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The effect of self-regulated learning on students' mathematical concept understanding ability

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Abstract

Mathematical concept understanding is a fundamental competency in undergraduate calculus learning. However, students' achievement in this area remains low, necessitating investigation of contributing factors, one of which is self-regulated learning. This study aimed to: (1) describe the levels of students' self-regulated learning and mathematical concept understanding ability; and (2) analyze the effect of self-regulated learning on students' mathematical concept understanding ability. A quantitative approach with an ex post facto design was employed. The research subjects consisted of all 46 students enrolled in the Integral Calculus course in Class A at the Department of Mathematics Education, Halu Oleo University, in the 2024/2025 academic year, selected through saturation sampling. Data were collected using a self-regulated learning questionnaire and a mathematical concept understanding test, both validated by subject-matter experts. Data were analyzed using descriptive statistics and simple linear regression. The results showed: (1) descriptively, most students had a moderate level of self-regulated learning (71.74%) and a low level of mathematical concept understanding ability (63.04%); (2) self-regulated learning had a positive and significant effect on students' mathematical concept understanding ability, with a coefficient of determination of 42.2% ($F = 32.162$; $p < 0.05$). These findings imply the need for instructional strategies that explicitly foster self-regulated learning in undergraduate mathematics courses.

Keywords: Self-regulated learning; Mathematical concept understanding; Integral calculus; Ex post facto

1. Introduction

Mathematical concept understanding is one of the fundamental competencies that undergraduate students must master in mathematics courses, including calculus. This ability enables students to represent their knowledge of concepts, principles, and algorithms, while simultaneously applying strategies to solve mathematical problems [1]. Furthermore, concept understanding is an essential prerequisite before students can master more complex mathematical principles and procedures, as failure to understand foundational concepts has serious consequences for the acquisition of subsequent material [2], [3].

Indicators of mathematical concept understanding ability include the capacity to restate a concept, classify objects based on their properties, provide examples and non-examples of a concept, present a concept in various mathematical representational forms, and apply the concept to solve problems [4], [5]. These abilities help students develop critical thinking and sound decision-making in mathematical situations [6].

However, numerous studies have reported that students' mathematical concept understanding ability remains low. [7] found that the majority of students struggled to apply concepts in novel situations, while [8] demonstrated that conventional instructional strategies were insufficiently effective in improving concept understanding. A similar

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condition was observed among students enrolled in the calculus course, where the average concept understanding test scores were well below the established mastery standard.

One factor believed to contribute to mathematical concept understanding ability is self-regulated learning. Self-regulated learning is defined as the process by which individuals activate and sustain their cognition, behavior, and affect in a systematic manner oriented toward achieving their learning goals [9], [10] argued that individuals with high self-regulated learning tend to actively plan, monitor, and evaluate their learning processes, thus enabling them to achieve academic targets more effectively.

In the context of mathematics learning, self-regulated learning encompasses three primary sub-dimensions: metacognitive knowledge, metacognitive regulation, and motivational-emotional regulation [11], [12]. Metacognitive knowledge concerns an individual's awareness of their own cognitive capabilities [13]; metacognitive regulation refers to the skills employed to manage thinking processes during learning [14], [15]; while motivational-emotional regulation involves monitoring and controlling one's emotional and motivational states during learning [16], [17].

Several studies have confirmed a positive relationship between self-regulated learning and mathematical concept understanding ability. [18], [19] found that self-regulated learning significantly influenced mathematical concept understanding among university students. [20] also demonstrated that students with higher self-regulated learning possessed better concept understanding. [21] identified a positive effect of self-regulated learning on mathematical concept understanding at the secondary school level. Nevertheless, research examining the effect of self-regulated learning on concept understanding specifically within the context of integral calculus courses remains limited.

Based on the foregoing background, this study aimed to: (1) describe the levels of self-regulated learning and mathematical concept understanding ability among students enrolled in the Integral Calculus course; and (2) analyze the effect of self-regulated learning on students' mathematical concept understanding ability. The findings of this study are expected to provide an empirical contribution to the development of calculus instructional strategies in higher education.

2. Material and methods

2.1. Research Design

This study employed a quantitative approach with an ex post facto design. In this design, the independent variable (self-regulated learning) was not manipulated by the researcher; rather, it was observed as it naturally occurred, after which its effect on the dependent variable (mathematical concept understanding ability). The relationship between the variables in this study is illustrated as follows:

$$X \rightarrow Y$$

Note: X = Self-Regulated Learning; Y = Mathematical Concept Understanding Ability

Figure 1 Relationship between research variables

2.2. Research Subjects

The population and sample of this study comprised all 46 students in Class A enrolled in the Integral Calculus course during the 2024/2025 academic year at the Department of Mathematics Education, Halu Oleo University, Kendari. The sampling technique used was saturation sampling (total sampling), in which all members of the population were included as the sample [22], given the relatively small population size.

