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SELF-DIRECTED LEARNING: A KEY FACTOR IN MATHEMATICAL LOGICAL COURSES

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Abstract

This study examines the effect of learning independence on student academic achievement in mathematical logic courses. Using the survey method, the study involved 72 second semester students at Indraprasta PGRI University who were randomly selected using proportional cluster random sampling technique. The research instruments included a learning independence questionnaire and a mathematical logic comprehension test, which were tested for validity through content validity and reliability using Cronbach's Alpha with a value of 0.68. Theresults of linear regression analysis showed that learning independence has a positive and significant effect on understanding mathematical logic, with each one-point increase in learning independence increasing learning outcomes by 0.527 points. However, this study has limitations, including the scope of the sample being limited to one university and potential respondent bias due to measurement through self-report questionnaires. This study recommends lecturers to adopt methods such as project-based learning to encourage students' learning independence. This recommendation can improve students' understanding of material that requires in-depth analysis. Further research is expected to involve a more diverse sample and use a longitudinal design to explore the impact of learning independence in more depth.

Keywords: Self-directed learning, academic achievement, mathematical logic

Abstrak

Penelitian ini mengkaji pengaruh kemandirian belajar terhadap pencapaian akademik mahasiswa dalam mata kuliah logika matematika. Dengan metode survei, penelitian melibatkan 72 mahasiswa semester dua di Universitas Indraprasta PGRI yang dipilih secara acak menggunakan teknik proportional cluster random sampling. Instrumen penelitian mencakup kuesioner kemandirian belajar dan tes pemahaman logika matematika, yang diuji validitasnya melalui validitas isi dan reliabilitasnya menggunakan Cronbach's Alpha dengan nilai 0,68. Hasil analisis regresi linear menunjukkan kemandirian belajar berpengaruh positif dan signifikan terhadap pemahaman logika matematika, dengan setiap peningkatan satu poin pada kemandirian belajar meningkatkan hasil belajar sebesar 0,527 poin. Namun, penelitian ini memiliki keterbatasan, termasuk ruang lingkup sampel yang terbatas pada satu universitas dan potensi bias responden akibat pengukuran melalui kuesioner self-report. Penelitian ini merekomendasikan dosen untuk mengadopsi metode seperti project-based learning untuk mendorong kemandirian belajar mahasiswa. Rekomendasi ini dapat meningkatkan pemahaman mahasiswa terhadap materi yang membutuhkan analisis mendalam. Penelitian lebih lanjut diharapkan melibatkan sampel yang lebih beragam dan menggunakan desain longitudinal untuk mengeksplorasi dampak kemandirian belajar secara lebih mendalam.

Kata kunci: Kemandirian belajar, hasil belajar, logika matematika

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Improving the quality of education has become a primary focus for many countries, both at international and national levels. One of the main challenges faced in higher education today is students' ability to learn independently. Self-directed learning has become increasingly important, especially in the context of technology-based and distance learning, which has gained popularity, particularly since the COVID-19 pandemic (Stajkovic & Sergent, 2019; Stajkovic & Sergent, 2019; Bandura, 2001). In Indonesia, the

education system has undergone significant changes with the implementation of distance learning, prompting students to enhance their self-management in the learning process (Aristovnik et al., 2023; Hwee et al., 2022). However, in higher education, particularly in courses requiring critical analysis and deep understanding, such as mathematical logic, the challenge of fostering self-directed learning remains a key issue that needs to be addressed ((Smith & Darvas, 2005).

Mathematical logic courses, in particular, demand students to engage in high levels of analytical thinking and problem-solving. These courses require learners to understand abstract concepts, construct logical arguments, and apply theoretical knowledge to complex problems, all of which necessitate independent and sustained effort outside the classroom. Self-directed learning is essential in this context as it empowers students to take ownership of their learning process by managing their time, setting goals, and seeking additional resources when needed. For instance, a student working on formal proofs in mathematical logic must often identify gaps in their understanding and independently seek clarification through self-study or supplemental materials. Without adequate self-directed learning skills, students may struggle to keep pace with the demands of such rigorous courses. Moreover, the structured and hierarchical nature of mathematical logic concepts where understanding foundational principles is critical for grasping more advanced topics further underscores the importance of students' ability to manage their learning effectively. Thus, fostering self-directed learning in mathematical logic not only helps students achieve better academic outcomes but also equips them with the skills necessary for lifelong learning and adaptability in complex, analytical fields

