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The Relationship between Self-Directed Learning and Problem-Solving Ability in Trigonometry

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ABSTRACT

Mathematical problem-solving abilities in trigonometry material remain a challenge for many students, partly because they lack self-directed learning skills to manage the learning process. This research aims to analyze the relationship between self-directed learning and students' mathematical problem-solving abilities in trigonometry material. The research approach is quantitative, using a correlational method. The research sample consists of 62 vocational high school students in Karawang Regency, selected through random sampling. The research instruments include a self-directed learning questionnaire and an essay test of problem-solving abilities. The questionnaire measures initiative, responsibility, self-regulation, and students' evaluative abilities in the learning process, while the problem-solving ability test assesses students' abilities to understand, plan, execute, and evaluate trigonometry problem solutions. Data analysis was conducted using the Pearson correlation test. The research results show a strong, significant positive relationship between self-directed learning and mathematical problem-solving abilities, with a correlation coefficient of $r = 0.679$ and a significance value of < 0.001. These findings indicate that increased self-directed learning tends to be followed by greater ability to solve mathematical problems.

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1. INTRODUCTION

Education plays a crucial role in shaping intelligent, character-driven, and adaptable human resources to meet the challenges of the 21st century. It serves a strategic function in preparing individuals to possess abilities that align with the developments and demands of 21st-century competencies [1]. In the era of globalization and technological advancement, education focuses not only on mastering knowledge but also on developing critical, creative, and independent thinking skills. The learning process in schools is expected to foster students' potential, enabling them to become individuals capable of solving various life problems logically and responsibly. Education plays a vital role in cultivating thinking abilities, which are the primary factors determining an individual's success in facing diverse life challenges [2].

Nevertheless, one ongoing challenge in Indonesia's education system is students' low ability to solve mathematical problems. This issue is significant to examine because problem-solving ability is a primary indicator of 21st-century skills and high-level thinking competencies in mathematics. This condition is evident in international assessment results, where Indonesia's PISA score in 2022 was only 366 in numeracy, far below the average of developed countries [3]. These findings indicate the need to improve the quality of mathematics education, particularly in developing problem-solving abilities, which is one of the core competencies in the curriculum and equips students to face real-life challenges.

One of the subjects taught in schools is mathematics. Mathematics plays an important strategic role in developing logical, analytical, and systematic thinking. As stated by Siahaan and Surya, mathematics is taught at every level of education, from elementary school onward, to equip students with logical, analytical, systematic, critical, and creative thinking abilities to face and solve various problems [4]. As a science closely related to reasoning and thinking structures, mathematics helps humans understand and solve various life problems. In line with that, according to Siswanto and Meiliasari, mathematics plays an important role in daily life, serves as the basis for various sciences, and provides the main support for the development of technology and modern knowledge [5]. One of the competencies emphasized in mathematics learning is problem-solving, which includes the ability to understand problems, formulate solutions, apply strategies, and interpret the results. As stated by Kania and Ratnawulan, problem-solving is a logical, critical, and scientific thinking process that seeks solutions through the stages of understanding, planning, implementing, and rechecking the results [6].

Various studies indicate that students' problem-solving abilities in Indonesia remain low. This condition highlights the need for efforts to identify factors that can enhance mathematical problem-solving abilities. One factor believed to influence this ability is self-directed learning. Low problem-solving ability is often influenced by students' passive, dependent learning patterns. In this context, self-directed learning becomes an important factor that can improve problem-solving abilities. According to Suhendri and Mardalena, self-directed learning is a process in which students learn independently, without relying on others, to achieve learning goals [7]. The principle of self-directed learning, in which learners actively manage the entire learning process, including planning, managing activities, and selecting problem-solving strategies, ensures that knowledge and skills are acquired through independent effort 8]. To address this issue, this research analyzed the relationship between self-directed learning and problem-solving ability in trigonometry material using a quantitative correlational approach. This analysis aims to identify the extent to which self-directed learning can predict improvements in mathematical problem-solving abilities, thereby providing a basis for formulating learning strategies that foster self-directed learning while also enhancing students' problem-solving abilities.

