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Algebraic thinking profile of pre-service teachers in solving mathematical problems in relation to their self-efficacy

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Abstract

Algebraic thinking is a person's ability to understand, analyze, and solve problems using algebraic concepts to simplify statements and find solutions. Currently, many prospective teachers still lack proficiency in applying algebraic thinking skills. Self-efficacy is one of the factors that influences algebraic thinking ability. This study aims to reveal the relationship between self-efficacy and algebraic thinking skills in pre-service mathematics teachers. In the context of solving math problems, especially algebraic ones, algebraic thinking skills are crucial. Using a qualitative method with a descriptive approach, the study employed interview guidelines, questionnaires, and tests as instruments. The results show a clear correlation between the level of self-efficacy and algebraic thinking ability. Pre-service teachers with high self-efficacy can effectively evaluate information, use symbols to represent variables, and solve algebraic equations well. They are also able to determine the values of unknown variables. On the other hand, participants with moderate self-efficacy can interpret and communicate information but are less systematic in selecting problem-solving steps that involve abstraction. Participants with low self-efficacy struggle to interpret information and cannot explain the relationship between the information in the problem and the question asked, leading to incorrect solutions. The conclusion of this study is that the higher the level of self-efficacy, the better one's algebraic thinking ability. This indicates the importance of enhancing students' self-efficacy to support more effective algebra learning.

Keywords: algebraic thinking, problem solving, self-efficacy

INTRODUCTION

Algebraic thinking is a fundamental skill in the era of the Industrial Revolution 4.0. It emphasizes the ability to analyze relationships between quantities, pay attention to structures, study changes, generalize, solve problems, model, justify, prove, and predict (Eriksson & Sumpter, 2021). It involves a specific way of thinking that goes beyond the use of letters and focused on general relationships and relational aspects (Radford, 2008; Sibgatullin et al., 2022). This type of thinking includes generalization, abstraction, dynamic thinking, modeling, analytical thinking, and organization (Yusrina & Masriyah, 2019). Research has shown that algebraic thinking is critical to success in mathematics, and its development in the early grades is an important component of supporting algebraic reasoning later in life (Dougherty et al., 2014). It is a mental activity that requires generalization abilities, transformation, and global meta-level skills to solve problems (Sukmaningrum & Kurniasari, 2022). Algebraic thinking extends beyond the use of symbols to explore relationships, generalize and formalize concepts, use algebra as a tool, and engage in logical reasoning and making connections between different representations (Walkoe et al., 2022).

The ability to think algebraically is a fundamental aspect of mathematical development, especially in the educational environment. Several key indicators are essential for assessing and promoting algebraic thinking in students: generalization, problem solving, reasoning, and the ability to represent data using tables and diagrams (Eriksson & Eriksson, 2020). These indicators not only help understand algebraic concepts, but also

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Contribution to the literature

- This study provides an opportunity to thoroughly examine pre-service teachers' thinking regarding algebraic thinking profiles.
- The research delves into the algebraic thinking profiles of pre-service teachers in solving mathematical problems based on self-efficacy.
- The results of this study are used to propose improvements aimed at enhancing the algebraic thinking abilities of prospective mathematics teachers and in studying mathematical problems.

provide a foundation for further algebra learning (Acosta & Alsina, 2020; Eriksson & Eriksson, 2020). True algebraic thinking skills go beyond algebraic notation; they include the capacity to generalize, solve problems, predict results, justify models, and prove mathematical ideas.

To improve algebraic thinking skills, it is imperative to cultivate proficiency in comprehending problems, constructing mathematical representations, solving difficulties, and interpreting answers. Students can master algebraic thinking skills well by mastering affective skills, one of which is self-efficacy. Students need to have self-efficacy in order to be successful in the learning process. Self-efficacy is the assurance that one has in organizing and directing one's capacity to adapt and cope with circumstances. Learning mathematics, including numeracy, requires willpower, survival skills, self-confidence, a good attitude toward mathematics, and the ability to solve mathematical problems (OECD, 2012). In terms of comprehending mathematical material, pre-service teachers scored inconsistently (Norton, 2019). Inadequate mathematical self-efficacy will affect reading comprehension and problem solving abilities (Öztürk et al., 2019).

Problem Statement

The initial findings from this current study indicate that pre-service mathematics teachers lack proficiency in algebraic thinking, including concepts such as variables, statements, algebraic connections (equalities and inequalities), change analysis (graphing), patterns, functions, and modeling (problem solving). The results of another study stated that one of the components of algebraic thinking is representation. In this case, Results from other research state that one of the components of algebraic thinking is representation. In this case, the weak ability of students in mathematical representation results in low achievement of the most dominant indicator of algebraic thinking ability, with an average achievement of only 1.57% (Toheri, 2013). There are still many students who, when presented with an algebra problem, immediately calculate without understanding the meaning of the question and the relationship between the sentences, making it difficult for them to solve and represent the problem. According to Wilujeng (2017), low algebraic thinking skills are caused by low algebraic readiness (Wilujeng, 2023). Agoestanto et al. (2019) stated that one of the causes of students' errors in algebraic thinking is students' lack of understanding of modeling algebraic forms. One of the things that teachers can use to develop and train students' algebraic thinking abilities is problem solving. Students frequently struggle to get information from the questions, which leads them to have difficulty predicting patterns and grouping information. It follows that self-efficacy and the capacity to think algebraically are related.

