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The Influence of Self-Efficacy on the Understanding of Science Concepts in Elementary Schools: A Meta-Regression Analysis

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Abstract: This research aims to determine the extent to which self-efficacy affects students' understanding of science concepts, specifically in terms of translation, interpretation, and extrapolation abilities. These aspects reflect students' cognitive skills in explaining, interpreting, and predicting scientific phenomena. The research design used is a quantitative approach with a survey method and non-experimental design. The sample of this study amounted to 50 students, consisting of 22 girls and 27 boys from five elementary schools that are part of Gugus 1 in Pasawahan District, selected through purposive sampling technique. Data collection techniques were carried out using tests in the form of test items measuring science concept understanding and non-tests in the form of questionnaires to measure student self-efficacy. Data were analyzed using simple linear regression to test the relationship between self-efficacy and understanding of science concepts. The results showed that there was a significant relationship between self-efficacy and understanding of science concepts, with a Pearson correlation of 0.341 ($p<0.05$). This finding indicates that students with a high level of self-efficacy have a better understanding of science concepts. The contribution of this research is to strengthen the understanding of the importance of self-efficacy in science learning. This research is also significant for the development of learning methods that can increase students' self-efficacy to improve understanding of science concepts in the future.

Keywords: conceptual understanding; science; self-efficacy

INTRODUCTION

Science is a branch of science that focuses on mastering scientific concepts related to natural phenomena. Science aims to develop critical and scientific thinking skills in students (Faisal & Martin, 2019). Science is more than just the mastery of scientific facts. It is a comprehensive process, which includes how science is developed, accepted, and applied in social life (Höttecke & Allchin, 2020). In addition to teaching scientific facts, science education must also provide an understanding of how science is done and how scientific knowledge is developed. By understanding science, students can better appreciate the scientific process and its application in everyday life (Yuniasih & Widodo, 2021).

In addition to imparting scientific knowledge, science education aims to foster students' critical thinking abilities, social consciousness, and sense of accountability for scientific matters in social, cultural, and political contexts (Hidayah, 2023). This viewpoint emphasizes the need for introspection and a thorough comprehension of science and how it relates to daily living. Additionally, science education is seen as a methodical attempt to promote knowledge of scientific ideas, scientific process abilities, and scientific attitudes, all of which support the growth of students' scientific literacy and character (Suryani et al., 2021). To achieve these goals, students must have faith in their ability to learn and use scientific knowledge in addition to cognitive abilities. This is where self-efficacy is crucial. To achieve these objectives, students must not only have cognitive abilities but also confidence in their capacity to apply scientific knowledge. High self-efficacy students are more likely to participate fully, persevere despite difficulties, and use scientific reasoning to solve practical issues. As a result, self-efficacy is a crucial psychological component that helps students succeed in science classes and in acquiring the knowledge and dispositions that science education encourages (Hidayati, 2016).

As a real implementation, science learning becomes a strategic tool in developing students' cognitive and affective potential. Effective science learning integrates hands-on experiences, such as experiments and observations, so that students can construct their own knowledge through problem solving and reflection on what they experience (Chan, 2023). This is important because students not only need to master scientific theories but also learn how to apply this knowledge to face challenges in the real world (Bektas et al., 2013). With an active learning approach, students will be better able to develop critical thinking skills and understand science concepts more deeply (Nuangchalerm & Kanphukiew, 2024).

One of the main objectives in science learning is concept understanding, which reflects the extent to which students can integrate and apply the knowledge they have learned. Deep concept understanding allows students to transfer their knowledge to new and more complex situations, as well as relate it to other concepts in science (Cañas et al., 2023). Good concept understanding allows students to transfer knowledge to new situations flexibly (Treagust & Duit, 2008). Thus, the success of science learning is not only measured by how many concepts are learned but also by the extent to which students can use the knowledge flexibly and relevantly in the context of their lives (Chiu et al., 2007).

