



Contribution of Metacognitive Skills to Students' Conceptual Understanding and Problem-Solving Skills in Elementary School Teacher Education

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Abstract: Metacognitive skills constitute one's cognitive awareness or affective experience that comes along with intellectual efforts. It represents one's awareness and knowledge about his/her own cognitive skills. Metacognitive skills affect one's conceptual understanding and problem-solving skills. Empirical research analyzing how metacognitive skills specifically contribute to conceptual understanding and problem-solving skills through free inquiry-based learning is still lacking. This study aimed to examine how metacognitive skills contribute to individuals' conceptual understanding and problem-solving using free, inquiry-based learning strategies. To this end, a descriptive correlational study was applied. The independent variable in this study was metacognitive skills, and the dependent variables were conceptual understanding and problem-solving abilities. Thirty-five students from the Elementary School Teacher Education Department of Universitas Nusantara PGRI Kediri participated. Data were analyzed using linear regression analysis. The result showed that metacognitive skills contribute 48.9% to students' conceptual understanding, higher than their contribution to problem-solving skills (i.e., 30.7%). These findings demonstrate the important role of metacognitive skills in shaping effective teacher preparation and fostering reflective and independent learners. This study provides empirical evidence for integrating metacognitive skill development into inquiry-based teacher education programs to enhance conceptual and problem-solving competencies.

Keywords: conceptual understanding; free inquiry; metacognitive skill; problem-solving skill

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INTRODUCTION

The 21st century demands higher-order thinking skills, which involve individuals' metacognitive skills, i.e., consciously controlled mental abilities. Metacognition is a higher-order thinking skill involving cognitive processes (Azizah et al., 2019). This skill comprises three components: planning, monitoring, and evaluation. It covers cognitive awareness and metacognitive knowledge. Cognitive awareness involves monitoring memory, understanding, and cognitive effort, while metacognitive knowledge is related to self-control, enabling one to understand what he/she sees, hears, and learns (Sevgi & Karakaya, 2020). Metacognitive skills play a pivotal role in education, as they can improve students' academic achievement. Metacognitive skills positively affect students' learning readiness, eventually improving their achievement (Rahayu & Hertanti, 2020; Abdelshiheed et al., 2022). Students with strong metacognitive skills tend to achieve better academically than those with weak metacognitive skills. Metacognitive skills are pivotal to the learning process and academic achievement (Fleur et al., 2021).

Metacognitive skills also affect one's cognitive activities, including conceptual understanding (Ermin, 2021; Brycz et al., 2015). Conceptual understanding is one of the learning outcomes that should receive considerable attention to help students master the presented materials. Conceptual understanding has been reported to correlate with metacognitive skills, which are part of critical thinking (Atmaja, 2021). Conceptual understanding is students' cognitive ability to understand and master a concept through learning activities, thereby developing their problem-solving skills (Amanda et al., 2021). Problem-solving skills may promote higher-order thinking (Setyarini et al., 2018; Hargrove & Niefeld, 2015), enabling students to link one fact or concept to another to solve problems. In solving problems, students also need metacognitive skills to monitor and control cognitive processes and to help them understand when, why, where, and how knowledge is applied to solve problems (Güner & Erbay, 2021).

This study examines the contribution of metacognitive skills to conceptual understanding and problem-solving among students in the Elementary School Teacher Education study program. One of the courses in the

curriculum is Basic Concepts of Science, which, so far in the learning process, still uses the old, lecturer-centered paradigm. This is not in accordance with the learning outcomes of graduates (Learning Outcomes), one of which is mastering theoretical concepts of a particular field of knowledge in general and of specific parts within that field in depth, as well as being able to formulate procedural problem-solving strategies.

Based on observations during the Basic Concepts of Science course, conceptual understanding and problem-solving skills remain low; this is evident in the final-semester grades, which are still in the lower category. The Basic Concepts of Science course provides students with the option to take other courses, namely Science Learning and Problem Solving and Science Laboratory Education. On the other hand, from a metacognitive perspective, it is also still lacking, so that increasing metacognitive skills can improve conceptual understanding and problem-solving skills (Rahayu & Hertanti, 2020).

