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Mathematical Problem-Solving and Self-Efficacy in the Context of Algebraic Derivatives: A High School Study

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ABSTRACT

The derivative of algebraic functions as a foundation for applications in mathematics, science, and engineering. Due to its complexity and contextual relevance, learning this topic demands not only strong problem-solving skills but also high levels of self-efficacy to support students' confidence and persistence in mastering the material. Therefore, this study aims to analyze students' mathematical problem-solving abilities and self-efficacy related to algebraic function derivatives. Conducted at a high school in Yogyakarta City, the study used a qualitative descriptive approach. Problem-solving was examined based on Polya's steps: understanding the problem, devising a plan, carrying out the plan, and looking back. Self-efficacy was analyzed using Bandura's dimensions: level, generality, and strength. The data was taken by self-efficacy questionnaire with Likert scale. The results elaborate students' problem-solving abilities in the topic of algebraic function derivatives fall into the good category. Students are also at a good level of self-efficacy. This study leads to the main conclusion that students' problem-solving ability and self-efficacy in algebraic function derivatives are both categorized as good, and that there is a positive relationship between the two, indicating that higher self-efficacy corresponds to better problem-solving performance. These findings suggest that self-efficacy plays a significant role in supporting students' success. Further research is recommended to explore this relationship more deeply, both qualitatively and quantitatively.

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Introduction

Problem-solving is an integrated part of mathematics learning (Căprioară, 2015; Santos-Trigo, 2020; Szabo et al., 2020; Olivares et al., 2021), confirming that learning

mathematics is closely related to problem-solving abilities. Learning mathematics means becoming a problem solver, as mathematical content inherently demands problem-solving skills. Several research findings support the strong link between problem-solving skills and students' mathematical thinking (Csapó & Funke, 2017; Delima, 2017; Nursoffina & Efendi, 2021). As a result, many studies in mathematics education emphasize the importance of problem-solving. This issue is also relevant in Indonesia. The Program for International Student Assessment (PISA) by the Organization for Economic Co-operation and Development (OECD), which regularly evaluates students' ability to apply knowledge in real-life contexts, highlighted the importance of mathematical problem-solving skills in its 2022 report (OECD, 2023).

Based on the latest results, OECD (2023) reported that Indonesian students' abilities are generally at level 1c to level 3, with the majority at level 1a and 1b, while there are no students from Indonesia at level 5 or 6. At level 1a, students can answer problems in simple contexts, while level 1b shows the ability to solve problems with easily understood contexts and clearly defined information. The absence of Indonesian students at level 5 or 6 explains that Indonesian students have not been able to cope with complex situations, solve abstract problems, apply problem-solving strategies, and think critically. Strengthen by the report that students' ability to solve math problems at almost all levels of education is still low, thus posing a significant challenge to mathematics teaching (Hadi et al., 2023; Fenanlampir et al., 2019; Septian et al., 2022).

The ability to solve mathematical problems has a fundamental role in learning the topic of derivatives of algebraic functions. The research council reported that understanding derivatives will provide a more comprehensive understanding of quantitative aspects in fields such as economics, medicine, and engineering, as well as open pathways to technical careers that shape modern life (Kunwar & Laxmi, 2023). Furthermore, Alhassn & Alfefi (2023) state that in addition to having uses in everyday life, derivatives are materially the basis of broader mathematical ideas. For example, Rojas Suárez et al. (2019) explained that derivative is a key idea in differential calculus. Wang et al. (2024) added that derivative learning is a critical topic in high school mathematics, therefore students are required to master it as well as possible. Hence, derivatives of algebraic functions serve as a suitable topic for enhancing and assessing students' mathematical problem-solving abilities.

Based on research conducted on the material of the derivative of algebraic functions, it was found that the derivative of algebraic functions is one of the difficult topics to learn. Prospective mathematics teachers reported that there are obstacles faced by students in learning the topic of derivatives of algebraic functions including limitations in understanding mathematical connections to the basic concepts of derivatives, errors in performing operations on functions, and lack of in-depth understanding of the concepts learned so that problem solving tends to focus only on procedural steps (Prihandhika et al., 2020; Rodríguez-Nieto & Moll, 2025). Another study analyzed students' understanding of the derivative of algebraic functions based on school origin, reported that Senior High School has a good memory of the material but tends to be less thorough, Islamic Senior High School students often forget to write symbols in equations, while Vocational High School students face difficulties in understanding algebraic concepts such as factoring quadratic equations and grouping terms (Mutia et al., 2021; Mulyani & Siregar, 2025).

