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Developing Mathematical Proficiency in Junior High School: A Case Study on Linear Equations in One Variable

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Abstract. This study aimed to support the development of mathematical proficiency in Junior High School students, especially on linear equations in one variable. This research is a case study in two public schools in Bandung, Indonesia, involving 50 class VII Junior High School students. This qualitative study collects data from test results and reviews documentation results. The data were analyzed with instrument validity, data collection, data reduction, data presentation, and concluding stages. The result showed 1) Students achieve the category of high mathematical proficiency in conceptual understanding with a percentage of 81%; 2) Students achieve the category of high mathematical proficiency in procedural fluency with a percentage of 87%; 3) Students achieve the category of moderate mathematical competence in strategic competence with a percentage of 67%, 4) Students achieve high mathematical skills in the category of adaptive reasoning and productive disposition with a percentage of 96%. This is due to the teacher's proper design of learning and learning flow and anticipating every student response that appears in the learning process. The learning design starts from understanding the concept of closed sentences and open sentences, forms of similarities and equations, understanding, solving, and using linear equations in one variable everyday life. This research impacts the development of mathematical proficiency in the material of good students' linear equations in one variable.

INTRODUCTION

Mathematical skills are expertise, competence, knowledge, and proficiency in mathematics that a person needs to determine his success in mathematics and other fields [1]. Mathematical proficiency is believed to be necessary for everyone to learn mathematics [2]. Mathematical proficiency is essential for students to develop to make students proficient in mathematics, foster student confidence, and achieve the skills expected in the 21st century. The three categories of 21st-century skills that students must possess today are learning and innovation skills, digital literacy, and skills in their careers and future lives [3]. To achieve the skills in chapter 21, students must have proficiency in learning mathematics. However, the mathematics proficiency of students in Indonesia is still low. This can be seen in PISA 2018, which states that around 28% of students in Indonesia reach level 2 or higher in mathematics than the OECD average of 76%. About 1% of students scored level 5 or higher in math proficiency from the OECD average of 11% [4]. In addition, the study results concluded that the average mathematical proficiency of students only reached 65.912% [5]. Students have not been able to find a solution to a problem because learning is still glued to the examples and procedures given by the teacher, so students do not have the confidence to develop their knowledge [6].

Several studies on developing students' mathematical proficiency use illustrative examples that can provide opportunities for students to think autonomously, and teachers guide students to formulate or build their strategies to solve problems ([7], [8]). Mathematical skills have five components: conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition. The relationship between the five components of mathematical ability is conceptual understanding is an essential ability that must be mastered by students to

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achieve good mathematical skills; procedural fluency skills without conceptual understanding skills result in students becoming memorizers without understanding what they are doing and causing the use of inappropriate procedures; strategic competence skills without conceptual understanding and procedural fluency result in students having limited strategies that can be used to solve problems; adaptive reasoning skills without the ability to understand concepts, procedural fluency, and strategic competence will result in students not being able to solve problems because they do not have adequate conceptual understanding and strategic competencies to be used in solving problems; and productive disposition as a tendency to view mathematics as something valuable and valuable, to believe that continuous efforts to study mathematics will be beneficial in the future, and to view oneself as an effective learner and user of mathematics [2].

One of the materials in mathematics that is still low in mathematical proficiency is the linear equation in one variable. This can be seen from the number of learning barriers that students go through in studying the material of linear equations in one variable. Barriers to students in studying linear equations in one variable include ontogenic walls, namely students' thinking jumps from arithmetic thinking to algebraic thinking, epistemological obstacles found due to limited context in working on problems, and didactical obstacles encountered due to procedural teacher teaching so that concept formation the material does not go well [9]. The obstacles experienced by students in solving linear equations in one variable problem were caused by students only understanding procedurally. Hence, students had obstacles understanding algebraic forms and completing mathematical operations on linear equations in one variable questi [10]. Therefore, it is necessary to design learning to develop students' mathematical proficiency to overcome these obstacles.

This paper attempts to explain how to develop mathematical proficiency in linear equations in one variable in grade VII Junior High School. Specific questions explored were how the strategy for developing indicators in mathematical proficiency in linear equation in one variable was applied in class VII Junior High School. The main novelty are:

1. Development questions for each mathematical proficiency indicator
2. Especially for linear equation in one variable material in junior high school
3. Lesson plan.