Research has shown that self-directed learning is closely linked to academic achievement. (Akpen et al., 2023) explains that self-directed learning is crucial for educational success, as independent students are better able to manage their time and learning strategies. (Gureckis & Markant, 2012), further emphasize that self-directed learning is essential in courses requiring deep understanding and critical analysis. Nevertheless, although self-directed learning is recognized as important, many students still lack the ability to learn independently, particularly in online learning environments (Mercado, 2024). In this context, students often struggle to manage their time and maintain focus without direct supervision from instructors (Akpen et al., 2023). (Suhendri, 2011) stated that learning independence has a significant effect on math learning outcomes by 9.42% while (Alwi Maulana et al., 2022) stated that students who have a higher level of learning independence tend to be more successful in math subjects that demand logical thinking and independence in learning. Therefore, enhancing self-directed learning skills among students in online and hybrid learning environments is an urgent need to support their academic success. Learning independence is an important factor that influences mathematics learning outcomes or achievements. students' ability to learn independently plays a crucial role in improving understanding and learning outcomes in mathematics, which demands analytical and logical skills.

Several previous studies have explored the relationship between self-directed learning and academic performance across disciplines. For instance, research by (Aljermawi et al., 2024) revealed

that self- directed learning plays a crucial role in improving academic performance in distance learning contexts. Another study by (Paredes-Velasco et al., 2024) showed that students with higher levels of self-directed learning tend to achieve better academic results, as they can effectively manage their time and learning resources. However, these studies have generally not specifically examined the impact of self-directed learning in courses that require logical reasoning, such as mathematics, and are often limited to specific programs or universities. Therefore, a gap in the literature needs to be addressed, particularly concerning the impact of self-directed learning on academic performance in mathematical logic courses in higher education.

This study is unique in that it highlights self-directed learning as a key factor in the learning process for mathematical logic, a subject requiring conceptual understanding and critical thinking skills. Mathematical logic, as a discipline, inherently demands a structured approach to reasoning, where students must not only memorize concepts but also apply them to solve abstract problems and construct sound arguments. The abstract nature of mathematical logic involves understanding fundamental principles, such as propositions, inferences, and proofs, which form the basis of logical reasoning in advanced mathematics and computer science. The choice of mathematical logic as the focus of this study is rooted in its dual role as both a theoretical and practical subject. It serves as a gateway for students to develop higher-order thinking skills and problem-solving capabilities, which are critical for success in STEM fields. Furthermore, theself-paced and analytical nature of mathematical logic aligns seamlessly with the principles of self- directed learning. Students must independently analyze problems, seek out resources, and verify the validity of their solutions. Skills that are central to lifelong learning and adaptability in professional contexts.

Bandura (2001), in his social learning theory, emphasizes the importance of active student involvement in developing self-directed learning skills to achieve academic success. Self-directed learning not only aids students in understanding material more deeply but also prepares them to face academic challenges independently. This concept aligns with the constructivist approach in education, suggesting that effective learning requires students to actively manage their learning process (Meir et al., 2023). By focusing on mathematical logic, this study provides valuable insights into how self-directed learning can be fostered and applied in domains that demand a rigorous and independent approach to knowledge acquisition. Thus, this study contributes to the literature by exploring how self-directed learning influences academic performance in the context of mathematical logic, an area that has not been widely explored in previous research.

This study aims to analyze the impact of self-directed learning on students' academic performance in mathematical logic courses at Indraprasta PGRI University. The focus is to determine the extent to which students' self-directed learning affects their understanding of mathematical logic concepts. This study is expected to provide new insights into the role of self-directed learning in supporting academic success, particularly in learning contexts that require analytical and critical thinking skills.

METHOD

This study uses a survey method to evaluate the impact of self-directed learning on students' academic performance in a mathematical logic course. In the research to be conducted, the researcher uses a survey method and uses a proportional cluster random sampling technique, where the number of samples from each class is taken proportionally based on the ratio of the number of students in each class to the total population of regular students in semester II of the Informatics Engineering Study Program, Indraprasta PGRI University, so that a sample of 72 students was obtained.