Further exploration of student self-efficacy in the area of derivatives was conducted to provide a more comprehensive report on students' confidence in learning the derivatives of algebraic functions. Self-efficacy is an individual's belief in their capabilities within a specific domain (Bandura, 1997; Maddux, 2016; Farmer & Dupre, 2019). This definition highlights that self-efficacy can vary across different areas; for instance, some students may

feel confident in math but struggle with other subjects. Similarly, describes self-efficacy as a person's perception of their ability to take action. From these perspectives, it is clear that an individual's self-efficacy influences the actions they choose to take, which is directly relevant to the problem-solving approaches used by students when working on derivatives of algebraic functions in this study (Schunk, 2012; Artino Jr, 2012; Schunk & DiBenedetto, 2016). In support of this, students' self-efficacy in mathematics strongly influences their math anxiety and problem-solving performance (Pajares & Kranzler, 1995; del Carmen Pérez-Fuentes et al., 2020; Zhang & Wang, 2020). This suggests that a student's ability to tackle math problems is fundamentally tied to their confidence in learning mathematics. Furthermore, students with high self-efficacy are significantly more effective at solving math problems than their peers with moderate or low self-efficacy (Fatmasari et al., 2021; Soleymani & Rekabdar, 2016; Yousuf & Rajeswari, 2024). Although in several research shows that low self-efficacy is not a major inhibiting factor for algebraic ability in high school students, their study still underscores the importance of understanding self-efficacy in the context of algebra learning (Firmanti & Reflina, 2022; Kusuma & Mariani, 2024). Given these insights, it is essential to thoroughly examine students' self-efficacy in the context of algebraic function derivatives during problem-solving.

The higher the self-efficacy of university students, the better their achievement in derivative-related material (Kula, 2016; Hiltrimartin & Pratiwi, 2025). This finding suggests that students' self-efficacy is one of the factors influencing learning outcomes in derivative topics. Although the study was conducted in a higher education context, it highlights the impact of self-efficacy on understanding derivatives, which are also taught in senior high school. Furthermore, Street et al. (2022) stated that students who began learning a new topic in algebra tended to have lower self-efficacy compared to those who started a new topic in geometry. This result is particularly relevant in this discussion because algebraic derivatives are directly related to algebraic concepts. Therefore, analyzing students' self-efficacy in learning algebraic derivatives is crucial. Such analysis will contribute to a deeper understanding of the relationship between self-efficacy and achievement in algebraic derivative topics.

This research presents novelty by integrating two important aspects of mathematics learning, namely mathematical problem-solving ability and self-efficacy, in the context of the algebraic derivative topic, which is often considered complex by high school students. Therefore, this study focuses on exploring high school students' problem-solving ability and self-efficacy in the topic of algebraic function derivatives, as both factors are closely linked and play a crucial role in learning success. Although students often remember mathematical procedures well, they sometimes struggle to apply them accurately in problem-solving contexts, which may be influenced by their level of self-efficacy. Students with higher self-efficacy tend to approach problems with greater confidence and persistence, which can positively impact their problem-solving ability. By analyzing both self-efficacy and problem-solving ability simultaneously, this study aims to provide a deeper understanding of how these two aspects interact when students work through algebraic derivative problems. Most previous studies on difficulties in learning algebraic derivatives have been conducted at the university level, leaving a gap in the literature concerning high school students.

This research is significant because it provides a deep understanding of how students' confidence in their mathematical abilities can influence their strategies and success in solving problem-based tasks. The findings of this study have the potential to serve as a foundation for developing more effective learning strategies that focus on strengthening both the affective and cognitive aspects of students in calculus learning at the high school level. Further investigation at the high school level is necessary to determine whether similar

patterns exist and to provide insights into how self-efficacy and problem-solving ability together influence student achievement in this topic. The results of this study can serve as a reference for future research on problem-solving and self-efficacy in the context of algebraic function derivatives. In addition, this study provides a descriptive overview of the relationship between students' problem-solving ability and self-efficacy, which can be used as a basis for further research on mathematics learning achievement across different educational levels.

