

Conceptual Knowledge of Seventh Graders with High-Mathematics Ability in Solving Linear Equation Problems

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Abstract: Conceptual knowledge is a crucial foundation for learning more advanced mathematics, especially when students begin to explore algebraic concepts such as linear equations. However, even students with high mathematical ability may encounter challenges in articulating and transferring conceptual understanding to new contexts. This study aims to describe a seventh-grade student's conceptual knowledge of solving linear equation problems. A qualitative descriptive method was used, involving one student selected based on mathematics ability and communication skill. Data were collected through a conceptual knowledge task and a semi-structured interview. The results indicate that the student demonstrated a solid understanding of unit conversion and the structure of the problem, applied procedures accurately, and showed awareness of relationships among concepts. However, the student struggled to express formal mathematical terminology and encountered difficulty transferring concepts when the problem context was slightly altered. These findings emphasize that even high-performing students may benefit from instructional support that increases flexibility and the depth of conceptual knowledge.

INTRODUCTION

Mathematics is a field that requires a strong understanding of concepts, alongside the ability to solve problems accurately (Sáenz, 2009). In mathematics education, conceptual and procedural knowledge are two crucial, complementary components (Kilpatrick et al., 2001). This study specifically focuses on conceptual knowledge, which plays a foundational role in enabling students to understand, apply, and reason with mathematical ideas. According to Hiebert & Lefevre (1986), conceptual knowledge is knowledge rich in relationships, forming a connected web in which the relationships between concepts are as meaningful as the ideas themselves. Rittle-Johnson & Schneider (2014) further emphasize that conceptual knowledge supports flexible thinking and problem solving, and that it develops in tandem with procedural knowledge. Because of its important role in mathematical reasoning, examining students' conceptual knowledge in linear equations is essential for deeper learning and long-term memory.

In the Indonesian education context, the implementation of the *Kurikulum Merdeka* has emphasized the importance of conceptual knowledge. Unlike previous approaches that focused more on memorizing formulas, this curriculum encourages students to understand the logic behind mathematical concepts before learning shortcuts to solve problems (Pusat Kurikulum dan Pembelajaran, Badan Standar, Kurikulum, dan Asesmen Pendidikan,

Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, 2024). As a result, students are expected not only to get the correct answers but also to understand the reasoning behind the steps they take (Barumbun & Kharisma, 2022). However, curriculum changes alone have not yet resolved the ongoing challenges regarding students' low mathematics competence.

International studies, such as PISA 2022, show that Indonesian students scored an average of 366 in mathematics, far below the OECD average of 472 (OECD, 2023). Only about 18% of students reached level 2, the minimum threshold for functional mathematical literacy. This indicates that most students are still unable to solve simple real-life math problems. This situation highlights the urgent need to pay more attention to students' understanding of basic mathematical concepts, especially when they transition to junior secondary school.

Seventh grade is a crucial transition stage from primary to secondary education, where students begin to learn more abstract mathematical content, such as algebra and linear equations (Kaur et al., 2022; Piercea et al., 2010). At this stage, conceptual knowledge plays an important role in helping students succeed in learning more complex mathematics in the future (Blanton et al., 2015; Boaler, 2008). Difficulties in understanding these early concepts may reduce students' motivation and contribute to math anxiety, thereby negatively impacting their academic performance (Gresham, 2007).

Previous studies have investigated students' conceptual understanding in solving mathematical problems. Syam (2019) found that while students were often able to carry out procedures correctly, their conceptual understanding was still lacking. Felia & Defitriani (2021) also showed that strong conceptual knowledge can improve students' flexibility in applying procedures, but their study did not explore in depth the manifestation of conceptual knowledge in actual problem-solving. Valentine et al. (2024) reported that only 39.39% of students at a junior high school in Cirebon demonstrated high conceptual understanding of linear functions. However, the findings were largely presented in percentage form and did not explore how students' thinking processes reflected their conceptual knowledge.

While much research has focused on students who struggle with mathematics, less attention has been given to how students with high mathematical competence demonstrate their understanding of concepts. These students are often assumed to have fully mastered conceptual knowledge, yet this assumption is rarely examined in depth. Exploring their reasoning can provide valuable insight into how strong mathematical thinkers structure their understanding and solve unfamiliar problems.