2.3. Research Instruments

Two instruments were used in this study. First, a self-regulated learning questionnaire developed based on the sub-dimensions proposed by Whitebread et al. (2009), encompassing metacognitive knowledge, metacognitive regulation, and motivational-emotional regulation. The questionnaire used a four-point Likert scale with 30 items. Second, a mathematical concept understanding ability test consisting of essay items covering the following indicators: restating a concept, classifying objects, applying a concept, and presenting a concept in various representations. Prior to use, both instruments underwent content validation by two expert validators, as well as a readability test. Validation results confirmed that both instruments were suitable for data collection.

2.4. Data Analysis Technique

Data were analyzed using two techniques. Descriptive analysis was used to depict the distribution and categories of self-regulated learning levels and mathematical concept understanding ability based on predetermined criteria. Subsequently, inferential analysis using simple linear regression was employed to test the research hypothesis. Prior to regression analysis, a classical assumption test was conducted, specifically a residual normality test using the Kolmogorov-Smirnov test. All analyses were performed using SPSS version 26. The decision criterion for hypothesis testing was set at a significance level of $\alpha = 0.05$.

3. Results

3.1. Description of Students' Self-Regulated Learning

Based on the questionnaire data processing, the distribution of students' self-regulated learning levels is presented in Table 1 below.

Table 1 Distribution of Students' Self-Regulated Learning Categories

Category	n (%)	Mean	Min	Max	SD
High	8 (17.39%)	80.66	77.34	92.19	4.90
Moderate	33 (71.74%)	69.48	63.28	75.78	3.24
Low	5 (10.87%)	58.75	48.44	62.50	5.91

Table 1 shows that the majority of students (71.74%) were in the moderate self-regulated learning category, 17.39% were in the high category, and 10.87% were in the low category. Thus, students' self-regulated learning in the Integral Calculus course was generally at a moderate level.

3.2. Description of Students' Mathematical Concept Understanding Ability

The descriptive analysis results for students' mathematical concept understanding ability are presented in Tables 2 and 3 below.

Table 2 Descriptive Statistics of Mathematical Concept Understanding Ability

Mean	Median	Mode	SD	Minimum	Maximum
54.89	54.17	50.00	13.79	25.00	87.50

Table 3 Distribution of Students' Mathematical Concept Understanding Ability Categories

Score Range	Category	f	%
$X > 70$	High	9	19.57
$55 < X \leq 70$	Moderate	8	17.39
$X \leq 55$	Low	29	63.04
Total		46	100

Table 2 shows that the mean score for students' mathematical concept understanding ability was 54.89 out of 100, with a minimum score of 25.00 and a maximum of 87.50. Based on Table 3, 29 students (63.04%) were in the low category, 8 students (17.39%) were in the moderate category, and 9 students (19.57%) were in the high category. These findings indicate that students' mathematical concept understanding ability in the Integral Calculus course was generally low.

3.3. Classical Assumption Test

Prior to regression analysis, a residual normality test was conducted using the Kolmogorov-Smirnov method to verify the normality assumption. The results are presented in Table 4.

Table 4 Residual Normality Test Results (Kolmogorov-Smirnov)

Kolmogorov-Smirnov Sig. Value	**Description**
0.849	Normally Distributed

Table 4 shows that the Asymp. Sig. (2-tailed) value for the standardized residual was 0.849 > $\alpha = 0.05$, so H0 was accepted. Accordingly, the normality assumption for the residuals was satisfied and simple linear regression analysis could proceed.

3.4. Hypothesis Testing: The Effect of Self-Regulated Learning on Mathematical Concept Understanding Ability

The hypothesis tested in this study was that self-regulated learning has a positive and significant effect on students' mathematical concept understanding ability. The results of the analysis of variance (ANOVA) and regression coefficient tests are presented in Tables 5 and 6 below.