Students' self-efficacy, which is described as their confidence in their own capacity to finish learning assignments and overcome academic obstacles, is crucial to attaining optimal conceptual knowledge learning (Schunk & DiBenedetto, 2021). Students that have strong self-efficacy are more likely to be confident when interacting with complicated materials, such as scientific concepts, according to prior study (Talsma et al., 2019). Deeper conceptual comprehension is supported by this notion since it increases drive, resilience, and persistence (Zimmerman, 2000). Although many studies have examined the general role of self-efficacy in learning, only a few have specifically focused on its influence in the context of science conceptual understanding among elementary school students. At this level, students are forming the foundation for future scientific thinking. Most existing studies discuss self-efficacy in broad academic terms, without examining how it relates directly to science learning outcomes. This shows the presence of a theoretical gap in the literature, particularly in understanding how self-efficacy affects students' mastery of science concepts in elementary education.

Filling this gap is important for developing learning strategies that not only build knowledge but also increase students' confidence in their abilities. Therefore, this study aims to explore the relationship between self-efficacy and science conceptual understanding and to use this relationship as a basis for formulating research hypotheses. The relationship between self-efficacy and concept understanding in science learning has been the focus of various previous studies. There is a significant influence between self-efficacy and students' understanding of science concepts. This research shows that students with high self-efficacy tend to have better concept understanding compared to students with low self-efficacy

(Novanto et al., 2024). This shows that students' beliefs in their own abilities can affect how well they understand science concepts.

METHODS

This study employed a quantitative approach with a survey method and a non-experimental design. This approach was selected to statistically analyze the relationship between self-efficacy and understanding of science concepts without direct intervention on the research subjects (Creswell, 2018). The survey method allows data collection in a relatively short time with a wide range of respondents (Haegele & Hodge, 2015), while the non-experimental design is appropriate because researchers only observe variables as they are in a natural environment, without providing special treatment (Sugiyono, 2017).

The sample of this study amounted to 50 students, consisting of 22 girls and 27 boys from five elementary schools that are part of Gugus 1 in Pasawahan District. The sample selection was carried out using a purposive sampling technique based on the academic classification of students, namely students with upper, middle, and lower ranks. This technique was used so that the data obtained reflected the diversity of students' academic characteristics in a representative manner (Teddlie & Yu, 2007). This ranking-based selection also allows for a more in-depth analysis of how self-efficacy works across different ability levels (Sekaran, 2016).

The test instrument in this study was used to measure students' understanding of scientific concepts. The questions were in the form of essay items that required students to explain, describe, or elaborate on the concepts they had learned. The indicators of concept understanding in this instrument included translation, interpretation, and extrapolation. Translation refers to the students' ability to express scientific information using their own words, interpretation refers to their ability to understand and explain the meaning of data or scientific situations, and extrapolation refers to the ability to make predictions or inferences from known information (Bloom, 1956).

Meanwhile, the non-test instrument consisted of a self-efficacy questionnaire with 17 statement items. Respondents answered using a Likert scale with four options: Strongly Agree (SS), Agree (S), Disagree (TS), and Strongly Disagree (STS), each scored from 1 to 4. The questionnaire measured students' confidence in their ability to carry out learning tasks. The aspects of self-efficacy measured in this study included initiative, persistence, and effort. Initiative refers to the students' readiness to begin tasks independently, persistence refers to their ability to continue working despite obstacles, and effort refers to the amount of energy they invest in completing duties (Bandura, 1997).

Items with loading scores below 0.60 were considered invalid and excluded from the final analysis to ensure result reliability, only the valid questions were used in the final analysis to keep the results accurate and reliable (Hair J et al., 2014). The exclusion of these items may have affected the breadth of construct representation but ensured greater internal consistency. Additionally, a residual analysis was conducted during the regression testing phase to verify the assumptions of homoscedasticity and linearity (Ghasemi & Zahediasl, 2012).