To follow up on these findings, this study focuses on how seventh-grade students with high mathematical ability demonstrate conceptual knowledge when solving a linear equation of one variable problem. This study uses one problem that targets higher-order thinking at the apply level (C3) based on the revised Bloom's taxonomy (Anderson, L. W., & Krathwohl, 2001). The problem is designed not only to assess students' ability to perform

calculations but also to explore how they apply the concepts they have learned in a new context and represent their understanding logically.

Therefore, the researcher conducted a study entitled “Conceptual Knowledge of Seventh Graders with High-Mathematics Ability in Solving Linear Equation Problems”, which aims to describe how students with high mathematical ability demonstrate their conceptual knowledge in solving linear equation problems.

METHOD

Research Design

This research employed a qualitative descriptive approach to explore and describe the conceptual knowledge demonstrated by a seventh grader with high mathematics ability in solving a linear equation problem. A qualitative method was chosen because it allows for an in-depth understanding of individual thinking processes, represented in words and visuals rather than numerical data (Moleong, 2017).

Participants

The participant in this study was a seventh-grade student at a private junior high school in the 2024/2025 academic year. The student was selected through purposive sampling. The selection process included a Mathematical Ability Test (MAT), administered to all students in the class to assess their level of mathematical ability. Based on the results and guided by Somakim’s classification scale (Novitasari, 2015), the researcher selected one student from the high mathematical ability category who also demonstrated good communication skills. This student was chosen as the research subject of this study.

Data Collection

The data collection techniques used in this research were written tests and interviews. The written tests consisted of a Mathematical Ability Test (MAT) and a Conceptual Knowledge Task (CKT). At the same time, the interview was conducted after the written task to explore the students’ thinking processes in greater depth.

The MAT was administered to all seventh-grade students in the selected school to classify students into three levels of mathematical competence: high, medium, and low. The test consisted of nine questions: five multiple-choice and four short-answer. The content focused on algebraic fundamentals, such as arithmetic operations with variables, properties of equality, and algebraic expressions, and aligned with C2 to C4 cognitive levels based on Bloom’s Revised Taxonomy (Anderson & Krathwohl, 2001). This test identified the research subject, a student with high mathematical ability.

The Conceptual Knowledge Task (CKT) consisted of one descriptive question focusing on linear equation problems. This question was developed to target the apply (C3) levels, which was designed to examine how the student applied conceptual knowledge in solving a linear equation problem.

The interview was conducted after the student completed the CKT and was semi-structured. The interview aimed to confirm the subject’s reasoning behind their written response and to uncover aspects of their conceptual knowledge that may not have been

visible from the written task alone. The interview questions were guided by conceptual knowledge indicators developed by Hiebert and Lefevre (1986), and the researcher adapted the questions as necessary to explore deeper into the student’s thinking. The following figure is the conceptual knowledge task question used in this study.

Dina wants to send a package containing several bottles of liquid soap to another city. The empty box weighs 200 g, and each bottle of liquid soap weighs the same. She measures the total weight of the package and finds that it weighs 3.2 kg. If Dina puts 5 bottles of liquid soap in the box, how many grams does one bottle of liquid soap weigh?

Figure 1. Conceptual Knowledge Task Question

Data Analysis

The Mathematics Ability Test (MAT) in this research was used to classify students into three levels of mathematical competence: high, medium, and low. The test consisted of five multiple-choice and four short-answer questions related to linear equations and algebraic concepts. The test was conducted in 60 minutes, and students' work was scored according to predetermined scoring guidelines.

The student scores were analyzed using the average ($\bar{x} = 64.14$) and standard deviation (SD = 23.07) based on their total results. The categorization of mathematics ability level followed the criteria based on Somakim’s classification scale (Novitasari, 2015). The following table shows the range used for grouping students in this research:

Table 1. Classification of Students’ Mathematics Ability

Score Interval	Category
$MAT\ Score \geq 87,21$	High
$41,07 \leq MAT\ Score < 87,21$	Medium
$MAT\ Score < 41,07$	Low

Based on the test results, one student was selected to represent the high-mathematical-ability group. After choosing the subject, the student was given a Conceptual Knowledge Task (CKT) consisting of a single problem on linear equations.