METHOD

The method in this study uses a case study. Case study research allows the researcher to explore how or why a situation occurred [11]. This research was conducted in two parallel courses with two public schools in Bandung, Indonesia, involving 50 class VII Junior High School students. The material taken in this case study is a linear equation in one variable. Students are given linear equations in one variable question, which is arranged to develop students' mathematical proficiency. We analyze students' answers based on conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition. Apart from tests, this qualitative collects data from test results and review documentation results. The data were analyzed with the stages of instrument validity, data collection, data reduction, data presentation, and data collection conclusions [12]. The categories of achievement of mathematical skills in this study are as follows [13] (see Table 1):

TABLE 1. Category of Mathematics Proficiency Achievement

Score	Mathematical Proficiency
$s > 70$	High
$60 \leq s \leq 70$	Moderate
$s < 60$	Low

RESULT AND DISCUSSION

The development of the mathematical proficiency of junior high school students in this study was carried out by researchers carrying out four meetings based on student activities with the sequence of learning materials 1) understanding closed sentences, open sentences, and linear equations in one variable; 2) solving linear equation in one variable; 3) solving linear equation in one variable in the form of fractions; 4) application of the concept of linear equation in one variable. Next, the researchers tested each indicator of mathematical proficiency, namely conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition. The results of mathematical proficiency development are described according to the following indicators [2].

Conceptual Understanding

Conceptual understanding is the ability to understand mathematical concepts, operations, and relations. This conceptual understanding is essential, a fundamental ability that students must master to achieve good mathematical proficiency [2]. The indicators of conceptual understanding are: 1) the ability to describe mathematical situations in different ways, and 2) the ability to know how these different images can be used for different purposes. The following are questions used to measure conceptual understanding and student answers considered the most ideal in Figure 1.

Question:

Determine the value of the variables below!

a. $8 + 4 = x + 5$
b. $y = 10 - 1$
c. $73 + 56 = 71 + a$
d. $20 \times 48 = b \times 24$
e. $64 \div p = 32 \div 28$
f. $68 + 58 = 57 + 66 + q$

Answer:

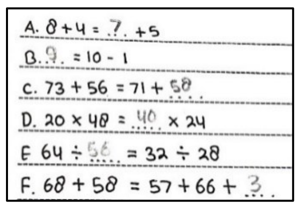

FIGURE 1. Students' Answers to Conceptual Understanding Questions

The questions above lead to students' understanding of the initial concept of an equation and similarity; students are brought to understand an open sentence made into a correct sentence. As many as 81% of students answered the question correctly, with the correct answer as in the example answer above. The students' responses above show that students understand the similarities and similarities in each question. This means that students do not have the wrong concept in studying the linear equation in one variable [14].

Procedural Fluency

Procedural fluency is the skill of using procedures and performing procedures flexibly, accurately, and efficiently. The ability of procedural fluency without conceptual understanding results in students becoming memorizers without understanding what they are doing and causing inappropriate procedures [15]. Indicators of procedural fluency are 1) able to remember, choose, and apply the right formula, 2) accuracy in calculations and 3) precision in using algorithms. The following are the questions used to measure the procedural fluency and the students' answers that are considered ideal in Figure 2.

Question:

If $5(x - 4) = 2x - 8$, find the value $x - 2$.

Answer:

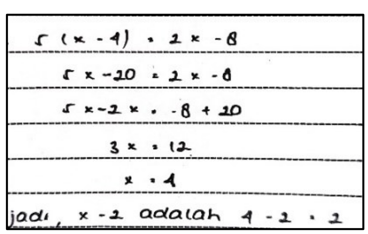

FIGURE 2. Students' Answers to Procedural Fluency Questions

The question above measures how students can apply the concepts they have learned with the proper procedures in working on linear equations in one variable. As many as 87% of students already understand how the techniques are used in solving the problems above. In this case, students can find a procedure for finding a solution to a linear equation in one variable. Students' procedural fluency, in this case, is the ability to apply a concept that is translated into problem-solving steps if students can choose the proper procedure to use or modify the existing steps so that it is more efficient [16].