Research Instruments

The instruments used in this study include the Self-Directed Learning Questionnaire and the Learning Outcome Test. The Self-Directed Learning Questionnaire aims to assess the extent of students' self-directed learning by evaluating key indicators such as their abilities in planning, self-motivation, time management for independent study, and initiative in learning. This questionnaire employs a Likert scale to simplify the assessment of student responses, providing a quantitative measure of self-directed learning behaviors. Meanwhile, the Learning Outcome Test is designed to measure students' understanding of mathematical logic concepts upon completion of the course. Before these instruments were used in the study, both underwent rigorous testing for validity and reliability to ensure their effectiveness in measuring the intended constructs and providing consistent results. Validity testing was conducted to ensure that each item on the questionnaire and test aligned with its theoretical concept, while reliability testing focused on ensuring measurement consistency. The results of the reliability test indicated a Cronbach's alpha level of 0.68, suggesting an acceptable level of internal consistency. Furthermore, after the validation process, it was found that only 11 out of the initial 20 questions were valid, underscoring the importance of refining the instruments for accurate data collection.

Data Collection Technique

Data were collected by distributing questionnaires and learning outcome tests to the sampled students over the course of one week. This process was conducted during mathematical logic class hours to ensure a high level of participation. Students were given 60 minutes to complete the mathematical logic learning outcome test. with supervision carried out by the researcher himself after the instrument has been analyzed for validity and reliability tests. Next, students were asked to complete the questionnaire which was distributed using a gform link to the class group so that students could open the questionnaire from their cell phones.

Data Analysis

The data analysis process includes several stages:

- Descriptive Analysis

  Data were analyzed descriptively to obtain the mean, standard deviation, frequency distribution, median, and mode, providing an overview of students' self-directed learning levels and their performance in mathematical logic.

- Assumption Testing

  The statistical analysis conducted in this study involved several essential tests to ensure the validity and reliability of the regression model. The normality test was used to confirm that the data were normally distributed, which is a crucial requirement for regression analysis. The linearity test was performed to verify that the relationship between self-directed learning and mathematical logic performance followed a linear pattern. Additionally, the heteroscedasticity test was applied to assess whether the variance of residuals was consistent across all levels of the independent variable. A good regression model requires the absence of heteroscedasticity, ensuring that residual variances are constant and evenly distributed.

For hypothesis testing, simple linear regression analysis was utilized to determine the effect of self-directed learning on academic performance. This included a correlation test, which examined the strength and direction of the relationship between self-directed learning and academic performance.The simple linear regression analysis further quantified the extent to which self-directed learning, as the independent variable, impacted students' performance in mathematical logic, the dependent variable. Together, these tests provided a comprehensive approach to validating the study's findings and establishing the significance of self-directed learning in academic achievement.

- Hypothesis Testing

  The hypotheses of this study are:

  H0 (Null Hypothesis) : There is no effect of self-directed learning on understanding mathematical logic concepts.

  H1 (Alternative Hypothesis) : There is an effect of self-directed learning on understanding mathematical logic concepts.

  The decision is based on the significance of value (p-value). If p-value < 0.05, Ho is rejected, and H1 is accepted, indicating that self-directed learning significantly impacts performance in mathematical logic. If the analysis shows a significant effect of self-directed learning on mathematical logic performance, this study will support the theory that self-directed learning is an essential factor in academic achievement, especially in courses requiring deep understanding like mathematical logic. These findings are also expected to serve as a reference for developing teaching methods that encourage students to learn more independently.

RESULTS AND DISCUSSION

Results

This study aims to examine the extent to which self-directed learning influences students' academic performance in mathematical logic courses. Data collected from students' self-directed learning scores and learning outcomes were analyzed using descriptive statistics and simple linear regression, assisted by SPSS 24 software.

Table 1. Descriptive Statistics

Variable	*N*	*Minimum*	*Maximum*	*Mean*	*Std. Dev.*
Self-Directed Learning	72	11	63	52.96	7.518
Learning Outcomes	72	60	100	87.35	7.605

Based on the data presented in Table 1, the Self-Directed Learning variable was measured on 72 students with a minimum score of 11 and a maximum of 63. The average self-directed learning score was 52.96 with a standard deviation of 7.518, indicating that most students had a relatively good level of self-directed learning, although there was moderate variation among participants. This variation indicates individual differences in students' ability to learn independently.

Meanwhile, for the Learning Outcomes variable, the minimum score achieved was 60 and the maximum was 100. The average student learning outcome was 87.35 with a standard deviation of 7.605, indicating that most students had a high understanding of the mathematical logic course. The relatively small standard deviation indicates that students' scores tend to be concentrated around the average, with little difference between one student and another.