The student's conceptual knowledge was analyzed using indicators adapted from Hiebert and Lefevre (1986). The indicators were classified into four main dimensions with corresponding sub-indicators, as shown in the following table:

Table 2. Conceptual Knowledge Indicators in Solving Linear Equation Problems

Indicator	Sub-Indicator	Code
U (Understanding of Principles Underlying Mathematical Concepts)	Giving logical explanation for the decisions or solutions	U1
	Giving the correct definitions of mathematical concepts used in the given problem	U2
R (Recognition of Relationships Among Mathematical Ideas)	Demonstrating an understanding of how mathematical concepts apply to solve equations	R1
	Demonstrating how mathematical concepts are related in solving problem by expressing the given problem in mathematical form	R2
I (Ability to Integrate Facts into a Connected Knowledge Network)	Connecting facts and concepts learned in different contexts to form an understanding	I1
	Justifying why certain steps were taken in solving problem	A1

Indicator	Sub-Indicator	Code
A (Awareness of Why Mathematical Rules and Procedures Work)	Explain why certain procedures or methods are effective when solving problem	A2

The student's written work on the CKT was analyzed based on the presence of these indicators. To enrich the analysis, a semi-structured interview was conducted after the test. The interview aimed to explore the students' reasoning in more detail and confirm responses that were unclear in the written task.

The interview data were analyzed using the model by Miles, Huberman & Saldana (2014), which consists of data reduction, data presentation, and conclusion drawing.

RESULT AND DISCUSSION

Data collection in this research was conducted at a private junior high school in Sidoarjo. The process began with a Mathematical Ability Test (MAT) for seventh graders in a class of 32 students. This test was used to classify students into three categories of mathematical competence: high, medium, and low, based on predetermined scoring criteria.

Based on the MAT results, students were grouped by their average and standard deviation. Based on this classification, one student from the high category was selected to participate in the next stage of the research. The selection was also based on the student's communicative ability, which was considered essential to ensure that the subject could clearly express their thinking process during the interview.

The selected subject, referred to as SR, achieved the highest score of 100 in the mathematics ability test and demonstrated strong communication skills during the selection process. The subject was then given a Conceptual Knowledge Task (CKT) focused on solving linear equation problems, followed by a semi-structured interview to explore the student's reasoning in more depth.

This section presents the findings and interpretation of SR's conceptual knowledge, based on both written and oral data. The analysis is structured according to the indicators of conceptual knowledge as proposed by Hiebert and Lefevre (1986), including understanding of principles, recognition of relationships, integration of facts, and awareness of procedures. To support the findings, this section also includes samples of student work and excerpts from the interview.

Understanding of Principles Underlying Mathematical Concepts

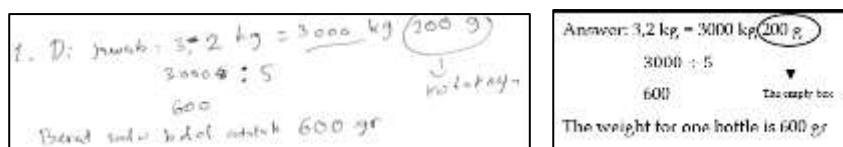


Figure 2. SR's Answer for CKT Question

In the first sub-indicator, namely giving a logical explanation for the steps or decisions of problem solving, students showed good ability. This can be seen from the student's explanation related to the conversion of weight units. She stated that the kilogram unit

needed to be converted to grams because the question asked in grams (Figure 2). The following are transcript of interviews conducted to help clarify the reasons for student work.

- R.01 : How do you solve this problem?
 SR.01 : First, 3.2 kg is converted to grams because the problem required the answer in grams. **(U1)**
 R.02 : How much will it be?
 SR.02 : 3000 kg 200 grams. [sic].
 R.03 : What does that mean?
 SR.03 : 3000 kg plus 200 grams. Eh, I mean 3000 grams plus 200 grams. **(U1) (R1)**
 R.04 : How do you convert kg into grams?
 SR.04 : It is multiplied, because it's going down (pointing to the graph she wrote). If it goes up, it's divided. **(U1) (R1)**
 R.05 : Then how much does it go down from kg to grams?
 SR.05 : It goes down 3 times so multiply by 1000. **(U1)**

Although in the interview transcript the student initially mentioned an incorrect unit (SR.02 and SR.03), this appears to be a verbal inaccuracy. She was able to recognize and immediately correct the unit from kilograms to grams, indicating that she understood the concept of unit conversion. Therefore, this minor slip does not reflect a misconception, but rather a momentary verbal error during the interview process.

Furthermore, students can explain the unit conversion procedure using the unit ladder they remember. The following is a picture of the unit ladder that the student wrote on the answer sheet.