According to Kieran (2004), if students engage in good algebraic thinking through problem solving, it will encourage and help in their cognitive learning process. More studies are needed to understand how algebraic thinking skills of teachers and pre-service teachers adapt teaching practices to meet the needs of students (Manly, & Ginsburg, 2010). Previous research, including that of Hill et al. (2005), has shown that student achievement is closely related to teachers' mathematical knowledge. However, many teachers lack a strong foundation in algebraic thinking skills, which affects their ability to teach algebraic concepts effectively (Magiera et al., 2013). The development of algebraic thinking skills is influenced by various factors. Some students tend to avoid using variables in problem-solving due to a lack of confidence in their own abilities, commonly referred to as self-efficacy. Self-efficacy is defined as the belief in one's ability to solve mathematical problems, the approach to learning or working in understanding concepts, the ability to communicate mathematical ideas with peers and educators, as well as the competence in demonstrating specific levels of reasoning. Consequently, self-efficacy constitutes a critical aspect of self-knowledge that significantly impacts mathematical problem-solving abilities.

Research Gaps

The lack of in-depth studies on the algebraic thinking profiles of pre-service teachers remains a concern. Although some research has developed and mapped the stages of algebraic thinking development, there is still limited research that systematically describes how pre-service teachers move through various stages within different frameworks. Further research is needed to specifically identify the algebraic thinking profiles, particularly about the affective abilities of pre-service teachers. This is important in the learning context, where teaching strategies can be adjusted to different algebraic thinking profiles and their connection to self-efficacy.

Research Questions

A review of the available research on the algebraic thinking profiles of pre-service mathematics teachers reveals a gap. Therefore, the research question for this study is: How do the algebraic thinking profiles of students in teacher education programs approach solving mathematical problems when viewed through the lens of self-efficacy?

Research Goal

This study undertakes an in-depth analysis to examine in detail the algebraic thinking profiles of prospective teachers in solving mathematical problems from the perspective of self-efficacy. The aim of this research is to analyze the algebraic thinking profiles of prospective teachers in constructing new knowledge. The findings will be utilized to propose improvements in the teaching and learning of algebra courses, viewed through the framework of self-efficacy.

LITERATURE REVIEW

Algebraic Thinking Skills for Pre-Service Mathematics Teachers

Algebraic thinking often involves the process of generalizing arithmetic operations, and as it gets more complex, it deals with unknown quantities. The five categories of algebraic thinking are

(a) generalization and formulation of arithmetic operations,

(b) manipulation and transformation of certain equality problems through inverse operation and principal syntax,

(c) analysis of mathematical structures,

(d) relations and functions, including numbers and letters, and

(e) algebraic language and representation (Stephens et al., 2015).

Additional studies have demonstrated that the development of algebraic thinking comes from recognizing the structural connections within arithmetic patterns and structures, which includes understanding concepts such as generalized arithmetic, functional reasoning, and utilizing generalizations as modeling languages. It is an approach to problem solving that emphasizes general relationships and relational aspects, using tools beyond symbolic representation (Rudyanto et al., 2019). The development of algebraic thinking is viewed as a process. Pattern generalization is an excellent strategy for developing students' algebraic thinking skills (Nurwidiyanto & Zhang, 2020; Rudyanto et al., 2019).

Reviewing the investigative studies that have been conducted algebraic thinking involves the generalization of mathematical procedures and the handling of unknown numbers (Sibghatullah et al., 2022). It emphasizes the skills of pattern recognition, mathematical generalization, and symbolization that are important for children in Piaget's formal operational stage, which spans the ages of seven to fifteen. Teachers and pre-service teachers need to understand and promote algebraic thinking to improve students' problem-solving skills and overall mathematical competence. As noted above and according to the findings of Wahyuni and Herman (2019), algebraic thinking involves various components such as reasoning, mathematical modeling, pattern recognition, and the ability to generalize and predictions. Developing algebraic thinking in students in the early grades is critical to building a strong foundation for later algebra learning (Dougherty et al., 2014). Teachers play an important role in cultivating algebraic thinking in their students by recognizing moments of algebraic potential in them and supporting their generalization and formalization skills (Walkoe et al., 2022).

Low algebraic thinking skills can lead to difficulties in solving algebraic problems and interpreting mathematical relationships. Accordingly, in the view of Kusumaningsih et al. (2018), teachers needs to have a comprehensive understanding of their students' algebraic cognitive processes in order to effectively provide instructional content on topics such as polyhedrons, numbers, functional relations, social arithmetic, and other topics that require the utilization of algebraic concepts and problem solving techniques. Introducing algebraic thinking early in mathematics education can lead to better outcomes in algebra learning. This introduction includes recognizing patterns, using symbols for quantity variables, and systematically representing relationships (Manly & Ginsburg, 2010). Teachers needs to be aware of the algebraic thinking skills of their students, especially if they are middle school students, in order to help them solve mathematical problems. Teachers need to have a thorough understanding of how student reason algebraically. This is important for teachers to consider when teaching topics such as linear programming, equations and inequalities, exponentials and logarithms, and other topics that involve the use of algebraic forms and algebraic solutions. In particular, teachers of mathematics for younger age groups should plan instruction to develop algebraic thinking skills (Sibghatullah et al., 2022). From the results of other studies it was found that prospective mathematics teachers still had difficulty developing algebraic thinking skills, which had an impact on solving mathematical problems of prospective teachers (Kusuma et al., 2024). Based on mathematical problems, particularly in algebra, a strong algebraic thinking process is required to solve such problems. A good algebraic thinking profile can be identified through an individual's cognitive style, which can serve as a reference in solving algebraic problems.