Overall, this data suggests that the majority of students have a good level of learning independence,which is likely to contribute to their high learning outcomes in mathematical logic. However, the differences in scores across the two variables highlight the importance of paying attention to individualvariations in learning strategies and academic understanding.

Regression Analysis

To further explore the influence of self-directed learning on mathematical logic outcomes, a simplelinear regression analysis was conducted. The regression results are presented below:

Table 2. Significance Test of Self-Directed Learning on Mathematical Logic Outcomes

Model	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig*
Regression	1112.655	1	1112.655	26.017	0.000
Residual	2993.665	70	42.767		
Total	4106.319	71			

An F-value of 26.017 with a significance level of 0.000 indicates that the regression model is significant. This means that self-directed learning has a significant effect on students’ performance in mathematical logic.

Regression Coefficients

The detailed regression coefficients are shown below:

Table 3. Regression Coefficients of Self-Directed Learning on Mathematical Logic Outcomes

Model	*B*	*Std. Error*	*Beta*	*t*	*Sig*
(Constant)	59.461	5.521		10.770	0.000
Kemandirian (X)	0.527	0.103	0.521	5.101	0.000

The interpretation of these coefficients is as follows: The constant (intercept) value of 59.461 suggests that if the level of self-directed learning were zero, the expected score for mathematical logic would be approximately 59.461. This baseline value represents the score when no self-directed learning is involved. On the other hand, the self-directed learning coefficient of 0.527 indicates that for every one-point increase in self-directed learning, the mathematical logic score increases by 0.527 points. This positive relationship highlights that as students engage more in self-directed learning, their performance in mathematical logic tends to improve. This suggests that self-directed learning plays a significant role in enhancing students' ability to grasp and apply logical concepts in mathematics.

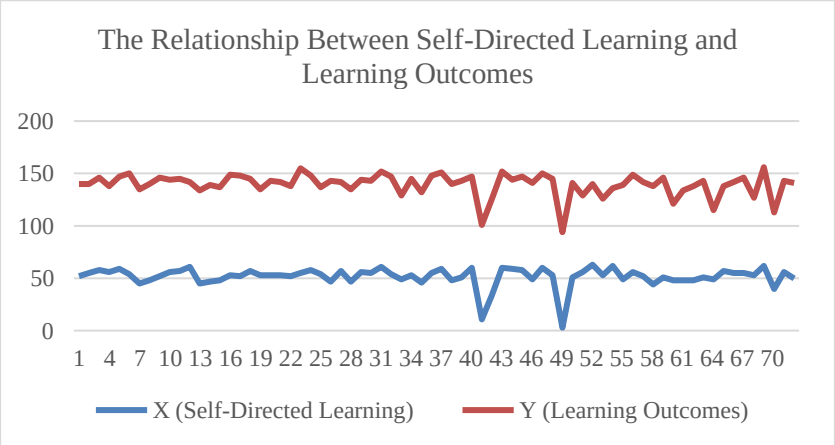

Figure 1. The Relationship Between Self-Directed Learning and Learning Outcomes

The graph above shows the relationship between learning independence and learning outcomes in mathematical logic among 72 students. Learning outcomes were mostly stable, with most students scoring high, while the level of learning independence varied. In general, students with higher learning independence tended to obtain better learning outcomes, although there were some cases where students with low independence still managed to achieve high scores. A sharp decline in learning independence was not always followed by a decline in learning outcomes, suggesting that other factors, such as lecturer support or teaching methods, also played a role. However, overall, there is a positive influence between learning independence and learning outcomes.

Hypothesis Testing

From the regression results, a significance level of 0.000 ($p < 0.05$) was obtained, leading to the rejectionof the null hypothesis and acceptance of the alternative hypothesis, confirming a significant influence of self-directed learning on mathematical logic outcomes.

Normality and Linearity Tests

The analysis also includes tests for normality and linearity to ensure the validity of the regression model. The normality test shows that the data are normally distributed, with a significance value of 0.095 (>0,05), thus meeting the assumption of normality. Similarly, the linearity test confirms that the relationship between self-directed learning and learning outcomes is linear, as indicated by the significant regression model. With both assumptions normality and linearity fulfilled, the regression model in this study is considered valid and reliable, providing a solid foundation for drawing meaningful conclusions about the relationship between self-directed learning and student performance.