Proper learning strategies are necessary to develop metacognitive skills during the learning process, and an inquiry-based learning strategy is among them. Inquiry-based learning is a learning process that involves activities that highlight one's critical and analytical thinking to obtain answers to specific problems (Bahiyah et al., 2019). Inquiry-based learning strategies may help develop students' problem-solving skills, conceptual understanding, and metacognitive skills. This learning strategy provides students with the freedom to choose how to solve problems. Previous studies on metacognitive skills have reported on their relationships with learning outcomes, conceptual understanding, learning retention, and problem-solving skills. These studies have reported a positive relationship between metacognitive skills and learning outcome, retention, and conceptual understanding (Amanda et al., 2021; Bahiyah et al., 2019; Ijirana, 2017; Lestari et al., 2017; Agustinsa et al., 2022).

Based on previous studies, there have been no reports on how metacognitive skills contribute to students' conceptual understanding and problem-solving skills through free inquiry-based learning. Therefore, this study aims to examine the effects of metacognitive skills on students' conceptual understanding and problem-solving skills, and to examine differences in the contributions of metacognitive skills to conceptual understanding and to problem-solving using free inquiry-based learning methods among students in the elementary school teacher education department.

METHODS

This descriptive correlational study examined how metacognitive skills contribute to students' conceptual understanding and to problem-solving skills through free inquiry learning (Creswell, 2012). The stages of free-inquiry learning strategy are presented in Table 1.

Table 1. Stages in free inquiry- based learning strategies

Stages	Lecturer's activity	Student's activity
Stage 1: Presenting Problems	Stating learning goals, Motivating students by presenting contexts of problems	Identifying problems independently
Stage 2: Collecting data	Serving as informants, facilitating students by providing sources of information	Discovering problem-solving resolution
Stage 3: Conducting the experiment	Monitoring the self-designed experiment, providing tools and materials for the experiment.	Collecting information through experiments and making notes
Stage 4: Organizing data and formulating explanations	Serving as informants, asking students to discuss the experiment results in the classroom, and communicating the experiment results of each group.	Formulating explanations to organize and formulate explanations regarding problems and discussing experiment results with other groups.
Stage 5: Analyzing and evaluating the problem-solving process.	Paying attention to students' analysis and providing opportunities to ask questions more effectively and productively.	Analyzing findings and proposing more effective and productive questions

Participants were thirty-five students in the Elementary School Teacher Education Department of Universitas Nusantara PGRI Kediri. Instruments used in this study included a syllabus, a lesson plan, students' worksheets, Corebima's (Siswati & Corebima, 2017) metacognitive skill rubric, and problem-solving and conceptual understanding rubrics developed by the author. The metacognitive skills assessment rubric refers to Corebima, which is integrated into essay-style questions and scores from 0 to 7. The syllabus, lesson plan, student worksheet, and essay questions were validated by two experts in Biology and yielded a mean score of

89.90 (categorized as highly feasible and requiring no revision). The questions used to collect data on conceptual understanding and problem-solving abilities were in essay format, totaling 32, and were validated by 2 expert validators in biology learning from Universitas Nusantara PGRI Kediri and Universitas Muhammadiyah Malang.

Assumption tests were performed prior to conducting the regression test, including tests for normality, autocorrelation, and heteroscedasticity. Criteria for these tests were met, and the data could be analyzed using a linear regression test with a significance level of 5% in SPSS for Windows 23.

RESULT AND DISCUSSION

Table 2 presents the contribution of metacognitive skills to conceptual understanding through free inquiry-based learning.