Method

This research was qualitative research with a descriptive method. This method was used to provide a thorough and in-depth description of students' mathematical understanding ability. Qualitative descriptive research aimed to describe the phenomena that occurred at the time of the research, as well as to explain and detail various aspects related to students' mathematical understanding ability based on certain predetermined indicators. The research subjects were 27 high school students in grade XI of the Sciences program at one of the high schools in the city of Yogyakarta who had learned the material on the derivative of the algebraic function, limit function, and the properties of the derivative of the algebraic functions.

The problem-solving analysis in this study follows Polya's (2015), problem-solving stages, namely understanding the problem, devising a plan, carrying out the plan, and looking back. Gulam & Arenas (2024) affirmed in their study that Polya's method facilitated the formation of a systematic approach to thinking and problem-solving in pupils, which is crucial for their mathematical advancement. Building on this foundation, the study also incorporates Bandura's (1997) framework on self-efficacy, which identified three critical dimensions: level or magnitude, generality, and strength. These dimensions provided a comprehensive basis for assessing self-efficacy (Bruning et al., 2011) and were used in this research to evaluate how self-efficacy contributed to enhancing students' mathematical competence.

As shown in Figure 1, the research utilized a test instrument consisting of three essay questions that were constructed based on Polya's problem-solving steps. In addition, to measure students' self-efficacy, the researchers employed a questionnaire comprising 20 statement items using a Likert scale, with the statements developed based on Bandura's self-efficacy dimensions. The questionnaire applied a four-point Likert scale for scoring, with response options including: strongly agree, agree, disagree, and strongly disagree.

Before being used to collect research data, both the problem-solving ability test and the self-efficacy questionnaire were first analyzed for their validity and reliability. Content validity was evaluated using the Aiken's V index, which measured the level of agreement among three expert raters. The results of the validity test indicated that both instruments were considered valid. Reliability testing was then conducted using Cronbach's Alpha formula, yielding a reliability coefficient of 0.66 for the problem-solving ability test and 0.90 for the self-efficacy questionnaire. The classification criteria for determining the degree of instrument reliability used in this study are presented in Table 1 (Rasmuin et al., 2021).