Table 1. Result of Outer Loading and Cronbach's Alpha Self-Efficacy

Construct	Indicator	Outer Loading	Decision	Cronbach's Alpha	Decision
Initiative	P1	0.579	Not Valid	0.864	Reliable
	P2	0.564	Not Valid		
	P3	0.573	Not Valid		

	P4	0.029	Not Valid		
	P5	0.520	Not Valid		
	P6	0.631	Valid		
	P7	0.195	Not Valid		
	P8	0.595	Not Valid		
	P9	0.539	Not Valid		
Persistence	P10	0.307	Not Valid	0.693	Reliable
	P11	0.600	Valid		
	P12	0.639	Valid		
	P13	0.714	Valid		
	P14	0.647	Valid		
Effort	P15	-0.883	Not Valid	0.225	Unreliable
	P16	0.500	Not Valid		
	P17	-0.015	Not Valid		

Based on the validity test, several items were identified as invalid due to outer loading values below the threshold of 0.60. These items were excluded from further analysis to improve the overall measurement accuracy of the instrument. Subsequently, a reliability test was conducted to determine the internal consistency of the instrument items using the Cronbach's Alpha criterion. In the field of social science, a coefficient value greater than 0.60 is considered acceptable (Taber, 2018), indicating that the instrument demonstrates a sufficient level of reliability for research purposes.

Furthermore, to assess the validity and reliability of the science concept understanding instrument, the same procedure was applied to ensure consistency and comparability of the findings. This comprehensive approach strengthens the credibility of the instrument and supports its use in measuring students' conceptual understanding accurately.

Table 2. Result of Outer Loading and Cronbach's Alpha Conceptual Understanding

Construct	Indicator	Outer Loading	Decision	Cronbach's Alpha	Decision
Translation	P1	0.743	Valid	0.706	Reliable
	P2	0.836	Valid		
	P3	0.689	Valid		
Interpretation	P4	0.507	Not Valid	0.816	Reliable
	P5	0.484	Not Valid		
	P6	0.831	Valid		
	P7	0.736	Valid		
Extrapolation	P8	0.801	Valid	0.660	Reliable
	P9	0.592	Not Valid		
	P10	0.633	Valid		

Based on the results of the outer loading test, most indicators in each construct have values above 0.60, indicating that the validity of the indicators on the latent constructs is met. This aligns with the guideline that an outer loading value ≥ 0.70 indicates a strong correlation between the indicator and the construct represented (Hair J et al., 2014). Additionally, most constructs achieved acceptable reliability, as Cronbach's Alpha values were ≥ 0.70. Although some constructs like 'Extrapolation' had alpha values slightly below

0.70, these are still tolerable in educational research, particularly for newly developed instruments (Taber, 2018).

To examine the relationship between self-efficacy and students' understanding of science concepts, an association test was conducted. This test aimed to determine both the presence and strength of influence between the variables. Simple linear regression was employed as the analysis method, linking one independent variable (self-efficacy) with one dependent variable (science concept understanding) (Sekaran, 2016). After meeting the assumption requirements, hypothesis testing was performed using regression analysis as follows:

1) H1: There is no influence of self-efficacy on the understanding of science concepts.
2) H2: There is an influence of self-efficacy on the understanding of science concepts.

To test the hypothesis, the obtained data were analyzed using the F-test and t-test formulas through the SPSS version 25 program (Pallant, 2020). The F-test is used to test whether the regression model as a whole is significant, while the t-test is used to test the influence of each independent variable on the dependent variable partially.

RESULT AND DISCUSSION

The findings of the research conducted across five elementary schools reveal important insights into students' conceptual understanding and self-efficacy levels in science learning. A statistical description of the collected data is summarized in table 3, highlighting key measures such as the minimum, maximum, mean, and standard deviation for each variable. This comprehensive overview serves as the basis for further analysis, allowing for a deeper exploration of the relationship between self-efficacy and students' ability to grasp scientific concepts effectively. The detailed descriptive statistics presented in the table provide a clear picture of the distribution and variability of the data, supporting the interpretation of students' learning outcomes and confidence levels in understanding science.