Table 2. Regression Test, ANOVA Test, Linear Regression Analysis Summary

Model	R	R square	F	sig	Unstandardized Coefficients
1	.700 ^a	.489	31,639	.000 ^a	30,845 .580

As shown in Table 2, the correlation coefficient (R) is 0.700 with a coefficient of determination (R^2) of 0.489. It indicates that metacognitive skills contribute 48.9% to students' conceptual understanding, whereas other factors account for the remaining 51.1%. This result was further examined using an ANOVA test to see the significance of the predictor. Moreover, shows a p-value $< \alpha$ ($\alpha = 0,05$), indicating that metacognitive skills significantly contribute to conceptual understanding among students taught using a free inquiry-based learning method. And then shows the linear regression equation for metacognitive skills and conceptual understanding using a free, inquiry-based learning strategy: $Y = 30.845 + 0.58X$. Metacognitive skills contribute to students' conceptual understanding using the Search-Solve-Create-Share (SSC) learning model (Saputri et al., 2019; Liline et al., 2024). A positive relationship between metacognitive skills and students' conceptual understanding has also been reported in previous works (Ganing, 2015; Nurisya et al., 2017; Aloqleh & Teh, 2019).

Metacognitive skills account for 48.9% of students' conceptual understanding, which is categorized as a moderate contribution. Several factors appear to affect students' learning outcomes, which could be categorized into internal and external factors. Internal factors include health, interests, aptitude, motivation, intelligence, and thinking skills, among others. Meanwhile, the external factors include family, school, and the community. Students' poor motivation and concentration may also affect the learning process (Atmaja, 2021; Sercenia et al., 2023). The regression analysis results regarding the contribution of metacognitive skills to problem-solving skills are presented in Table 3.

Table 3. Regression Test, ANOVA test, Linear Regression Analysis Summary

Model	R	R square	F	sig	Unstandardized Coefficients
1	.554 ^a	.307	14,647	.001 ^a	36,636 .400

As shown in Table 3, the correlation coefficient (R) is 0.554, and the coefficient of determination (R^2) is 0.307. This indicates that metacognitive skills contribute 30.7% to students' problem-solving, whereas other factors account for the remaining 69.3%. This result was further examined using an ANOVA test to see the significance of the predictor. Shows a p-value $< \alpha$ ($\alpha=0.05$), indicating that the metacognitive skills were significantly associated with students' problem-solving skills. And then shows the linear regression equation between metacognitive and problem-solving skills using a free, inquiry-based learning strategy: $Y = 36,636 + 0.40X$. The goal of learning is to empower metacognitive skills that will maximize brain capacity, thereby increasing independence in learning. Students will understand how to manage their learning process, when to study quickly, and when to slow down (Wilson & Conyers, 2016). While studying and working on assignments, students will assess their progress using metacognitive skills and will adjust their strategies based on their current knowledge (Schunk, 2012). Having good metacognitive skills, planning, monitoring, and self-assessment also enables the thinking process to be controlled. This will affect the ability to understand the material being studied. The more often students are aware of their thinking, the higher their thinking ability and their control over their goals (Kusuma & Nurmawanti, 2023). The information processing model explains the relationship between metacognitive skills and conceptual understanding in a mechanistic manner. The output of information processing is human capitalities consisting of: verbal information, intellectual abilities, cognitive strategies, attitudes, and motor skills (Basith et al., 2014; Dessie et al., 2024). All the facts that students obtain about the cognitive process of acquiring knowledge and skills are called metacognitive knowledge and are strategies for students to plan, monitor, and evaluate learning activities independently, so that conceptual understanding is better (Wicaksono, 2014; Mediana et al., 2025).

The study results show that metacognitive skills contribute to conceptual understanding through a free inquiry learning strategy at 48.9%. This aligns with previous research indicating that using the Search-Solve-Create-Share (SSC) learning model will improve conceptual understanding (Saputri et al., 2019; Kusuma & Baskara, 2022). There is a positive relationship between metacognitive skills and students' conceptual understanding (Ganing, 2015; Nurisya et al., 2017; Aloqleh & Teh, 2019), while 51.1% of the variance is explained by several internal and external factors that influence learning outcomes. Internal factors include health, talent, interest, motivation, intelligence, and thinking skills, among others. In comparison, external factors are from outside, such as family, school, and society. Low student motivation and concentration affect the implementation of learning (Hermanto et al., 2021).