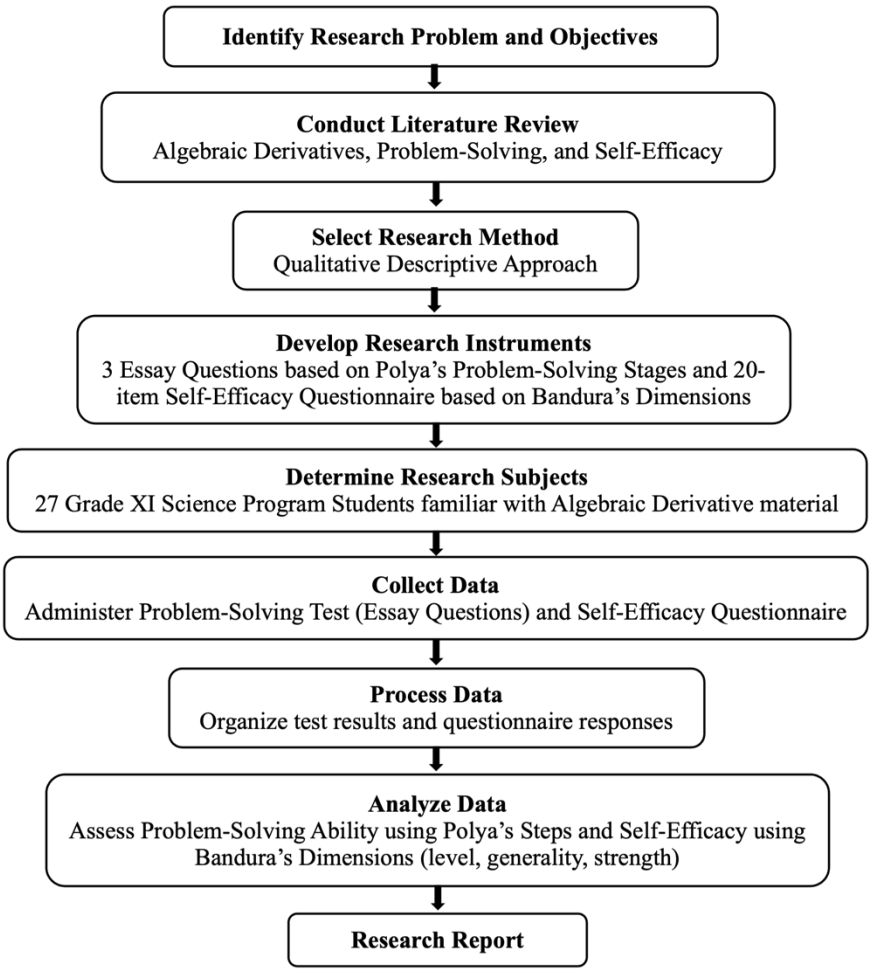


Figure 1. Research flows

Table 1. Classification of Reliability Degrees

Reliability Coefficient	Reliability Criteria
0,80 – 1,00	Very high
0,60 – 0,79	High
0,40 – 0,59	Enough
0,20 – 0,39	Low
0,00 – 0,19	Very Low
<0	Unreliable

Based on Table 1, the problem-solving ability instrument used in this study demonstrated high reliability, while the self-efficacy questionnaire exhibited very high reliability. Therefore, both instruments were considered appropriate for use in this research. The next step involved the categorization of students' problem-solving ability and self-efficacy levels, which was conducted using the following formula. The categorization criteria are presented in Table 2 (Zakiyah et a., 2018).

Table 2. Criteria for Percentage Classification of Problem-Solving Ability and Student Self-Efficacy

Criteria (%)	Classification
$0 \leq N \leq 20$	Very low
$20 < N \leq 40$	Low
$40 < N \leq 60$	Enough
$60 < N \leq 80$	Good
$80 < N \leq 100$	Very good

Table 2 categorizes students' problem-solving abilities according to Polya's stages and examines their performance on each item. This same categorization method was also applied

to assess students' self-efficacy levels. Following the categorization, as shown in Figure 1, the categorized data were then analyzed using qualitative descriptive analysis to provide a detailed and in-depth understanding of the students' problem-solving abilities and self-efficacy.

Results and Discussion

Problem-solving skills are explored from students' ability to solve problems and stages of problem-solving. The following are details of the problem-solving ability test results analyzed based on the items. Table 3 is a calculation based on question items.

Table 3. Percentage of Problem-Solving Ability Based on Questions Items

Questions	Amount	Percentage	Classification
1		93,73	Very good
2		79,49	Good
3		53,56	Enough
Total		75,95	Good

Table 3 shows that overall students' problem-solving skills based on the items are in a good category. Specifically, item 1 is relatively easier than items number 2 and 3 and item number 3 requires the most problem-solving skills. Table 5 below presents the results of the analysis of students' problem-solving skills based on indicators to provide analysis and discussion on the problem-solving steps taken by students.

Table 4. Percentage of Problem-Solving Ability Based on Indicators

Indicators of problem-solving ability	Percentage	Classification
Identify the problem and understand the problem by stating what is known and asked in the problem.	84,63	Very good
Planning problem solving by stating the right strategy in solving the problem.	76,85	Good
Solve the problem according to the plan and perform the calculation operation correctly.	73,77	Good
Evaluate the solution and draw conclusions.	64,81	Good
Total	75,01	Good

The analysis of Polya's problem-solving steps, as presented in Table 4, indicates that students' problem-solving abilities in the topic of algebraic function derivatives fall into the good category. Students demonstrated very good proficiency in the "understanding the problem" stage, while their performance in the stages of "devising a plan," "implementing the plan," and "looking back" was categorized as good. The high level of proficiency in understanding the problem suggests that students were able to interpret and comprehend the given problems accurately and thoroughly. The categorization results of students' self-efficacy are presented in Table 5.

Table 5. Results of Problem-Solving Ability Analysis Based on Indicators.

Self-efficacy indicators	Percentage	Classification
Confidence in oneself in performing or completing tasks based on the level of difficulty.	66,67	Good
Confidence in one's own abilities in various activities or breadth of topic areas and tasks.	66,78	Good
Confidence in one's ability or determination when doing assignments, exams, and questions as well as determination in the subject or material.	73,15	Good
Total	68,87	Good