Strategic Competence

Strategic competence is the ability to formulate, present, and solve mathematical problems. Strategic competence without conceptual understanding and procedural fluency causes students to have limitations on strategies that can be used to solve problems [17]. Indicators of strategic competence are: 1) formulating problems, 2) planning the right strategy, 3) representing the problem well, 4) implementing the planned strategy, and 5) solving problems with the right strategy. The following are the questions used to measure strategic competence, along with the student answers that are considered the most ideal in Figure 3.

Question:

Determine a number that must be added to the numerator and denominator of the fraction $\frac{3}{4}$ so that a new fractioequalsal $\frac{11}{12}$.

Answer:

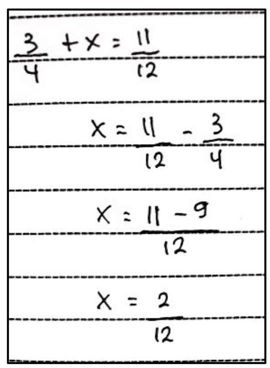

FIGURE 3. Students' Responses to Strategic Competence Questions

The problem with strategic competence is that the researcher makes a linear equation in one variable in a fraction because there are still many obstacles in studying fractions. It can be seen that only 67% of students can answer correctly, as in the example above. Students must go through a reorganization of the basic understanding of numbers that represent fractions and relate them to students' algebraic understanding [18]. Strategic competence, in this case, is how students find keywords in finding problems at hand, finding mathematical relationships in a problem, and finding solutions to problems given [19].

Adaptive Reasoning

Adaptive reasoning is the ability to think logically about the relationship between situations and mathematical concepts and think reflectively, explain, and justify. Adaptive reasoning without conceptual understanding, procedural fluency, and strategic competence will result in students not solving problems because they do not have sufficient conceptual knowledge and strategic competence to solve problems [2]. Indicators of adaptive reasoning are: 1) thinking logically in choosing the right mathematical concepts and situations, 2) using the correct procedure, and 3) rechecking the answers. The following are questions used to measure adaptive reasoning and student answers considered ideal in Figure 4.

Question:

One morning on the streets of Surabaya, Andi was jogging at a speed of 12 km/hour in the first part of his jog. Then, Andi continued flying at a 20 km/hour speed in the second part. During the jogging, Andi has covered a distance of 34 km for 2 hours. How long has Andi traveled on the second part of his jog?

TABLE 2. The Problem.

First part	Second Part
Speed I = 12 km/hour	Speed II = 20 km/hour
Distance I = $\mathbf{34-x}$	Jarak II = x

Answer:

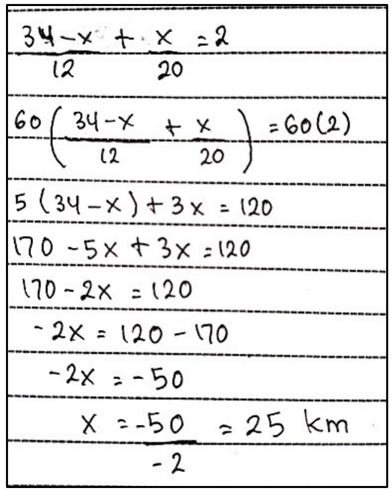

FIGURE 4. Students' answers to adaptive reasoning questions

As many as 96% of students have solved the above problems correctly. This is because the students' previous learning has been strengthened in the concepts, facts, and procedures of this linear equation in one variable. Adaptive reasoning in this study is how students can draw logical conclusions, predict answers, and explain the concept of answers and procedures used so that their answers are mathematically correct [20].

Productive Disposition

Productive disposition tends to view mathematics as something valuable and valuable, believe that continuous effort in learning mathematics will be beneficial in the future, and view oneself as an effective learner and user of mathematics [2]. In contrast to the previous four components, productive disposition uses observation instruments. In general, indicators of productive disposition include 1) beliefs, 2) attitudes, and 3) confidence. Of the three indicators, 96% of students have an excellent productive disposition. The effective disposition relationship with the other four components is that when students build conceptual understanding, procedural fluency, strategic competence, and adaptive reasoning abilities, they must believe that mathematics can be understood and not arbitrary so that it can be learned and used with diligent effort. They can understand it [21].