Table 3. Statistical Data Description

	N	Minimum	Maximum	Mean	Std. Deviation
Conceptual Understanding	50	25	80	44.38	10.437
Self-Efficacy	50	53	90	71.90	8.447
Valid N (listwise)	50				

Based on the descriptive data presented in table 3, it is known that students' science concept understanding scores range from 25 to 80, with an average of 44.38 and a standard deviation of 10.437. The score is included in the low category because it is in the range of 40-54 (Putri & Hermon, 2024). Meanwhile, students' self-efficacy scores ranged from 53 to 90, with an average value of 71.90 and a standard deviation of 8.447. The score belongs to the moderate category because it is in the range of 55-71, although it is at the upper limit, which is close to the high category (Novanto et al., 2023).

Before presenting the hypothesis testing, it is essential to ensure that the data meet the assumptions required for parametric analysis. One of the primary assumptions is the normal distribution of the data. To verify this, the researchers conducted a one-sample Kolmogorov-Smirnov test, considering the sample size of 50 students. This normality test was performed to confirm that the collected data are normally distributed, which is crucial for the validity of subsequent statistical tests. Additionally, a homogeneity test was also carried out to examine the equality of variances across groups, ensuring that the data are suitable for further analysis. The results of both tests are summarized in table 4 below.

Table 4. Normality Test Results

		Unstandardized Residual
N		50
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	2.44480256
Most Extreme Differences	Absolute	.103
	Positive	.103
	Negative	-.068
Test Statistic		.103
Asymp. Sig. (2-tailed)		.200[c,d]

The results of the normality test in table 4 show that the data meet the assumption of normal distribution required for parametric statistical analysis. The test was conducted using the Kolmogorov–Smirnov method, which produced an Asymp. Sig. (2-tailed) value of 0.200, exceeding the significance threshold of 0.05. This result indicates that the residuals of the regression model are normally distributed (Ghasemi & Zahediasl, 2012). A normal distribution of residuals suggests that the error terms are spread symmetrically around the mean, and there is no serious skewness or kurtosis that could bias the regression estimates.

After knowing that the residual data is normally distributed, the next step is to test whether the data has a uniform or homogeneous variance. This test is important to ensure that differences in data groups are not caused by too large differences in data distribution between groups.

Table 5. Homogeneity Test Results

		Levene Statistic	df1	df2	Sig.
Conceptual Understanding	Based on Mean	1.891	13	34	.068
	Based on Median	1.495	13	34	.170
	Based on Median and with adjusted df	1.495	13	15.376	.224
	Based on trimmed mean	1.915	13	34	.064

The homogeneity test results presented in table 5 show that the significance value (Sig.) of Levene's Test is above 0.05 for all approaches, namely 0.068 (based on mean), 0.170 (based on median), 0.224 (based on median with adjusted df), and 0.064 (based on trimmed mean). These values indicate that there is no significant difference in variance between data groups, so the data can be declared homogeneous (Field, 2013).

With the assumptions of normality and homogeneity of variance fulfilled, the data in this study are suitable for further analysis using the relevant parametric statistical approach.

Table 6. Correlation Test Results

		Self-Efficacy	Conceptual Understanding
Self-Efficacy	Pearson Correlation	1	.341*
	Sig. (2-tailed)		.015
	N	50	50
Conceptual Understanding	Pearson Correlation	.341*	1
	Sig. (2-tailed)	.015	
	N	50	50

The correlation test results presented in table 6 show the relationship between self-efficacy and conceptual understanding with a Pearson correlation value of 0.341 and a significance value (Sig.) of 0.015. This significance value is below 0.05, which indicates that there is a significant relationship between the two variables.