Previous research findings also indicate a positive relationship between self-directed learning and learning outcomes. Nainggolan, Yuni, and Suryanti demonstrated a significant positive correlation between self-directed learning and mathematics learning outcomes, with a correlation coefficient of rxy = 0.879 [9]. Self-directed learning is strongly associated with students' success in understanding trigonometry concepts. As stated by Arsyad et al., there is a positive and significant relationship between self-regulated learning and mathematics learning outcomes, accounting for 40% students' achievement in trigonometry material [10]. However, several studies also show that students still struggle to understand concepts and solve trigonometry problems. Sari and Roesdiana found that students' comprehension level of trigonometry material remains relatively low [11]. Amini, Qudsiyah, and Meifiani discovered that some students are not yet able to develop the concepts they have learned to achieve correct final results [12]. Noviyanti and Riajanto also found that almost all students experience difficulties understanding problems, and most do not write down the final results when solving trigonometry problems [13]. The research by Sari, Kamid, and Rusdi further revealed that many vocational high school students are unable to identify key information in trigonometry problems and face difficulties formulating problem-solving steps. This research indicates a connection between self-directed learning and problem-solving, with students who exhibit high levels of self-directed learning demonstrating better mathematical problem-solving[14].

Based on this review, it can be concluded that research on self-directed learning and research on trigonometry problem-solving abilities have been extensively conducted. However, most studies examine self-directed learning only in relation to learning outcomes, without directly linking it to problem-solving. Conversely, other studies focus on difficulties in trigonometry problem-solving without considering internal or psychological factors in students, such as self-directed learning. Thus, there is a research gap in the form of a lack of studies that simultaneously analyze the relationship between self-directed learning and problem-solving abilities, specifically in trigonometry material at the vocational high school level. Therefore, this study offers a new contribution by examining the relationship between these two variables in the context of trigonometry learning.

The urgency of this research lies in the need to obtain an empirical understanding of the extent to which self-directed learning enhances students' mathematical problem-solving abilities, particularly in conceptual and continuous trigonometry material. In the current learning context, self-directed learning has become a crucial competency for developing higher-order thinking skills. Therefore, the findings of this research are expected to serve as a basis for educators in formulating learning strategies that can foster self-directed learning while optimizing students' problem-solving abilities.

Based on this description, the objective of this research is to determine whether there is a significant relationship between self-directed learning and students' mathematical problem-solving abilities in trigonometry material. Theoretically, this research is expected to enrich the literature on factors influencing mathematical problem-solving abilities. In practice, this research is expected to provide information and recommendations to teachers and schools on designing effective learning strategies to improve students' self-directed learning and mathematical problem-solving abilities. Thus, this research makes an important contribution to efforts to enhance the quality of mathematics learning in schools.

2. METHOD

A quantitative research design with a correlational method was applied in this study. Correlational research is intended to measure the extent to which variables are related, without altering or treating them in any way [15]. The study explores how self-directed learning relates to students' problem-solving abilities. Therefore, the researcher assumes that the correlational method is the most appropriate method for this study.

This research design illustrates the relationship between self-directed learning (X), serving as the self-directed variable, and problem-solving ability (Y), serving as the dependent variable. The model of this relationship was adapted and modified from the research design proposed by Ismail and Zulkarnaen [16].

The study population consisted of 73 grade X students from a vocational high school in Karawang Regency who had received trigonometry instruction. The sample size determination followed Arikunto's guideline, which states that when the population exceeds 100 individuals, a sample of 10–15%, 20–25%, or more than 25% may be taken [17]. This research employed a random sampling technique, ensuring that each member of the population had an equal chance of being selected [18]. The Number of participants was determined using Slovin's formula [19], that is:

$$n = \frac{N}{1 + N\alpha^2}$$

Information:
n = Number of samples
N = Number of populations
α = Percentage of permissible error (5% or 0.05)

A total of 62 students were selected as samples based on calculations. A random sampling approach was used because the population was highly homogeneous and there was no significant variation between classes.

This study involved two main variables, namely: (1) self-directed learning (X): students' ability to consciously organize, control, and evaluate their learning process without relying on others, in terms of: learning initiative, identifying learning needs, setting learning goals, monitoring and regulating learning activities, perceiving difficulties as challenges, utilizing and seeking relevant learning resources, possessing and applying learning strategies, assessing both the learning process and outcomes, and maintaining a positive self-concept [20]. (2) problem-solving ability (Y): students' ability to understand, plan, implement, and evaluate the solution of mathematical problems. The assessment aspects are drawn from the steps in solving problems according to Polya: understanding the problem, designing a solution, working on the solution, and checking the results [21].

The research used two types of instruments: tests and non-test. Test instruments consist of questions used to test problem-solving abilities, while non-test instruments are questionnaires used to measure students' self-directed learning levels. Additionally, essay tests were used to assess their mathematical problem-solving abilities. Both tools were taken from previous thesis research and checked for reliability and validity.