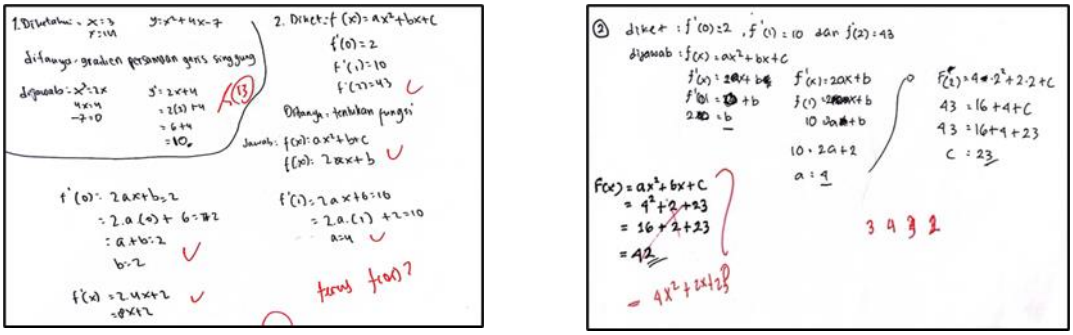
Based on Table 5, the analysis results of all self-efficacy indicators indicate that students are at a good level of self-efficacy. This suggests that the 27 eleventh-grade science students who participated in this study possess a good level of self-efficacy in learning the

topic of algebraic function derivatives. Among the three indicators, Indicator 3 shows the highest percentage at 73.15%, indicating that students exhibit greater confidence in their own abilities during the learning process compared to their perceived flexibility in engaging with task activities or their confidence in completing tasks based on varying levels of difficulty. Meanwhile, the percentages for Indicator 1 and Indicator 2 are relatively similar, at 66.67% and 66.78%, respectively. These findings suggest that students' self-efficacy related to task difficulty and task breadth is relatively balanced. Overall, students demonstrate good self-efficacy in the context of algebraic function derivatives, with a particularly stronger sense of confidence in their personal capabilities compared to their perceptions of task complexity and scope.

The results from Table 4 and Table 5 indicate that students' problem-solving abilities in the topic of algebraic function derivatives are influenced by their self-efficacy related to the subject matter being taught. The findings reveal that the average level of students' problem-solving ability falls into the good category, as does their self-efficacy. Therefore, it can be concluded that a high level of self-efficacy contributes positively to students' achievement in problem-solving tasks. These results are consistent with previous research, which has shown that students with higher self-efficacy tend to perform better in solving mathematical problems (Fatmasari et al., 2021; Soleymani & Rekabdar, 2016; Yousuf & Rajeswari, 2024).

In addition, the findings of this study differ from those of Mulyani & Siregar (2025), who reported that students demonstrated low mathematical understanding in the topic of algebraic function derivatives. This discrepancy may be attributed to the high level of self-efficacy observed among students in the present study, which contributed to their confidence and motivation to engage with the learning material. The higher a student's self-efficacy regarding algebraic function derivatives, the better their academic performance tends to be, including in problem-solving tasks (Kula, 2016; Hiltrimartin & Pratiwi, 2025). While that study was conducted among undergraduate students majoring in mathematics education, the present study confirms that similar patterns also apply to high school students.

To provide a more in-depth description and identify opportunities for further research, the analysis of students' written work is elaborated. Based on Table 3, in item number 1, almost all students achieved high scores, including when analyzed through the lens of Polya's problem-solving steps. However, some student errors on this item were found in calculation mistakes and drawing inappropriate conclusions. For item number 2, students' errors can be observed in Figures 2 below.



(a) (b)

Figure 2. Error analysis of problem
(a) number 2 type 1, (b) number 2 type 2

Based on Figure 2(b), it can be seen that students have written the known information from the problem correctly but have not written what is asked. This makes students unable to give a good conclusion, even though mathematically the student's answer is correct, they

just have not written the answer as asked in the question, namely the final function formed. In Figure 3, it can be seen that students already know the information and asked, but students have not answered what is asked. Student answers that are by the steps of problem-solving are presented in Figure 3 below.