The next statistical test conducted by researchers is simple linear regression analysis with the aim of identifying whether or not there is a linear relationship between self-efficacy and conceptual understanding variables. More precisely, to determine the extent to which the independent variable (x) affects the dependent variable (y). The results of simple linear regression analysis can be seen in the following table:

Table 7. Simple Linear Regression Test Results

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.012	1.872		2.144	.037
	Self-Efficacy	.239	.095	.341	2.517	.015

Based on the simple linear regression test results, the relationship between self-efficacy and conceptual understanding can be explained through the regression equation Y = 4.012 + 0.239X. The constant value in this equation indicates that when self-efficacy (x) is close to zero, conceptual understanding (y) will reach 4.012. In addition, the regression coefficient for self-efficacy (x) is 0.239, revealing that every 1 unit increase in self-efficacy is associated with an increase in conceptual understanding by 0.239. That is, the higher the self-efficacy, the greater the influence on conceptual understanding.

The analysis results indicate that the residual distribution does not significantly deviate from the normal distribution, as confirmed by the Kolmogorov-Smirnov test. The obtained significance value was greater than 0.05, supporting the conclusion that the residuals are normally distributed. Meeting the normality assumption is essential, as it ensures the validity of regression analysis and other parametric statistical procedures. When this assumption is violated, the estimated parameters may become biased and the statistical inferences unreliable (Ghasemi & Zahediasl, 2012). This result is also in line with the view that normally distributed residuals contribute to the robustness and reliability of regression models (Field, 2013).

In addition to normality, the assumption of homogeneity of variance was tested using Levene's Test. The result showed a significance value above 0.05, indicating that the variance across the data groups is homogeneous. This assumption is crucial in statistical analysis because unequal variances can distort the accuracy of test statistics, especially in regression or ANOVA (Ghasemi & Zahediasl, 2012). Ensuring homogeneity of variance also strengthens the generalizability of the findings, as more balanced data tend to yield more stable interpretations (Pallant, 2020).

The Pearson correlation test was conducted to assess the strength and direction of the relationship between self-efficacy and students' conceptual understanding. The correlation value of 0.341 suggests a moderate positive relationship between the two variables. Although the strength of the correlation is not high, it remains statistically significant and implies that self-efficacy contributes meaningfully to conceptual understanding (Alsaqr, 2021). This suggests that while self-efficacy is important, there are likely other contributing factors that influence science learning outcomes.

Students with high self-efficacy tend to exhibit greater persistence and effort in learning, which supports their ability to understand complex concepts. The results presented in table 6 also show that students with higher self-efficacy scores tend to achieve higher levels of conceptual understanding. This pattern supports the theoretical framework that individuals who believe in their capabilities are more motivated to take on challenges and persevere in learning tasks (Bandura, 1990).

These findings are consistent with previous studies that emphasize the important role of self-efficacy in supporting students' success in science learning. For example, research has shown that elementary students with strong self-efficacy beliefs are more likely to engage actively in learning and demonstrate better academic performance (Firdaus et al., 2023). Moreover, other findings also highlight the significant influence of self-efficacy on science learning outcomes, indicating that students who are confident in their abilities tend to develop a deeper understanding of scientific concepts (Suryandari, 2024).

CONCLUSION

Based on the findings obtained from the research in five elementary schools, it can be concluded that there is a significant relationship between self-efficacy and students' understanding of science concepts. Although the relationship is moderate, the results of this study indicate that higher levels of self-efficacy can contribute to improving students' understanding of science concepts. This finding confirms the importance of psychological factors, particularly self-efficacy, in the science learning process. This research makes a significant contribution to the development of educational theory, particularly in understanding the role of self-efficacy as a factor influencing students' understanding of science concepts. The practical implication of this research is the importance of implementing learning strategies that can increase students' self-efficacy to encourage better understanding of science concepts in elementary schools.

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