1. Self-Directed Learning Questionnaire

   The questionnaire contains 26 statements with aspect: showing that students have initiative in learning, showing that students can diagnose learning needs, showing that students have learning goals, showing that students can monitor, manage, and control learning, showing that students view difficulties as challenges, showing that students can utilize and seek relevant learning resources, showing that students can choose and apply learning strategies, showing that students evaluate the learning process and outcomes, and showing that students have self-concept [20]. The questionnaire was filled out by placing a check mark (√) on one of the options: strongly disagree (SDA), disagree (DA), agree (A), or strongly agree (SA). The scoring criteria are presented in Table 1.

Table 1. Scoring Guidelines for the Self-Directed Learning Instrument

Alternative Answers	SDA	DS	A	SA
Positive	1	2	3	4
Negative	4	3	2	1

2. Problem-Solving Ability Test

   The Instruments are displayed as essay questions on trigonometry material. The problem-solving test questions were adopted from the thesis [21]. The following is an outline of the problem-solving test in Figure 1.

KISI-KISI TES PEMECAHAN MASALAH

Sekolah : SMKN Cilebar
Mata Pelajaran : Matematika
Kelas : X
Materi Pokok : Trigonometri
Alokasi Waktu : 60 menit

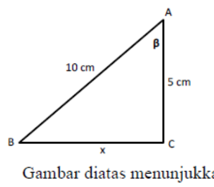
No	Pemecahan Masalah Matematika		Butir Soal	Skor Maksimal
	Tahapan	Indikator		
1	Memahami Masalah	1) mampu menentukann apa yang diketahui dan apa yang ditanyakan pada masalah 2) mampu menjelaskan masalah dengan bahasa dan kalimat masing-masing	1. Sebuah pohon memiliki tinggi 12 meter. Sebuah kabel dipasang dari ujung pohon hingga ke tanah, membentuk sudut 30° terhadap tanah. Tentukan panjang kabel yang dipasang?	50
2	Menyusun Rencana Pemecahan Masalah	1) mampu menentukan rencana yang digunakan untuk menyelesaikan masalah 2) mampu menentukan rumus yang digunakan untuk menyelesaikan masalah	2. Perhatikan Gambar Berikut  	50
3	Melaksanakan Rencana Penyelesaian	1) mampu menerapkan setiap langkah yang direncanakan untuk menyelesaikan masalah 2) mampu menerapkan setiap rumus yang telah ditentukan untuk menyelesaikan masalah		
4	Memeriksa Kembali	1) mampumenentukan kesimpulan dari masalah mampu 2) memeriksa Kembali rencana dan perhitungan yang telah di lakukan	Gambar diatas menunjukkan segitiga siku-siku dengan panjang sisi samping yang berhadapan 5cm dan panjang sisi miring 10 cm. Tentukan nilai dari a. Sin β b. Cos β c. Tan β	

Figure 1. Problem-solving test outline

Data collection involved a descriptive test to evaluate students' mathematical problem-solving and a questionnaire to determine their self-directed learning level. A questionnaire serves as a data-gathering tool consisting of a set of written items that respondents are required to answer [18].

Data analyzed using JASP software version 0.95.3. JASP is open-source, graph-based statistical software with an "easy-to-use" graphical interface for performing a wide range of common statistical analyses. This program can be run on Windows, Mac OS X, and Linux [22]. The following are the instructions for use:

a. Preliminary Assumption Test, including the Normality Test using the Shapiro–Wilk method to identify the data distribution, and a Linearity Test using a *scatter plot* to ensure that the relationship between variables is linear.
b. Pearson Product-Moment Correlation Test. The Pearson Product–Moment correlation (r) was employed to examine both the direction and the strength of the relationship between the variables, as reflected in the correlation coefficient [23]. The relationship between variable X (problem-solving ability) and variable Y (self-directed learning) can be either positive or negative. The decision rules are as follows: (1) a significance value less than 0.05 indicates that a correlation is present, and (2) a significance value greater than 0.05 indicates that no correlation exists. If the significance value equals 0.05, the Pearson correlation coefficient must be compared with the critical r value. The criteria for this comparison are: (1) if the computed Pearson coefficient exceeds the critical r value, a correlation is confirmed, and (2) if it is lower, a correlation is not supported [23]. The interpretation of the resulting correlation coefficients is displayed in Table 2 [24].

Table 2. Interpretation of Correlation Coefficients

Correlation Coefficients	Interpretation
$0{,}000 \leq x < 0{,}199$	Very Low
$0{,}200 \leq x < 0{,}399$	Low
$0{,}400 \leq x < 0{,}599$	Currently
$0{,}600 \leq x < 0{,}799$	Strong
$0{,}800 \leq x < 1{,}000$	Very Strong

3. RESULTS AND DISCUSSION

3.1. Result

Prior to performing the correlation analysis, the data were examined for normality and linearity to confirm that the assumptions of parametric statistics were satisfied. Table 3 displays the findings of the normality test.