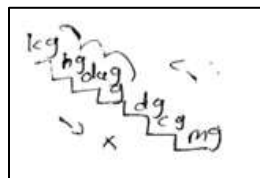


Figure 3. Weight Unit Ladder Written by SR

Based on the results of student work and student answers during the interview, a high-ability student can demonstrate that she understands the basic principles of unit conversion that support her understanding of the steps to solve the problem.

However, in the second sub-indicator, namely, providing correct definitions of the mathematical concepts used in the problem, the student has not shown adequate understanding. This was made clear during the interview session, the researcher asked about the term "variable", "coefficient" and "constant", and the student only answered hesitantly by mentioning 5 bottles of soap as a variable. and the number 200 grams as a constant, but was unable to explain precisely. This can be seen from the following interview excerpt.

- R.09 : Since you said this is linear equation of one variable, what do you think the variables are?
 SR.09 : Hmm, the variable is 5 bottles.
 R.10 : Which is the coefficient? Do you remember what the coefficient is?
 SR.10 : The coefficient is the number in front of the variable. But I don't know which one.
 R.11 : What about the constant?
 SR.11 : The constant is 200 grams. **(U2)**

Based on the interview results, it shows that student has not mastered the conceptual definition of the components in linear equation of one variable when applied in a problem.

Recognition of Relationships Among Mathematical Ideas

Student can show an understanding of the application of mathematical concepts in solving the given problem. In her written answer, the student converted 3.2 kg into 3000 kg 200 grams then divided 3000 grams by 5 (Figure 2). However, the student realized the error in writing her answer and corrected it during the interview session (SR.03).

The student's work shows that the student understands that the division represents the process to determine the weight of one bottle of liquid soap. Further explanation provided by the student in the interview session as follows.

R.06 : Then you wrote 200 grams here as the weight of the empty box, right?

SR.06 : Yes, so the 200 grams did not use for the calculation. So only 3000 grams divided by 5 bottles equals 600 grams per bottle. (R1) (A1)

However, in the second sub-indicator, namely expressing the relationship between concepts in mathematical or symbolic form, students seemed unable to express the form of a linear equation of one variable from the problem. This can be seen when she asked to write the form of linear equation of one variable, the student answered as follows.

R.07 : Do you think this problem is linear equation of one variable?

SR.07 : Yes.

R.08 : Okay, can you write the linear equation of one variable form of this problem??

SR.08 : Hmm, I'm still confused.

The student's answer in this interview session shows that although the student understands the context and the solution procedure, she has not been able to present and represent it in symbolic form according to his knowledge of linear equations of one variable.

Ability to Integrate Facts into a Connected Knowledge Network

She mentioned that the conversion of units from kilogram to grams follows the pattern "if it goes up then it is multiplied, and if it goes down then it is divided" and even drew a unit ladder on her paper (Figure 3 and SR.04). The use of this unit ladder shows that student also need visualization to support her understanding.

This knowledge is then not only used by students to work on the problem, but also serves as the basis for their decisions in solving it. Therefore, the student has succeeded in showing the connection between the facts she has learnt and the problem's context.

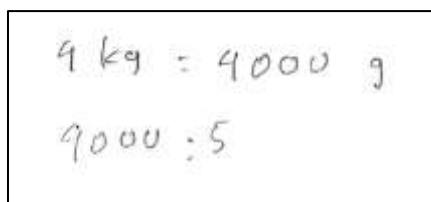
Awareness of Why Mathematical Rules and Procedures Work

The student has also shown awareness of the reasons for using specific steps in problem-solving. She explicitly stated that the 200 grams (the weight of the empty box) should not be included in the division (Figure 2). This is also supported by the interview excerpt (SR.06).

The student's written answer and interview showed that she understood that the weight of the empty box was not part of the five bottles referred to in the division, although she did not write it explicitly in the form of subtraction $3200 - 200$.

However, when the researcher proposed a different problem variation during the interview to dig deeper into students' understanding by changing the total weight of the package to 4 kg, students did not subtract the weight of the empty box first, and immediately

divided 4000 by 5. This is evident in students' written work in Figure 4 and in the excerpt below.



$4 \text{ kg} = 4000 \text{ g}$
 $4000 : 5$

Figure 4. SR's Answer for Variation Problem

R.12 : Suppose that the total package is 4 kg. What will you do?

SR.12 : Change the kg into grams first, so it will be 4000 grams.

R.13 : Then what will you do?

SR.13 : 4000 grams divided by 5. The result is already the weight for 1 bottle.