Self-Efficacy

Self-efficacy also predicts numeracy performance (Gatobu et al., 2014). A self-efficacious individual is one who believes in their own talents before approaching a problem (Kirbulut & Uzuntiryaki-Kondakci, 2019). In addition to students' conceptual understanding, it is suggested to consider students' self-efficacy also in learning success. Self-efficacy is an individual's belief in his ability to succeed in doing something. Sun (2020) revealed that student self-efficacy positively impacts student learning outcomes and is positively related to academic achievement in both before class and in class learning environments. Students' self-efficacy in collaborative learning also has a positive impact on students' conceptual understanding. Math self-efficacy and math grades showed a unidirectional relationship with former math grades being related to later math self-efficacy. Considering math test scores, reciprocal relationships could be found for math self-efficacy (Arens et al., 2020).

Schunk and Dibenedetto (2016) mathematical self-efficacy has a direct influence on students' cognitive abilities and stated that mathematical self-efficacy serves as a better predictor of mathematics performance compared to gender and previous learning experiences and . The confidence of a person in overcoming different challenges is related to the strength dimension. Meanwhile, confidence in predicting the success of the problem-solving procedures undertaken is related to the generality dimension. To improve students' algebraic thinking skills, educators need to provide students with high self-efficacy with practice questions and familiarize them with expressing mathematical ideas and provide students with moderate self-efficacy with training in identifying problems to get a pattern (Setyawati et al., 2020). with high, medium, and low levels of self-efficacy have differences in algebraic thinking skills, this shows that algebraic thinking skills and self-efficacy are interrelated.

METHODOLOGY

Study Design

This study used a qualitative descriptive approach that aimed to describe the algebraic thinking profiles of students based on self-efficacy categories. The objective of this study is to provide a comprehensive profile of algebraic thinking of future mathematics teachers, focusing specifically on their self-efficacy category.

Sampling and Data Collection

Data were collected from students in the fourth semester of the mathematics education program at Kusuma Negara Teacher Training and Education College, Indonesia. This study involved twenty-five participants as subjects. The selection of research subjects is based on the consideration that the subjects have studied linear programming material, which is a practical application of algebraic concepts, particularly in solving problems involving systems of equations and linear inequalities. Three samples were then selected from twenty-five subjects using purposive sampling. Purposive sampling is a method of selecting data sources based on certain criteria or considerations (Sukestiyarno, 2020). In this study, the concern was to select samples that represented high, moderate and low self-efficacy criteria. Subjects (participants) were referred to by initials to facilitate data analysis.

The survey used a set of 12 items rated on a scale of 1 to 10, with 1 indicating uncertainty and 10 indicating strong certainty. Expert judgment validated the algebraic thinking skills test instrument and declared it suitable for use in obtaining data according to the objective of the study. Limited trials of the instrument were then conducted. The results of the validity test showed that the algebraic thinking skills question items were valid and reliable. In the meantime, the self-efficacy questionnaire and the interview guide were reviewed by psychological experts. Expert judgment validates the algebraic thinking test instrument and is declared eligible to be used to obtain data according to the purpose. Then, the researchers conducted a limited trial of the research instrument. The results of the validity test show that the algebraic thinking questions are included in the valid and reliable categories. Meanwhile, expert judgment in the field of psychology validated the interview guide and self-efficacy questionnaire. Validity test using content validity test and reliability test using Cronbach's alpha. Testing the validity of the data in this study used triangulation technique. Data obtained from written test results were compared with think aloud results and students' answers during interviews so that the data obtained is accurate.

Data Analysis

Based on the data collected, a self-efficacy test was administered using a questionnaire to the twenty-five selected research subjects. Based on their self-efficacy test scores, participants were categorized into three different groups according to their level of self-efficacy: high, medium, and low. Student self-efficacy is categorized into three levels: low, moderate, and high, based on the scoring categorization method by Frisbie and Ebel (1991). Subsequently, participants were given an algebraic thinking ability test, with attention given to answer variations, the uniqueness of responses, and

Table 1. Distribution of participants based on self-efficacy questionnaire scores

Total number of participants	Self-efficacy		
	High	Moderate	Low
25	7	12	6

communication skills. From each category, one subject was selected for an in-depth interview. The in-depth interviews and test results were used in the data analysis stage to group, reduce, present, and hypothesize (Sukestiyarno, 2020). The credibility of the data was tested using triangulation by comparing data from algebraic thinking tests and in-depth interviews.

RESULTS

This study began with the collection of student self-efficacy data using a questionnaire from 25 participants. Based on the results of the self-efficacy questionnaire completed by all participants, the participants were grouped based on their self-efficacy levels, as shown in **Table 1**.

Table 1 shows that of the 25 students who were given the self-efficacy questionnaire, 7 students had high self-efficacy, 12 students had moderate self-efficacy, and 6 students had low self-efficacy. A total of two participants were then selected from each category to construct an algebraic thinking profile centered on the self-efficacy category. Considering the range of responses, the distinctiveness of responses, and the proficiency in communicating, six study participants from each category were selected to participate in comprehensive interviews. Then, one student from each of the three categories was selected to participate in an interview focused on the algebraic thinking process. As a result, three participants were selected, each of whom was referred to by initials NV, NU, and MH, respectively.

The algebraic thinking profile was derived from the combination of test results, interviews conducted with the three participants, and recording of the participants' worksheets. Algebraic thinking skills were measured using six markers, as follows:

1. **Generalization**, which is characterized by students being able to determine the general form of a linear equation in two variables.
2. **Abstraction**, which is characterized by understanding what is asked in questions that involve the use of variables symbolized by letters.
3. **Analytical thinking**, which is characterized by students being able to solve equations to find unknown values.
4. **Dynamic thinking**, which is the analysis of arithmetic patterns involving variables from a problem, characterized by performing algebraic manipulations to simplify equations or mathematical models.
5. **Modeling**, which is characterized by students being able to model and represent mathematical problems using algebraic forms.
6. **Organizations**, which is characterized by the ability to openly articulate changes in a process or relationship as functional connections between variables using mathematical equations or verbal expressions.