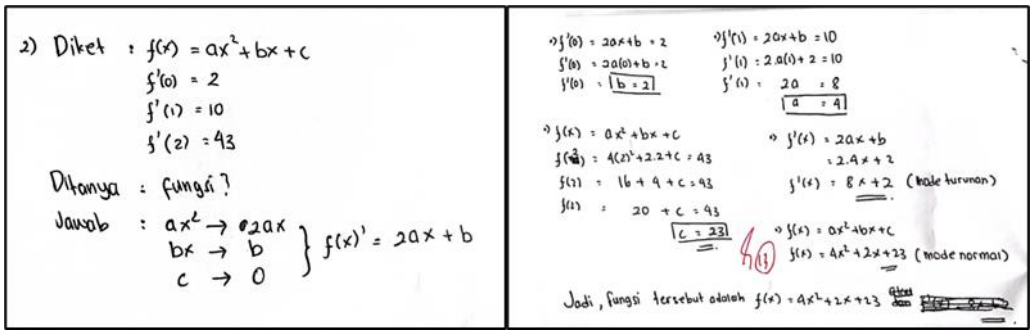


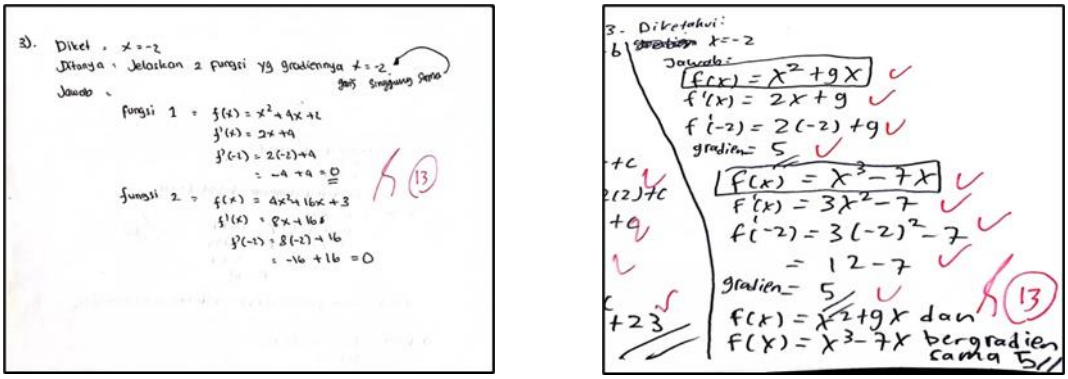
Figure 3. Correct Answer for Problem Number 2

Item number 3 is a problem with an open-ended problem context so students need creative thinking to solve the problem. This is by research (Bahar & Maker, 2015) which states that students have difficulty in solving open-ended problems whose answer is not only one compared to problems with closed solutions that only have one answer so creativity is needed in solving open-ended problems. Figure 5 and Figure 6 are examples of student errors in solving item 3. In Figure 4(a), it can be seen that students already know the problem and have been able to make a solution plan, but there is an error in the math multiplication operation. In Figure 4(b) it can be seen that students have not understood correctly what is asked so the plans and conclusions given are not correct.

(a) (b)

Figure 4. Error analysis of question
(a) number 3 type 1, (b) number 3 type 2

The following are the answers of students who answered correctly on question 3.



(a) (b)

Figure 5. Correct answer
(a) number 3 type 1, (b) number 3 type 2

Based on Figure 5, it can be seen that type 1 students have different answers from type 2 students but both are correct. This explains that these students have been able to solve the problem in question 3. From the overall explanation above, the errors that arise from

students' problem-solving are: 1) Errors in calculations during the plan implementation process, 2) Errors in identifying what is known and asked from the problem so that it affects the conclusion, and 3) students' difficulty in understanding problems with open-ended problem types. These results are by research conducted by Belnard et al. (2022) who reported that the errors obtained in learning the derivative of algebraic functions students were errors in understanding the problem, errors in transforming the problem, errors in the ability to process the calculation, and errors in writing the final answer. Overall, high school students in grade XI IPA who are the subjects of this study have good problem-solving skills, are very good at the stage of understanding the problem, and have a lower level of problem-solving on item number 3, namely on questions with open questions.

Conclusion

This study leads to three main conclusions. First, students' problem-solving ability in the topic of algebraic function derivatives is categorized as good. Second, students also demonstrate a good level of self-efficacy across all measured indicators. Third, there is a positive relationship between self-efficacy and problem-solving ability, indicating that the higher the students' self-efficacy, the better their problem-solving performance. Additionally, students showed stronger performance in the understanding the problem stage compared to devising a plan, carrying out the plan, and looking back. Meanwhile, all dimensions of self-efficacy were consistently categorized as good. These findings suggest that self-efficacy plays a significant role in supporting students' success in solving mathematical problems. Further research is recommended to explore this relationship in greater depth, both through qualitative and quantitative approaches, particularly within the context of algebraic function derivatives.

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