Table 5 ANOVA Results of Simple Linear Regression Analysis

Source	**SS**	**df**	**MS**	**F**	**Sig.**
Regression	3611.349	1	3611.349	32.162	0.000
Residual	4940.566	44	112.286	—	—
Total	8551.915	45			

Table 6 Regression Coefficients and t-Test Results

Model	**B**	**Std. Error**	**Beta (β)**	**t**	**Sig.**
(Constant)	-35.275	15.976	—	-2.208	0.032
Self-Regulated Learning (X)	1.003	0.177	0.650	5.671	0.000

$R^2 = 0.422$ (Coefficient of Determination = 42.2%)

Based on Table 5, the F-value of 32.162 with Sig. = 0.000 < $\alpha = 0.05$ indicates that the regression model was statistically significant and that self-regulated learning exerted a significant effect on students' mathematical concept understanding ability. Based on Table 6, the regression equation obtained was: $\hat{Y} = -35.275 + 1.003X$. This equation indicates that for each one-unit increase in self-regulated learning score, the average mathematical concept understanding ability score increases by 1.003 units, holding other variables constant. The coefficient of determination ($R^2 = 0.422$) indicates that self-regulated learning accounts for 42.2% of the variance in mathematical concept understanding ability, while the remaining 57.8% is explained by other factors not examined in this study

4. Discussion

The descriptive analysis results indicate that the majority of students (71.74%) had a moderate level of self-regulated learning. A closer examination by indicator reveals that students demonstrated adequate learning initiative and were capable of independently diagnosing their learning needs. However, they still required guidance in regulating and controlling their cognition and making autonomous learning decisions. This finding is consistent with [23], who noted that students with strong self-regulated learning tend to set higher academic goals and learn more effectively. The moderate level observed suggests that the internalization of self-regulated learning among these students has not yet been fully optimized and still requires facilitation from lecturers.

Meanwhile, students' mathematical concept understanding ability was generally at a low level, with a mean score of 54.89 and 63.04% of students falling below the moderate category threshold. This low ability was evident in students' difficulty completing tasks that required connecting multiple calculus concepts and presenting concepts in diverse representational forms. This finding is consistent with [2], who emphasized that weaknesses in concept understanding can have serious consequences for the mastery of subsequent mathematics material.

Hypothesis testing confirmed that self-regulated learning had a significant positive effect on students' mathematical concept understanding ability ($F = 32.162$; $p < 0.05$; $R^2 = 0.422$). This implies that students with higher levels of self-regulated learning tend to demonstrate better concept understanding ability. This finding can be explained through [24] theoretical framework, which posits that in the cognitive domain, self-regulated students are actively engaged in planning, monitoring, and regulating their cognition—including setting specific cognitive goals. These cognitive processes directly support the formation of deep conceptual understanding.

Furthermore, [9] explains that self-regulated learners activate systematic, mastery-oriented learning strategies rather than merely completing tasks. This disposition encourages students to study calculus concepts more thoroughly, reduces their dependence on lecturer assistance, and sustains their efforts to understand difficult concepts. With these characteristics, self-regulated students are better prepared to tackle problems requiring a high level of conceptual understanding.

The present findings extend and corroborate those of prior research. [18] reported a significant positive effect of self-regulated learning on mathematical concept understanding in a university sample. [20] also found that self-regulated learning contributed to mathematical concept understanding at the junior high school level. [21] identified a similar effect at the Islamic junior secondary school level. The present study extends this evidence to the context of the Integral Calculus course in higher education, with a coefficient of determination of 42.2% indicating the substantial role of self-regulated learning.

Nonetheless, the 42.2% contribution also implies that 57.8% of the variance in conceptual understanding ability is explained by other factors not examined in this study, such as mathematics anxiety [2], [25], instructional quality, achievement motivation, and students' prior knowledge. Future research should therefore examine these variables simultaneously to obtain a more comprehensive picture.

The practical implication of these findings is that mathematics lecturers need to design instructional activities that explicitly cultivate students' self-regulated learning. Applicable strategies include project-based assignments that require independent planning, the use of reflective learning journals, self-assessment rubrics, and tasks that encourage independent exploration of learning resources. By integrating the development of self-regulated learning into calculus instruction, students' mathematical concept understanding ability is expected to improve substantially.

5. Conclusion

Based on the research findings and discussion, the following conclusions are drawn. First, descriptively, most students enrolled in the Integral Calculus course had a moderate level of self-regulated learning (71.74%), while their mathematical concept understanding ability was at a low level (63.04%), with a mean score of 54.89. Second, self-regulated learning had a significant positive effect on students' mathematical concept understanding ability, as expressed by the regression equation $\hat{Y} = -35.275 + 1.003X$, with $F = 32.162$ ($p < 0.05$) and a coefficient of determination of 42.2%. This indicates that the higher a student's self-regulated learning, the higher their mathematical concept understanding ability.

Based on these findings, it is recommended that lecturers teaching calculus courses integrate strategies that promote self-regulated learning into their instructional design, such as problem-based independent assignments, self-reflection activities, and the use of diverse learning resources. Future research is encouraged to examine additional variables that influence mathematical concept understanding ability and to test more comprehensive models involving larger samples and varied settings.

Compliance with ethical standards

Disclosure of conflict of interest

The authors have declared no conflict of interest in relation to this article.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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