The following assessment questions can provide pre-service teachers with a mathematical profile of their algebraic thinking.

Sabrina, Geovani, Agatha, and Tari bought basketballs and soccer balls. As a punishment for losing some balls, Sabrina and Geovani bought 2 basketballs and 1 soccer ball for IDR 170,000. Agatha and Tari bought 1 basketball and 3 soccer balls for IDR 185,000. How much does 1 basketball and 1 soccer ball cost?

Self-Efficacy Category

The exam and interview results are thereafter compared and scrutinized to obtain a comprehensive understanding of the algebraic thinking profile of the teacher or potential Mathematics instructor. Below, we provide a description of the outcomes obtained from tests and interviews conducted with informants.

Based on **Figure 1**, participant NV was able to know the given information about each given problem. Participant NV was able to construct their own formula by trial and error and was able to identify two strategies for solving the problem, i.e., using elimination and substitution and determining the answer correctly. The participant was able to answer the problem well by writing down the information given and what the question the participant to find (**Figure 1**), indicating a good ability to analyze the information given in the question. Moreover, participant NV was able to write alternative solutions based on formulas obtained using different methods. In the implementation stage, participant NV solved the problem using the two formulas found. Two elimination and substitution formulas were used because it was easier to work with and check the result of the calculation.

Based on the interview, participant NV met all indicators:

(1) generalization, indicated by being able to determine the general form of a linear equation in two variables;

(2) abstraction, indicated by being able to understand mathematical concepts by giving reasons for the information given and what the question asked, using symbols related to concepts and rules in solving problems;

(3) analytical thinking, indicated by being able to solve equations to find unknown values by explaining what steps were taken;

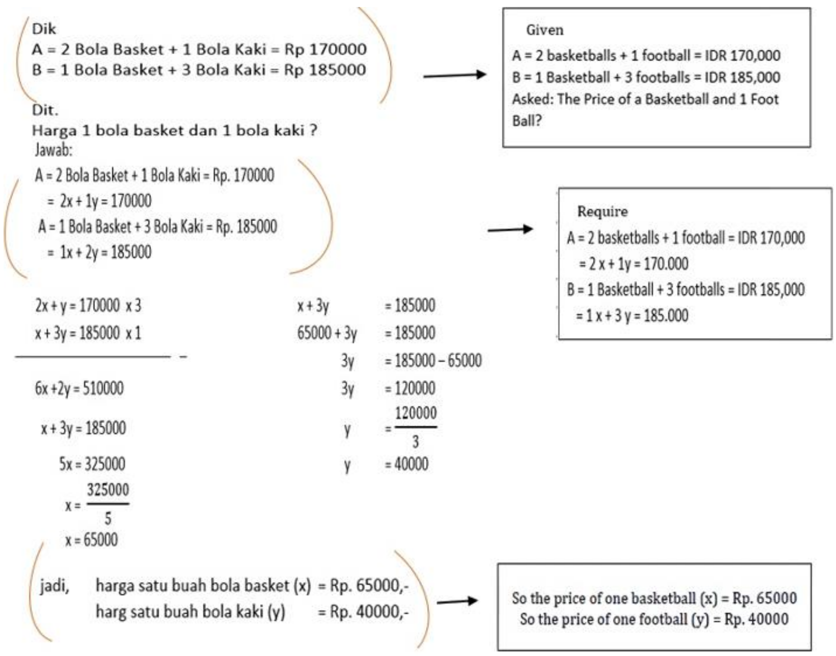

Figure 1. Response of the participant with initials NV to the test item (Source: Authors' own elaboration)

(4) dynamic thinking, indicated by being able to perform dynamic manipulation of mathematical objects by explaining the relationship between the information and what the question asked and being able to solve problems using multiple solving methods;

(5) modeling, indicated by being able to model and represent mathematical problems using algebraic forms; and

(6) organization, indicated by being able to simplify information related to the information given and what the question asked and choosing a solution plan that fits the problem.

Q: Can you identify the given information in the question and what the question asked you to find?

NV: Yes, I can.

Q: What did you have in mind when you were given this question?

NV: [I must first] understand the question by determining the information given and then what the question asked me to find, sir. Next, (I must) determine the solution.

Q: How did you solve the problem?

NV: [I solved the problem] by first determining each variable, x for basketball and y for soccer ball, to make it easier to work on,[and] then proceeded to create a mathematical model.

P: What method did you use and why?

NV: I have studied this topic before, so in my opinion, using either elimination or substitution is an efficient way to do it.

Q: Did you use both methods (to solve the question) and were the results the same?

NV: Yes, they were, sir. I've also solved (the problem) using the substitution method to confirm my answer.

Q: When (you were about to) work on the question, did you feel sure you could solve it the moment you saw it?

NV: I did, Sir. I know how to solve the problem, and I was sure that I could do it. (After all) I understand the topics I have learned.