The analysis concludes that self-directed learning positively and significantly affects students' performance in mathematical logic. Students with higher levels of self-directed learning achieve better outcomes. This finding aligns with previous studies that highlight the importance of self-directed learning in supporting academic success, particularly in subjects requiring strong analytical skills. Thus, self-directed learning can be considered a crucial factor in students' academic achievement, especially in mathematical logic courses.

Discussion

This study focuses on the influence of self-directed learning on students' academic performance ina mathematical logic course. Statistical results show variations in self-directed learning scores, with a mean of 52.96 and a standard deviation of 7.518, while the average score for mathematical logic is 87.35 with a standard deviation of 7.605. These figures indicate that most students demonstrate good self-directed learning skills and achieve high academic results. for example, lecturers use project-based learning in learning mathematical logic that encourages students to collaborate in completing group assignments. Creating e-books according to the sub-materials that have been given. Each student is required to be independent in learning and collaborating in completing the group assignment. Students are able to provide examples of applications of mathematical logic in the field of informatics engineering. In this context, as (Doo et al., 2023) explains, self-directed learning plays an essential role in supporting academic achievement, particularlyin subjects requiring analytical skills. Students with high levels of self-directed learning are better at managing time and employing effective learning strategies, positively impacting their academic performance.

Simple regression analysis reveals a significant effect of self-directed learning on mathematical logic outcomes, with an F-value of 26.017 and significance of 0.000. A regression coefficient of 0.527 suggests that a one-unit increase in self-directed learning can improve mathematical logic scores by 0.527 points. This finding is supported by (Wasyilah et al., 2021), who state that self-directed learning correlates with improved academic performance in subjects requiring critical understanding. In this study, students with high self-directed learning tendencies are more likely to develop in-depth independent learning strategies, enhancing their grasp of complex material like mathematical logic.

The analysis supports the hypothesis that there is a significant relationship between self-directed learning and mathematical logic outcomes, as indicated by a significance level of less than

0.05 (Doo et al., 2023). Thus, the null hypothesis (no effect) is rejected, and the alternative hypothesis (significanteffect) is accepted, confirming that self-directed learning is a critical factor in supporting academic success. This study also meets the normality assumption with a value of 0.095 (> 0.05), indicating thatthe data distribution is normal. This assumption strengthens the validity of the regression analysis performed, consistent with (Calucag et al., 2023) findings, which highlight that a linear relationship between self-directed learning and academic performance is common in educational studies.

Theoretically, self-directed learning is a core component of constructivist learning theory, emphasizing students' active role in learning (Bandura, 2001). Through self-directed learning,students not only achieve good academic outcomes but also develop critical thinking and problem-solving skills independently. This study demonstrates that self-directed learning is a strong predictor of academic success in subjects requiring analytical ability, as noted by (Pintrich & De Groot, 1990).Self-directed learning and independent learning strategies positively affect academic performance, particularly in subjects demanding a high level of logical understanding.

The implications of learning independence in learning mathematical logic can be seen from the increase in student learning activities, such as group discussions, daring to ask questions, expressing opinions, and participating in answering questions that arise during the learning process in class andbeing able to complete assignments on time. The findings imply that instructors can use teaching methods that encourage self-directed learning,suchas problem-based or project-based learning, to increase student engagement in the learning process andfoster independent learning strategies (Wong et al., 2021). These methods enable students to optimize their academic potential, particularly in mastering complex subjects like mathematical logic. However, the generalizability of these findings may be limited due to the study'ssample being confined to a single academic program at one university. This narrow scope raises thepossibility that the results may not fully represent the dynamics of self-directed learning across otherdisciplines, academic institutions, or cultural contexts.

For instance, the effectiveness of self-directed learning strategies could vary significantly dependingon the nature of the subject matter. Mathematical logic, being inherently analytical and hierarchical,requires a distinct set of skills that may not be directly transferable to subjects with a more qualitative or exploratory focus, such as social sciences or arts. Additionally, factors such as institutional support, teaching approaches, and students' prior exposure to self-directed learning may influence the outcomes. In institutions with less access to technological tools or where traditional pedagogical methods are more prevalent, students may face greater challenges in adopting self-directed learningstrategies.

To address these limitations and enhance the generalizability of the findings, future research shouldinclude a more diverse sample, encompassing students from different academic disciplines and institutions with varying teaching resources and methods. Furthermore, longitudinal studies that track the development of self-directed learning skills over time across multiple contexts could

provide deeper insights into how these strategies impact academic performance universally. By expanding the scope of research, it becomes possible to draw more robust and applicable conclusions, ensuring that the recommendations made are effective across a wider range of educational settings.