This error shows that although the student had realized the need to exclude the weight of the empty box in the main problem, the understanding was not fully embedded. This might have happened because in the main problem, the total weight was 3.2 kg, where the student could immediately separate 200 grams as the weight of the empty box, without fully understanding that it should be 3.2 kg minus 200 grams. Based on these results, the researcher can conclude that students' procedural awareness is not entirely stable when the context changes.

Discussion

The findings indicate that although the student demonstrated strong procedural fluency and intuitive problem-solving skills, her understanding was not yet fully formalized. In particular, the student was able to correctly perform unit conversions, identify relevant quantities, and apply appropriate numerical operations. However, she did not explicitly conceptualize the situation as a linear equation in one variable, nor did she consistently employ formal mathematical terminology such as *variable*, *coefficient*, and *constant*.

This limitation is pedagogically significant, even for students who appear to solve problems successfully through intuition. Explicitly conceptualizing a situation as a linear equation in one variable plays a crucial role in supporting the transition from arithmetic and contextual reasoning to formal algebraic thinking. Without such formalization, students may rely heavily on surface-level cues or familiar contexts, which can hinder their ability to generalize concepts, construct symbolic representations, and transfer knowledge to unfamiliar or more abstract mathematical problems.

For example, although the student intuitively identified "5 bottles" as a meaningful quantity, explicitly defining it as a *variable* is essential for developing algebraic reasoning. The concept of a variable allows students to move beyond specific objects or quantities and to represent relationships symbolically. Failure to articulate this explicitly may limit students' ability to manipulate algebraic expressions, interpret equations structurally, and engage in higher-level mathematical reasoning, such as solving systems of equations or working with functions.

These findings align with previous research by Fauziyah (2020), who reported that students with high mathematical ability often demonstrate strong interpretative and evaluative skills but may experience difficulty explicitly articulating appropriate mathematical representations or terminology. Similarly, Fauziyah (2020) emphasized that even high-achieving students may encounter challenges when faced with unfamiliar or modified contexts, particularly when required to transfer prior knowledge or apply formal concepts without explicit prompts. This pattern is further supported by Valentine et al. (2024) and Gultom and Tambunan (2022), who found that high-performing students may still make errors when contextual features of a problem change.

Despite these limitations, the student's responses reflect a deep and integrated conceptual understanding in familiar contexts. She was able to explain her reasoning, apply visual representations such as the unit ladder, and connect real-world situations to mathematical procedures. This suggests that while her conceptual knowledge is strong, it remains partially context-dependent and has not yet developed into a fully flexible and transferable understanding.

CONCLUSION AND SUGGESTIONS

This study aimed to explore the conceptual knowledge of a high-ability seventh-grade student in solving linear equation problems. The findings reveal that the student demonstrated strong conceptual understanding, particularly in applying unit conversions, identifying relevant quantities, and explaining the reasoning behind chosen procedures. Her ability to visualize concepts through representations, such as the unit ladder, further supported effective problem-solving strategies.

However, the student showed limited ability to explicitly define and formalize key mathematical components, including variables, coefficients, and constants, as well as to represent the problem symbolically as a linear equation in one variable. In addition, she experienced difficulty transferring her conceptual understanding to new or modified problem contexts. These findings suggest that although the student's conceptual knowledge is deep, it remains partly dependent on familiar situations and intuitive reasoning rather than explicit formalization.

It should also be acknowledged that this study is based on a single-case qualitative design, which inherently limits the generalizability of the findings to a broader student population. Nevertheless, the depth of analysis provides valuable insights into how high-ability students may still experience challenges in formalizing mathematical concepts. These findings can serve as a foundation for further research, including quantitative studies or multiple-case investigations, to examine whether similar patterns occur across different levels of mathematical ability and instructional contexts.

Based on these findings, the following suggestions are proposed. Teachers should provide learning opportunities that emphasize the explicit use of formal mathematical terminology (e.g., *variable*, *coefficient*, and *constant*) alongside intuitive and procedural problem-solving strategies. Instruction should incorporate varied and modified problem

contexts to support students' ability to transfer conceptual knowledge across different situations. Students should be encouraged to represent problems symbolically and to explain their reasoning using formal mathematical language, not solely numerical procedures. Future research could involve students with different levels of mathematical ability to gain a more comprehensive understanding of how conceptual knowledge is constructed and transferred across competence levels. Further studies using multiple-case or longitudinal designs may offer deeper insights into how students' conceptual understanding evolves over time and across diverse instructional contexts.

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