Based on the answer to the question and the interview results, participant NV was able to solve problems well. The participant was able to correctly write the information given and what the question asked. In addition, participant NV accurately arranged examples and equations in the correct order, represented the problem visually, and transformed the problem into mathematical language through the act of writing examples and equations expressed in mathematical notation. Then, participant NV was able to determine the method of solving the problem with the correct answer, answer the question, and write the conclusion correctly. The participants had very good confidence in working on the questions, as shown in the results of the interview. Participant NV, after reading the question, immediately responded by determining each variable so that no mistake was made in determining the algebraic

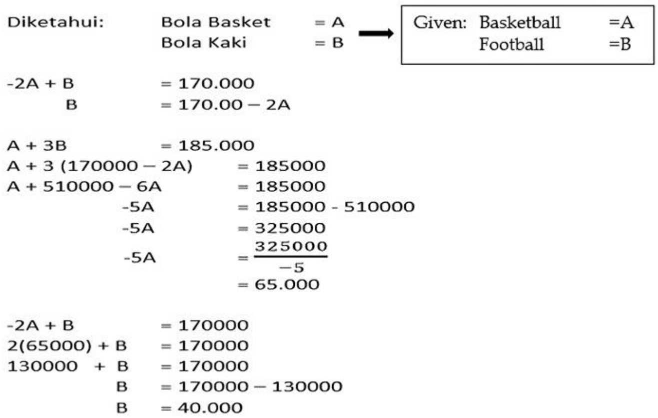

Figure 2. Response of the participant with the initials NU to the test item (Source: Authors' own elaboration)

modeling. Participant NV was quite confident in doing this because they still remembered the material they had been taught in the linear programming course. Participant NV seemed to have a very good stimulation. Participant NV felt challenged and enthusiastic about solving the problem.

Moderate Self-Efficacy Category

From **Figure 2**, it can be seen that participant NU knew the information given in the question well, as indicated by the fact that the participant wrote down all the known information in the given question. However, participant NU was not able to write down structurally appropriate and complete solution steps, and in the end, participant NU was able to complete the answer correctly, but did not write down the conclusion. According to the results of the interview, participant NU met only the following criteria:

(1) generalization, indicated by being able to identify the information given and what the question asked;
(2) analytical thinking, indicated by being able to solve equations to find unknown values;
(3) modeling, indicated by being able to model situations using patterns in solving problems by adopting the patterns used in the questions; and
(4) dynamic thinking, indicated by being able to solve problems using logical deduction and being able to explain the chosen solution plan according to the problem.

The results showed that participant NU was a student with moderate self-efficacy.

Q: Can you identify the given information in the question and what the question asked you to find?

NU: Yes, I can. [That is why I] let A be basketball and B be soccer ball

Q: What did you have in mind when you were given this question?

NU: [I had to first] understand the problem by determining the variables, then determine what the question asked, and then determine the solution.

Q: How did you solve the problem?

NU: after determining each variable, I immediately manipulated it to find each value that was sought for each price

Q: What method did you use and why?

NU: I used the substitution method because I have better understanding on the method, sir.

Q: Did you happen to try other methods and were the results the same?

NU: No, sir. I only used the substitution method.

Q: When [you were about to] work on the question, were you sure that you could do it right after seeing it?

NU: I was sure that I could do the question, but I was not sure about my answer, sir. I did my best to do it anyway.

Participant NU was able to understand well the information given in the question but was not able to achieve the criteria of dynamic thinking, because participant NU was not able to answer with a complete, sequential and detailed strategy, and was not able to achieve the criterion of organization because the participant was not able to solve problems based on the plans made. Participant NU was able to answer questions correctly by using the substitution method to get the results. The participant exhibited an exceptional proficiency in comprehending the content of the questions and a high level of confidence in approaching the question.

Low Self-Efficacy Category

From the response of participant MH to the question, as shown in **Figure 3**, it was concluded that MH achieved three indicators of algebraic thinking:

(1) generalization, indicated by being able to identify the information given and what the question asked, although not perfectly, and then construct the problem with a specified pattern;
(2) analytical thinking, indicated by understanding mathematical concepts and rules, such as giving reasons for the information given and what the question asked and performing calculation operations based on the information given using the elimination method, although only being able to explain well the steps to solve the problem

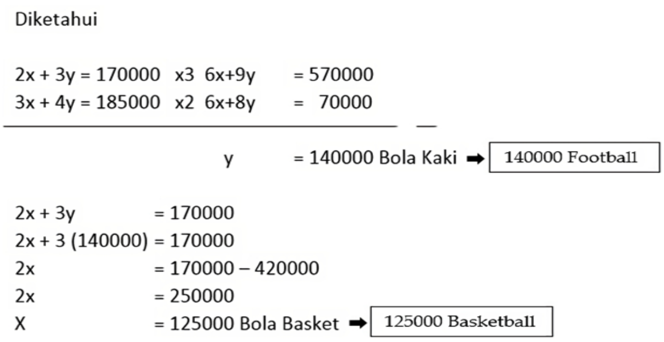

Figure 3. Response of the participants with the initials MH to the test item (Source: Authors' own elaboration)

using the elimination method, but not being careful in working on and determining the variables, which caused errors in the calculation; and

(3) modeling, indicated by participant MH being able to do mathematical modeling, although the answer was still incorrect.

The result shown by MH was usually shown by students with low self-efficacy.

Q: Can you possibly identify the information given and what the question asked?

MH: Yes, I can, sir.

Q: What did you have in mind when you were given this question?

MH: [I had to find] a value for the prices of soccer balls and basketballs.

Q: How did you solve the problem?

MH: [I solved it] using the elimination method.

Q: Why did you use the elimination method?

MH: It is the only method I know, sir.

Q: Did you happen to try other methods and were the results the same?

MH: I did not, sir.

Q: When [you were about to] work on the question, were you sure you could do it right after seeing the question?

MH: I was not sure [whether I could do it or not], but I did what I could, sir.