Table 3. Normality Test Results

	Self-directed learning	Problem-solving ability
Mean	78.65	71.79
Std. Deviation	8.559	15.46
Shapiro-Wilk	0.979	0.964
P-value of Shapiro-Wilk	0.362	0.069
Minimum	62.00	36.00
Maximum	102.0	95.00

The descriptive analysis results shown in Table 3 indicate that students' overall self-directed learning abilities are at a good level, with no significant differences in scores between individuals. This means that students' ability to manage and direct their learning process is relatively uniform. In contrast, the problem-solving ability exhibited a broader distribution of scores. This condition shows that students' ability to understand and solve trigonometry problems still varies. Some are quite good at it, while others still struggle to apply the concepts.

According to the Shapiro-Wilk decision rule, data are considered normally distributed when the p-value exceeds 0.05, whereas a p-value at or below 0.05 indicates non-normality. The results of the Shapiro–Wilk test indicated that both variables met the normality assumption, with p-values of 0.362 for variable X and 0.069 for variable Y, both of which are greater than 0.05. These results indicate that the distributions of self-directed learning and problem-solving ability are adequately centered around the mean and, therefore, satisfy the normality assumption required for subsequent parametric analysis. Following the normality assessment, a linearity test was performed to verify whether the relationship between the two variables is linear. The linearity test results are presented in Figure 2.

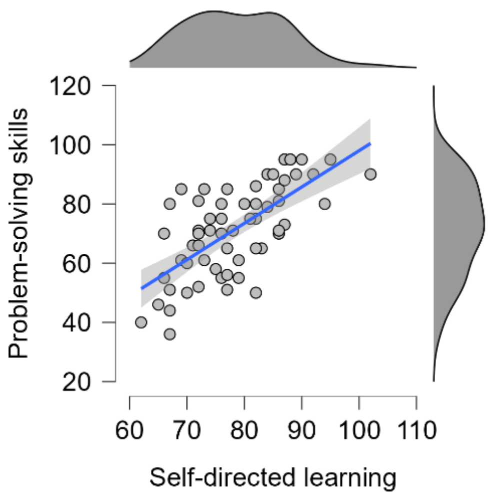


Figure 2. Scatter Plot of Self-Directed Learning and Problem-Solving Ability

As shown in Figure 3, the scatter plot for the linearity test shows that the data points align closely with the regression line and form an upward-sloping pattern. Based on the linearity criteria, this pattern indicates a linear relationship between the dependent variable (problem-solving ability) and the independent variable (self-directed learning).

The preliminary analysis verified that the data fulfilled both the normality and linearity assumptions. Therefore, the Pearson Product–Moment correlation test was applied to determine the strength and direction of the linear relationship between the two normally distributed variables [16]. The results of the correlation analysis are presented in Table 4.

Table 4. Correlation Test Results

Pearson's Correlations

			Pearson's r	P
Self-directed learning	-	Problem-solving ability	0.679	< 0.001

Based on Table 4, the significance value was 0.001, and the Pearson correlation coefficient was 0.679. According to the correlation testing criteria, a p-value below 0.05 indicates a meaningful relationship between the two variables. The level of relationship is measured using the Pearson correlation coefficient, and its interpretation refers to the classification established by Guilford [25]. Next, the direction of the correlation was determined based on the Pearson correlation coefficient. A negative correlation is indicated by a minus sign, while the absence of such a sign signifies a positive correlation. The Pearson correlation analysis yielded an r-value of 0.679 ($p < 0.001$), indicating a strong, statistically significant positive association between self-directed learning and mathematical problem-solving performance [23]. Accordingly, higher levels of student self-directed learning are accompanied by improved problem-solving capabilities.

3.2. Discussion

The findings indicate a strong, statistically significant positive relationship between self-directed learning and students' trigonometry problem-solving performance, as reflected in a correlation coefficient of 0.679 and a p-value of less than 0.001. This means that students who are more active in self-directed learning tend to be better at solving math problems. These findings indicate that students who can manage and direct their own learning processes tend to be more capable of thinking critically and systematically in solving mathematical problems. These findings are consistent with those of Sulistyani, Roza, and Maemunah, who demonstrated that self-directed learning is positively and significantly associated with students' ability to solve mathematical problems. They emphasized that students who are accustomed to self-directed learning have higher self-confidence and can think reflectively when facing academic challenges [26]. In this study, this is evident in students' ability to solve trigonometry problems in a more structured and focused manner, indicating that self-directed learning helps improve students' thinking skills.

