what the question wants. In addition, Mulyani et al. (2018) said that students' inability to understand mathematical concepts when answering the questions given and during the learning process, where students do not really understand the content of the material, is the reason why students often fail to learn mathematical concepts well and accurately. When studying the material, students often memorize formulas and then easily forget what they studied previously. The importance of mathematical education requires innovative didactic strategies to enhance the understanding and application of mathematical concepts (Vivanco-Galván et al., 2024)

Based on an analysis of students' answers to story problems related to their mathematical conceptual understanding, it was found that, overall, 59% of 22 students had very low comprehension, with scores below 3. Caused by various factors, including the fact that many students did not understand the prerequisite material for studying function composition. To determine the cause of these errors, interviews were conducted with the teacher in the class, who found that most students were still not fluent in multiplying, let alone dividing, whole numbers. Many students performed incorrect algebraic operations because their basic knowledge was not yet solid, likely due to the long period of online learning during the pandemic. Students studied independently without direct teacher guidance, leaving many confused and lacking a grasp of basic mathematical concepts by the time they reached vocational high school. NCTM (2000) states that mathematical understanding is a crucial aspect of the principles of mathematics learning. Mathematical understanding is more meaningful when developed by the students themselves. Therefore, understanding cannot be forced; the teacher provides mathematical concepts and logic. If students forget the algorithms or formulas provided, they cannot solve mathematical problems. In line with this, state that three important skills students must possess in learning mathematics are the ability to understand mathematical concepts, communication skills, and mathematical problem-solving skills (Chintya, 2021). Based on the above description, conceptual understanding is the initial and primary skill that students must possess, as it will be easier to master other skills and solve problems using algorithms. Therefore, Pebrianti & Puspitasari, (2023) stated that the foundation that must be instilled in students to learn mathematics is not just about calculating and memorizing formulas; students must first understand mathematical concepts. In line with this, understanding a concept is very important, as mastering prerequisite material makes it easier to understand the following material. In addition, well-structured and high-quality textbooks can help teachers understand content, pedagogy, and teaching strategies, as well as help students understand topics, activities, and exercises (Roslinda, 2020).

CONCLUSION

Based on the research results, it can be concluded that students experience three learning obstacles that were identified: (a) ontogenic – students lack prerequisite algebraic skills; (b) epistemological – students rely on personal beliefs rather than quantitative reasoning and misconceptions based on subjective considerations (students solve problems using their personal beliefs and views without analyzing and using quantitative information about the problem); and (c) didactic – instruction and textbooks do not support step-by-step understanding. Based on the identified learning obstacles, it is hoped that future didactic designs, such as integrating Liveworksheet with scaffolded story problems, are recommended.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

For research articles with multiple authors, a short paragraph stating each author's contributions should be included. The following statement should be used: “Conceptualization, SP and NR; methodology, SP; formal analysis, NP; writing—preparation of the original draft, NR. Authorship should be limited to those who have contributed substantially to the reported work.

AI DISCLOSURE STATEMENT

The author used Google Translate and Grammarly to translate this work into English. After using the tool/service, the author thoroughly reviewed and edited the content as needed and takes full responsibility for the publication's content. The authors declare that this research was prepared, researched, written, and edited without the aid of artificial intelligence (AI) techniques.

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