Based on the written answer and the results of the interview, participant MH had a good understanding of the information given in the question. Participant MH answered the question using the elimination method, but was not able to answer the questions correctly and did not write down the information given and what the question asked in full. Participant MH was not able to explain in a structured way the process of working from knowing, asking questions and mathematical modeling. It can be seen that participant MH knew the information given in the problem by writing down the mathematical model and the steps to do it, but the answer obtained is not correct due to errors in the calculation operations.

Table 2 shows that participants in different self-efficacy groups showed distinct tendencies in solving mathematical problems. Participant NV was able to determine the general form of a linear equation in two variables and use a sequential and systematic solution pattern and was able to identify information given in the

Table 2. Description of the algebraic thinking process of each participant

Indicator	Participants		
	NV	NU	MH
Generalization	Being able to determine the general form of a linear equation in two variables. Understand the use of symbols to represent variables as something not well known	Noticing the information given and what the question asked, and then identifying the factors involved	Being able to formulate linear equations without explicitly documenting the information given and the desired outcome
Abstraction	Being able to understand mathematical concepts by reasoning about what is known and what is asked, using symbols related to concepts and rules in solving problems, and performing calculation operations based on what is known using elimination and substitution methods	Being able to use symbols related to concepts and rules in solving problems, but not being able to write down the information given in the question and what the question asked using symbols systematically	Failing to write down the information given in the question and what the question asked, leaving the information incomplete
Analytical thinking	Being able to solve equations to find unknown values by sequentially and completely explaining the steps taken using elimination and substitution methods	Being able to write down the problem by explaining the steps taken using the substitution method, but not sequentially and completely	Being able to solve problems using elimination and substitution methods, but not being able to organize equations to describe the problem, making the results less accurate

Table 2 (Continued). Description of the algebraic thinking process of each participant

Indicator	Participants		
	NV	NU	MH
Dynamic thinking	Being able to perform dynamic manipulation of mathematical objects by explaining the correlation between existing knowledge and the specific question at hand and to solve problems using elimination and substitution methods	Being able to manipulate mathematical objects dynamically and find all the values of the variables to obtain the correct answer using the substitution method, but not write the conclusion	Not being able to manipulate mathematical objects dynamically and not being able to clarify the correlation between the existing knowledge and the specific question
Modeling	Being able to model and represent mathematical problems using algebraic forms and correctly perform mathematical modeling using elimination and substitution methods	Being able to model situations using patterns in solving problems by adopting the patterns used in the problem and use the substitution method	Being able to do mathematical modeling using elimination and substitution methods, but arriving at the wrong answer
Organization	Being able to provide information related to what is known and what is asked and choose a solution plan that fits the problem, make general rules from the pattern and find the correct answer	Being able to provide information related to the problem by only writing the information given in the question and being able to choose a plan in completion, thus making general rules from the pattern, but not completely and sequentially	Not being able to make general rules from patterns that have been sequentially and completely determined, thus arriving at a wrong answer

question and what the question asked and choose a solution plan that fit the problem. Meanwhile, participant NU, in interpreting information, was able to write down the information given in the question and what the question asked using symbols, then determine the variables, although not in a complete and sequential manner, and propose a correct solution result. Next, participant MH was able to construct a linear equation, then determine the information given in the question and what the question asked, albeit not completely and sequentially, but did not make general rules from the pattern determined sequentially and completely, thus arriving at an incorrect answer. Algebraic thinking profiles based on self-efficacy categories are presented in **Table 3**.

Table 3 shows that the profiles of algebraic thinking varied according to self-efficacy. The higher the self-efficacy, the better the students were at making general rules from the patterns, correctly writing conclusions from problem solving results, selecting and displaying the appropriate form of representation, and selecting and using the correct problem-solving approach.

DISCUSSION

Various algebraic thinking characteristics are believed to be influenced by several things. First and foremost in algebraic thinking is the ability to comprehend information. Errors in the algebraic thinking indicators will results from a failure to interpret the information. Interpretating information was usually not a problem for participants in the high and medium self-efficacy groups. Meanwhile, participants in the low self-efficacy category typically had incomplete information interpretation. These results are consistent with other studies that have indicated that reading and comprehension of text play a role in numeracy competence (OECD, 2016). Understanding, thinking about, and explaining numeracy difficulties are all influenced by text comprehension (Gal et al., 2020).

According to the results of this study, participant NV demonstrated proficiency on the generalization indicator. Specifically, the participant was able to identify the overall structure of an equation in two variables and was able to determine the significance of the variables in the given problem. This was indicated by the participant presenting all the information given in the question using specific variables, visualizing the question, and expressing it in mathematical terms by providing examples and equations in mathematical notation. In addition, the participant possessed denotative attributes (signs), where the participant recognized the need to assign names or symbols to ambiguous numbers (Radford, 2014). The current stage is crucial to progressing to the next stage. The more students understand the problem, the easier it becomes for them to solve it. Participant NV met the abstraction indicator. The participant was able to write down the information given in the question using symbols by substituting x for basketball and y for soccer ball and representing the relationship symbolically, numerically, and verbally. Furthermore, participant NV met the analytical thinking indicator by being able to solve equations to find unknown values. Participant NV was able to pose a question involving the relationship between variables by constructing a mathematical model based on the equations $2x + y = 170{,}000$ and $x + 3y = 185{,}000$. This was consistent with the information provided about the problem. In addition, participant NV met the dynamic thinking indicator, which is characterized by the ability to perform dynamic