Self-directed learning is very important in shaping students' logical and strategic thinking ability in problem-solving. Self-directed students will become accustomed to managing their study time, seeking additional sources of information, and finding solutions to complex problems [27]. This outcome is consistent with the current study's findings, suggesting that students who exhibit a high level of self-directed learning tend to perform better at understanding and solving trigonometric problems that require logical reasoning and sustained application of mathematical concepts.

These results are further supported by a study by Sari, Kamid, and Rusdi, which found that vocational high school students with high levels of self-directed learning were better able to meet the mathematical problem-solving aspect than students with low self-directed learning [14]. The results show that self-directed learning not only affects general academic ability but also plays an essential role in higher-order thinking ability, such as problem-solving.

Moreover, the findings of this research are consistent with those reported by Sari, Priatna, and Juandi, who emphasized the role of self-concept in logical thinking and mathematical problem-solving. Students with a strong self-concept tend to exhibit greater self-confidence and initiative in learning, which reflects a higher level of self-directed learning. Conversely, students with low self-concept showed greater dependence on teachers and were less able to manage their learning process self-directedly [28]. The same pattern was observed among the students in this study: those with low self-directed learning had difficulty understanding basic trigonometry concepts, especially during the planning and reviewing stages of problem-solving. Thus, self-concept can be viewed as an internal factor that reinforces self-directed learning, while self-directed learning becomes a tangible manifestation of the application of positive self-concept in the learning process.

The findings of this study hold significant implications for mathematics teaching practices in vocational high schools. Teachers are encouraged to strengthen students' self-directed learning by implementing instructional strategies that enhance active engagement, such as problem- or project-based learning. This approach allows students to manage their own learning process, evaluate their progress, and relate trigonometry concepts to real-world situations relevant to the workplace. In line with the findings of Akhiroh, Artiono, and Rachman, active involvement in solving real-world problems has been shown to increase students' self-directed learning and critical thinking ability [29].

From a pedagogical perspective, mathematics teachers in vocational schools should design learning activities that foster responsibility and self-reflection, for example, by allowing students to self-directedly design strategies for solving trigonometry problems and then discuss the results in groups. This step not only reinforces the concept of trigonometry but also fosters a habit of continuous self-directed learning. Group discussions provide students with the opportunity to collaborate and deepen their understanding of concepts through the exchange of ideas and the use of various problem-solving strategies[30].

Theoretically, the findings of this study reinforce Self-Determination Theory, which emphasizes that autonomy and a sense of competence are the main drivers of student motivation for learning and self-directed learning [31]. This means that the greater the students' sense of control and competence, the greater their tendency to take initiative in learning and solve problems self-directedly.

This study is limited by the scope of its sample, which was restricted to a single school in Karawang Regency. Therefore, the findings cannot be widely generalized. Future inquiries are encouraged to encompass a substantially wider range of schools with heterogeneous program orientations, thereby enabling a more exhaustive and nuanced examination of the relationship between self-directed learning and students' mathematical problem-solving competence.

4. CONCLUSION

This research demonstrates that self-directed learning plays a significant role in shaping students' trigonometry problem-solving abilities. In general, students with higher levels of self-directed learning tend to manage their learning processes more effectively, making them better prepared to tackle mathematical problems that require analysis, reasoning, and deep conceptual mastery. These findings reinforce the view that developing self-directed learning is a strategic aspect in enhancing the quality of mathematics education.

The implications of this research suggest that educators should implement learning strategies that encourage students to become more independent, such as applying problem-based approaches, using worksheets that facilitate self-reflection, or providing space for students to plan and evaluate their learning. These efforts not only have the potential to improve problem-solving abilities but also help students face other learning challenges with greater confidence and responsibility.

Nevertheless, this research has several limitations, including the contextual limitation of a single school sample and the limitation of instruments that measure self-directed learning based solely on students' perceptions. This may affect the generalizability of the findings. Given these limitations, future research is recommended to involve broader samples, use mixed-method designs to obtain a more comprehensive picture, and develop observational instruments that capture behavioral aspects of self-directed learning more objectively. Subsequent studies could also explore how self-directed learning interacts with other factors, such as motivation, interest, and metacognitive strategies, to influence problem-solving abilities.

In practice, this research's contribution can serve as a reference for schools, teachers, and education policymakers in designing programs or learning methods to strengthen students' self-directed learning. With increased self-directed learning, it is hoped that students can address mathematical learning challenges more effectively and ultimately improve the quality of learning in society.

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