Using a free inquiry learning strategy will provide students with the opportunity to acquire concepts by collaborating and discussing with friends and lecturers, thereby increasing understanding of the material in the Basic Concepts of Science course (Kasmanto & Anwar, 2025). Students with higher metacognitive skills were reported to have higher problem-solving skills (Bahiyah et al., 2019; Ambaryani & Putranta, 2022; Kusuma & Nurmawanti, 2023). Metacognitive skills have also been reported to affect problem-solving skills. Metacognitive skills help students solve their problems through effective planning, which involves processes of identifying problems, understanding them to obtain solutions, and selecting an effective strategy to solve them (Rahayu & Hertanti, 2020; Yüksel et al., 2021; Az-Zahra et al., 2021; Tachie, 2019). Metacognitive skills can optimize brain functions and help students achieve their learning goals, especially those related to problem-solving (Fitriyanto, 2016; Simamora et al., 2014; Ansari et al., 2021).

By using a free inquiry learning strategy, students can apply metacognitive skills and engage in group discussions, thereby improving their ability to identify problems, set goals, and develop problem-solving skills over time. However, students' problem-solving abilities also depend on their knowledge and experience in solving the problems they face (Ijirana, 2017; Harlanu, 2024). Metacognitive skills' contribution to students' conceptual understanding and problem-solving skills are inseparable from the learning strategies applied in this study, i.e., free inquiry-based learning. This study's free inquiry-based learning strategy aligns with metacognitive activities, in which students were asked to solve problems independently. Students may plan and set their learning strategies to solve the given tasks based on the stages of free inquiry-based learning. This setting allows students to develop their metacognitive skills, which, in turn, may affect their conceptual understanding and problem-solving. Free inquiry-based learning helps students identify problems and design an investigation process. Students were motivated to think critically and discover ideas, design the idea test, analyze arguments, and synthesize ideas to solve problems, and teachers are responsible for directing their students (Amin & Mariani, 2017; Bahiyah et al., 2019; Erikko et al., 2018; Siagian et al., 2019).

Metacognitive skills contribute more to conceptual understanding than to problem-solving skills. This is because metacognitive skills influence planning, monitoring, and self-assessment, enabling control of thought processes. This, in turn, impacts the ability to understand the concepts being studied. The more students are aware of their thinking, the stronger their thinking skills and the greater their control over their goals (Kusuma & Nurmawanti, 2023). There are still many teachers who use learning that emphasizes understanding concepts.

Stages in free inquiry include 1) preliminary discussion initiated by the directing questions; 2) variable identification; 3) problem formulation; 4) hypothesis development; 5) data collection; 6) hypothesis test; and 7) drawing of a conclusion. Stages 2-7 were performed by students, during which they were motivated to participate in the learning process and engaged in a guided investigation process. Free inquiry-based learning decreases the lecturer's domination during the learning process. Free inquiry-based learning is also supported by constructivism, which promotes learning through doing, developing social skills, and developing problem-solving skills (Moore, 2015). Metacognitive skills contribute more significantly to conceptual understanding than problem-solving skills because, during the learning process, students must understand the problem to be solved by discovering facts, concepts, and principles from direct experience. The free inquiry learning strategy was found to affect students' conceptual understanding. Theoretically, this study strengthens models of self-regulated learning by confirming the predictive role of metacognition across both conceptual and procedural domains. At the same time, it highlights the need to embed metacognitive training into inquiry-based curricula for pre-service teachers explicitly.

CONCLUSION

Metacognitive skills' contribution to conceptual understanding was higher than that to problem-solving skills. It contributes to conceptual understanding by 48.9% and to problem-solving skills by 30.7%. It was influenced by the free inquiry learning strategy, which requires students to independently determine their learning activities, making the learning process more interesting and meaningful. The findings provide empirical evidence that metacognitive processes such as planning, monitoring, and evaluation play a central role in supporting higher-order learning outcomes in teacher education. The results of this study could be used to develop other 21st-century skills, including communication, creativity, and scientific literacy.

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