Table 3. Algebraic thinking profile using the self-efficacy classification

Indicator	High	Moderate	Low
Generalization	Identifying the pattern of the problem completely and correctly.	Identifying the pattern of the problem completely and correctly	Identifying the pattern of the problem, but only partially and incorrectly
Abstraction	Make general rules from the pattern and suggesting the correct answer	Making general rules from this pattern, but not completely and systematically	Not making general rules for the pattern, resulting in an incorrect answers
Analytical thinking	Testing the identification results in the problem, which can be solved by systematically and comprehensively using the chosen approach	Testing the identification results in the problem, which can be solved according to the strategy used, albeit not always in a sequential or comprehensive manner	Understanding the use of symbols to represent variables and solving equations, but arriving at an incorrect answer
Dynamic thinking	Performing process and problem-solving outcome checks	Performing a process or problem-solving outcome check	Not checking the process and results of problem solving
Modeling	Doing mathematical modeling correctly	Doing mathematical modeling correctly	Doing mathematical modeling but arriving at an incorrect answer
Organization	Making general rules from the pattern and writing down the conclusion from the problem solving results correctly	Making general rules from the pattern and correcting them, but not writing down the conclusion from the problem solving results	Creating general rules from the pattern, but arriving at an incorrect answer and not writing the conclusion from the problem solving results

manipulation of mathematical objects and to test problem identification by using both substitution and elimination methods. This indicated that the participant was able to work on the problem in more than one approach and was able to express the answer using more than one notion, as evidenced by the correct answer that the participant proposed.

Participant NV also met the modeling indicator, demonstrating the ability to model and present mathematical problems in algebraic form in detail so that nothing was overlooked. Participant NV was able to visually represent issues and translate it into mathematical language through the use of examples and equations. Additionally, the participant met the organization indicator by being able to structure and present data in the form of equations and sentences. Participant NV was more organized in drawing conclusions. In summary, participant NV was able to solve questions well, write the information given in the question and what the question asked correctly, write examples and equations correctly, determine the method for solving questions with the correct answers, and answer questions and write conclusions correctly. These results align with research stating that another factor contributing to the significant difference in students' performance between groups is the level of self-efficacy (Bhowmick et al., 2017; Grigg et al., 2018)

With regard to participant NU, the results of the test and interview indicated that the participant met only four indicators. The first indicator that the participant met was generalization, indicated by being able to identify the information given in the question and what the question asked by creating linear equations. Then using analytical thinking, participant NU was able to determine the variables and solve the equation to find unknown values, doing the calculation directly using the substitution method. The process was not done in the correct order, although the answer obtained was correct. Furthermore, in terms of the modeling indicator, participant NU was able to model situations using patterns in solving problems by adopting the patterns used in the questions. Participant NU performed modeling according to their knowledge and showed dynamic thinking, which is characterized by being able to solve problems using logical deduction and being able to explain the chosen solution plan according to the problem. The results shown by participant NU indicated moderate self-efficacy. Participant NU showed a fairly good understanding of the question, but the solutions were not written down systematically and completely. However, participant NU did not meet the abstraction indicator because the participant did not completely and systematically write down the information given the question using symbols. In addition, participant NU did not meet the organization indicator because they were unable to explain the relationship between the information given in the question and what the question asked, although they found some of the values of the variables and obtained the correct answer. In summary, participant NU subject did not write down the information given in the question and what the question asked, but wrote the examples and equations correctly, was able to determine the solution method, although not writing it completely, and did not make a correct conclusion.

For participant MH, the results of the test and interview indicated that the participant met only three indicators of algebraic thinking. The first indicator met was generalization, was the participant was able to identify, albeit not perfectly, the information given in the question and what the question asked, and then assemble the problem in a specified pattern. Participant

MH was able to know the order of the problem, as indicated by the ability to construct linear equations and think analytically. Participant MH was able to translate the problem in the problem into mathematical language and understand mathematical concepts and rules, such as giving reasons for the information given in the question and what the question asked, and performing operations based on the given information using the elimination method. Participant MH was only able to explain well the steps to solve it using the elimination method but was still not careful in doing the calculation and determining the variables, which caused errors in the calculation. In terms of modeling, participant MH was able to determine the mathematical model to use, although the answer was still incorrect. Participant MH showed that they were able to work on the problem and understand the problem, but the solution was not appropriate because of an error in the calculation operation that began with the use of mathematical symbols. However, participant MH did not meet the abstraction and dynamic thinking indicators because the participant was unable to explain the relationship between the information given in the question and what the question asked, which the participant did not state sequentially and completely at the beginning of the solution, which led to an incorrect answer. Furthermore, the participant did not meet the organization indicator, as the participant was unable to simplify the information given in the question and what the question asked, unable to solve the problem well and unable to explain the chosen solution plan according to the problem. In summary, participant MH did not write the information given in the question and what the question asked, did not explain the example, did not determine the method, which caused inability to answer the purpose of the question, and did not write the conclusion of the question. According to Booth et al. (2013), errors in writing and manipulating variables are an indication that students do not understand key variables, which hinders their understanding of algebraic concepts. Other research findings also state that ability grouping for students in the low category affects self-efficacy (Schunk & Dibenedetto, 2016).