CONCLUSION

This study concludes that students' mathematical proficiency can be developed by designing appropriate learning and learning flows by the teacher and anticipating every student response that appears in the learning process. In this study, students achieved the category of high mathematics proficiency in conceptual understanding with a percentage of 81%; students completed the type of high mathematics proficiency in procedural fluency with a percentage of 87%, students achieved the category of moderate mathematics proficiency in strategic competence with a percentage of 67%. Students reached the type of high math skills on adaptive reasoning and productive disposition with 96%. Recommendations for developing mathematical proficiency in linear equation in one variable, namely starting from understanding the concept closed sentences and open sentences, forms of similarities and equations, understanding, completion, and use of linear equation in one variable in everyday life.

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REFERENCES

1. J. Soebagyo, Profil Pembelajaran dalam Mengakomodasi Mathematical Proficiency [Learning Profile in Accommodating Mathematical Proficiency], 474-603 (2017).
2. J. Kilpatrick, J. Swafford, and B. Findell, *Adding it up: Helping children learn mathematics* (National Academy Press, Washington DC, 2001), pp. 115-156.
3. J. Bishop, "Partnership for 21st Century Skill," in *The Conference Board, Corporate Voices for Working Families, P21, and SHRM-2006.*
4. OECD, *Programme for International Student Assessment (PISA) Result from PISA 2018* (OECD Publishing, Paris, 2018), Volume **I-III**.
5. P. Saputro, Wahyudin, and T. Herman, "Mathematical Proficiency Profiles of Elementary School Student: Preliminary Study" in *International Conference on Science Education and Technology*, (2021).
6. A. O. A. Awofala, Assessing Senior Secondary School Students' Mathematical Proficiency as Related to Gender and Performance in Mathematics in Nigeria, 488-502 (2017).
7. S. Groves, Journal of Science and Mathematics Education in Southeast Asia **35**(2), 119-145 (2012).
8. D. Evans. Journal of Learning Dissabilities **40**(5), 420-426 (2007).
9. S. M. Rohimah, Jurnal Penelitian dan Pembelajaran Matematika [Journal of Mathematics Research and Learning] **10**(1), 132-141 (2017).
10. A. Jupri, P. Drijvers, dan M. Heuvel-Panhuizen, *Difficulties in initial algebra learning in Indonesia,* 683-710 92014).
11. R. K. Yin, *Case Study Research: Design and Methods, Fourth Edition* (Sage Publications Inc, Thousand Oaks, CA, 2009).
12. M. B. Mile, A. M. Huberman, and J. Saldana, *Qualitative Data Analysis: A Methods Sourcebook, Third Edition* (Sage Publication Ltd, United Kingdom, 2014).
13. E. Khaerunnisa and Novaliyosi, Jurnal Penelitian dan Pembelajaran Matematika [Journal of Mathematics Research and Learning] **11**(2), 33-41 (2018).
14. Rauzah, Kusnandi and A. Jupri*, Analysis of Students Error in Solving Word Problem of One Variable Linear Equations* (1st International Seminar STEMEIF, Indonesia, 2019).
15. National Council of Teacher Mathematics, *Procedural Fluency in Mathematics* (Amerika Serikat, 2014).
16. R. G. Bautista, *The Students' Procedural Fluency and Written-Mathematical Explanation on Constructed Response Tasks in Physics*, pp. 49-56 (2013).
17. Darwani, C. M. Zubainur and Saminan, *Adaptive Reasoning and Strategic Competence through Problem Based Learning Model in Middle School*, Journal of Physics: Conference Series, (IOP Publishing, UK, 2020), 1460 012019.
18. H. Lortie-Forgues, J. Tian, and R. S. Siegler, *Why is learning fraction and decimal arithmetic so difficult?* (Developmental Review, Columbia, 2015), pp. 201-221.
19. J. M. Suh, *Trying it All Together: Classroom Practices That Promote Mathematical Proficiency for All Students* (Teaching Children Mathematics, USA, 2007), pp. 163-169.
20. A. Syukriani, D. Juniati, and T. Y. E. Siswono. "Investigating Adaptive Reasoning and Strategic Competence: Difference Male and Female" in *International Conference on Mathematics: Pure, Applied, and Computation, AIP Conference Proceedings, 1867* (AIP Publishing, Melville, NY, 2017), pp. 0200331-0200337.
21. S. Haji, Y. Yumiati and Zamzaili, Journal of Research and Advances in Mathematics Education **4**(2), 101–111 (2019).