The study reinforces the view that self-directed learning is a crucial predictor of student academic success, especially in mathematical logic courses and in the context of distance learning (Doo et al., 2023). During the pandemic, as distance learning became prevalent, self-directed learning was essentialin helping students cope with learning challenges without direct instructor interaction (Aristovnik et al.,2023; (Hwee et al., 2022). According to (G. Wangetal., 2023) , meeting statistical assumptions, including normality and linearity, is essential in ensuring the validity of regression analysis results, showing that self-directed learning accounts for 71.2% of the variance in mathematical logic performance. This finding is consistent with research by (Lin et al., 2023), which notesthat self-directedlearning contributes not only to academic outcomes but also to improved critical thinking and adaptability.

The literature supports the importance of self-directed learning traits identified by (Santoso et al., 2022),such as planning, self-motivation, and the ability to control learning activities independently. These skills are essential in distance learning, where students must manage their learning without direct supervision from instructors. This study is also supported by findings from (Doo et al., 2023), which indicate that students with high levels of self-directed learning tend to achieve better academic outcomes due to their ability to manage time and learning resources independently.

In this context, instructors should design teaching strategies that support self-directed learning, suchasproject-based or problem-based learning (Martinez-Carrascal et al., 2024) which enable students to takeresponsibility for their learning process. (Q. Wang & Huang, 2024) emphasize the importance of supportive learning environments, including the use of digital and collaborative learning resources, to help students achieve better understanding and academic performance in online learning.

Overall, this study contributes significantly to literature by demonstrating that self-directed learningis an effective predictor of students' academic performance, particularly in the context of mathematicallogic and distance learning. Thus, developing self-directed learning skills among students is essential for inclusion in the curriculum to enhance academic achievement and learning quality in this digital education era.

This study reveals a significant relationship between self-directed learning and students' mathematicallogic performance, although some limitations must be considered. First, this study only involved students from one academic program, so the results may not represent students from other disciplines. Second, self-directed learning was measured using a self-report questionnaire, which may introduce bias due to personal perceptions or a desire to provide socially desirable answers. For more accuracy, future studies could include direct observation or third-party assessment of self-directed learning. Third, this study focused only on self-directed learning as a variable, though academic performance is also influenced by other factors, such as motivation and environmental support. Fourth,

the analysis method used was simple linear regression, which may not capture more dynamic relationships among variables.In the future, more comprehensive analysis methods, such as multiple regression or structural modeling, could provide deeper insights. Lastly, this study is cross-sectional, limiting the ability to determine causal relationships. A longitudinal design in future research could better understand how students' self-directed learning develops and impacts learning outcomes over time.

CONCLUSION

This study shows that self-directed learning has a significant impact on students' academic performancein a mathematical logic course. The analysis results confirm that the higher the level of students' self- directed learning, the better their understanding of mathematical logic concepts. Students who can manage their learning process independently tend to be better prepared to face academic challenges thatrequire analytical thinking. These findings align with theories and previous studies emphasizing the importance of self-directed learning in academic achievement, particularly in courses that require deepcomprehension.

This study has important implications for instructors and educational institutions. The results indicate that developing self-directed learning should be an integral part of teaching methods, especially in online or hybrid learning environments. Instructors are encouraged to adopt approaches that foster self-direction, such as project-based or problem-based learning, to help students build more independent learning skills. Additionally, institutional support for providing a supportive learning environment, including access to digital learning resources and time-management training, can strengthen students' learning in mathematical logic.

However, this study has several limitations. First, the sample was drawn from a single academic program at one university, so the results may not be representative of a broader population. Second, self-directed learning was measured only through self-report questionnaires, which may contain perceptual biases. Third, this study focused on a single independent variable self-directed learning although other factors, such as motivation and environmental support, also affect learning outcomes. Lastly, the cross-sectional design limits the ability to understand the development of self-directed learning over time.

Overall, this study makes a meaningful contribution to education by highlighting the importance ofself-directed learning in students' academic achievement. Given these limitations, future research is recommended to involve a broader sample, including additional relevant variables, and employ a longitudinal design to explore the relationship between self-directed learning and academic performance across various academic contexts. This study underscores that self-directed learning is crucial not only for understanding complex material but also for developing students into independent and adaptive learners in the long term.

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