In the algebraic thinking process, participants with high and medium self-efficacy categories tended to be able to solve problems correctly. This is consistent with the study results of Wu (016), which stated that self-efficacy is the main part of motivational beliefs and has a positive association with mathematics achievement compared to other variables. From the answer of the student participant with high self-efficacy, it can be seen that the student participant was able to meet the algebraic thinking indicators. The participant with high self-efficacy presented relationships visually, numerically, and verbally in interpreting the information in the representation. In another previous study by Adni et al. (2018), students who had high self-efficacy had high mathematical connection abilities. Juhrani et al. (2017) found that there was a relationship between students' self-efficacy and students' mathematical understanding abilities. If students had high self-efficacy, or in other words, good self-confidence, then their mathematical understanding abilities would also be high, and so would be their algebraic thinking abilities, which could help them to analyze problems in order to explore and measure important things. Other research results state that students who are confident in their performance in mathematics tend to have better mathematics achievement (Muhtadi et al., 2022). This confidence reflects self-efficacy. Students with high self-efficacy have confidence in solving problems (Pratiwi et al., 2019). Self-efficacy have significant and positive effects on mathematics achievement. We recommend that every concerned body should pay concerted effort to these motivational variables so as to encourage students' achievements in mathematics (Woldemichael et al. 2023). In teaching, teachers with high self-efficacy are more prone to use student-centered and constructivist instruction, whereas those with low self-efficacy are more prone to use teacher-centered and traditional instruction (Zee & Koomen, 2016).

The participant in the moderate self-efficacy category appeared to be less systematic and structured in the process of problem solving. The participant demonstrated the ability to comprehend and articulate questions effectively as evidenced by their interview responses. They displayed a clear understanding of the problem presented in the question and exhibited a genuine interest in finding a solution. Moreover, the interview results indicated that they had a high level of confidence in their problem-solving abilities, were firmly convinced that their answer was correct, and were able to perform two stages in problem solving, preparing a problem solving plan and executing the problem solving process. Participants who had self-efficacy were quite capable of planning problem solving well, even though there were differences in the subject's beliefs in understanding the problem. The results of the study revealed that pre-service elementary mathematics teachers' self-efficacy beliefs scores towards mathematics teaching and mathematics are high and there is a positive relationship between mathematics teaching efficacy and mathematics self-efficacy (Ünlü & Ertekin, 2013). This is consistent with the statement of Zakariya (2021) high mathematics self-efficacy is associated with high performance in mathematics while low mathematics self-efficacy is associated with poor performance in mathematics.

Conversely, participants with low self-efficacy exhibited inaccurate problem-solving processes and outcomes. The information process was well received, but because the solution process was not performed systematically and sequentially by the participant, the solution result was incorrect. The participant was actually able to construct quadratic equations and use the quadratic equation method they had studied. From the results of the interviews, the student participant in the low self-efficacy category knew about the problem in the question but was not interested and motivated to solve it. This showed that participant, who had low self-efficacy, was less familiar with the problem solving question and lacked self-confidence when working on the problem solving question. This is consistent with the statement of Alifia and Rakhmawati (2018) that students with low self-efficacy tend to avoid difficult things, so when they are given challenges or obstacles in the form of questions that they consider difficult, they become less careful and work according to their needs and abilities. At the rechecking stage, the participant did not recalculate and did not show how they would recheck their answer. The participant also lacked stimulation to solve problems and was unable to develop strategies to achieve goals.

Self-efficacy gives one composure, persistence, good information and result interpretation, and the courage to use the best approach to solve problems in real life. This conclusion is consistent with previous studies that have shown that self-efficacy contributes to the reduction of mathematics anxiety (Macmull & Ashkenazi, 2019; Rozgonjuk et al., 2020), the achievement of predefined goals (Doÿru, 2017), sources of mathematics self-efficacy have effects on both mathematics test and course achievement (Özcan & Kültür, 2021). Overall, the results of the study support previous studies (Schöber et al., 2018; Zakariya et al., 2022) that have highlighted the importance of self-efficacy in academic success and the relationship between better mathematical comprehension and greater self-efficacy.

CONCLUSION

Based on the above data and discussion, it can be stated that self-efficacy exerts a significant influence on the process of algebraic thinking. The higher the self-efficacy, the better the algebraic thinking process will be. Students with high self-efficacy will be able to explain well the known and required information, can create mathematical models from the information in the problem, make equations and solve equations correctly, and perform calculation operations carefully. Optimizing a person's basic ability to think logically and solve mathematical problems strongly influences algebraic thinking skills. A strong understanding of basic mathematical concepts such as arithmetic, number operations and mathematical relationships is an important foundation for algebraic thinking. Good problem-solving skills will help to analyze problems, identify the necessary steps, and apply appropriate strategies to solve problems. The results indicate a significant relationship between levels of self-efficacy and algebraic thinking ability. Students with high and medium self-efficacy tend to exhibit a better understanding of algebraic concepts and demonstrate greater creativity in problem-solving. Conversely, students with low self-efficacy experience challenges in applying algebraic concepts and often lack the confidence necessary to respond effectively to the assigned questions. These findings underscore the importance of enhancing students' self-efficacy as a means of supporting more effective algebra instruction.

Implications

The practical implication of this study is to provide knowledge to mathematics teachers and pre-service teachers so that they can always maintain and improve self-efficacy in supporting students' algebraic thinking processes. It is on the basis that confidence in an individual's own ability to complete algebraic tasks greatly influences the performance and effort made by the individuals in algebraic thinking processes.

Research Limitations

This study was limited to those who had the ability to engage in algebraic thinking, as demonstrated by their ability to solve mathematical problems, which was assessed in terms of self-efficacy. Thus, it is still very open to study related to algebraic thinking in the form of other problems with different course characteristics, metacognition, cognitive styles and learning styles. Tracing the algebraic thinking process can also be done using assimilation and accommodation theory

Recommendations

Any problem that arises in daily life can be solved mathematically. Various difficulties in daily life require the process of algebraic thinking to be solved. Therefore, one must cultivate and get used to both learning and non-learning algebraic thinking. Self-efficacy in numerical reasoning is as important as knowledge aspects related to mathematical content. It is necessary to do more research on the elements that influence the algebraic thinking process and how it is applied in the classroom as well as in different everyday problems in different settings.

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