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Comparing pre-service teachers' problem-solving skills in relation to their metacognition and reading comprehension

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ABSTRACT

Problem solving has been identified as a critical skill for individuals to adapt to society and is particularly beneficial for educators, especially pre-service teachers. However, this process is complex and is influenced by other predictors, such as metacognition and reading comprehension, which remain underexplored. This study aims to evaluate pre-service teachers' problem-solving skills and compare them based on their levels of metacognition and reading comprehension. A total of 133 pre-service teachers were included in this study. They completed a self-developed problem-solving test that presented problems related to the use of technology and artificial intelligence in teaching and learning processes. Additional adapted instruments were used, including a reading comprehension test with seven items and a metacognitive questionnaire with eleven items. The participants were then clustered into three groups: the first group represented individuals with high reading comprehension and moderate metacognition; the second group, those with high metacognition and moderate reading comprehension; and the third group, those with moderate levels of both reading comprehension and metacognition. The collected data were analyzed using analysis of variance (ANOVA). The result revealed no significant differences in pre-service teachers' problem-solving skills ($F_{(130)} = 1.023$, $p = .363$). This finding may indicate that once a minimum level of metacognition and reading comprehension is reached, additional gains may not lead to significantly higher problem-solving performance. However, the results should be interpreted cautiously, considering the study's limitations and the potential presence of a metacognitive ceiling effect.

Keywords: Metacognition, pre-service teachers, problem solving, reading comprehension

INTRODUCTION

Teacher education requires the acquisition of pedagogical and cognitive skills to address classroom situations. Indeed, to become teachers, education graduates such as pre-service teachers must master essential skills for handling pedagogical activities (Chalkiadaki, 2018). Problem-solving has become a critical competence for addressing contemporary technology-related issues (Csapó & Funke, 2017), particularly those associated with artificial intelligence in the teaching and learning process. Nevertheless, despite the increasing prominence of AI-related pedagogical challenges, there is limited empirical evidence on how pre-service teachers' problem-solving skills are influenced by their metacognitive and reading comprehension abilities.

Problem-solving skills play an important role in helping pre-service teachers adapt to dynamic situations that may influence pedagogical practices in general (Greiff et al., 2021). Problem solving has been one of the important skills for individuals to adapt to a changing society. It benefits individuals by helping them succeed in the workplace through their ability to analyze problems, identify relevant information, make plans, and evaluate various solutions (Karla et al., 2022). Furthermore, several definitions of problem solving describe it as an individual's capacity to engage in cognitive processes to understand a problem situation where the method or solution

is not immediately obvious (OECD, 2013). In this context, problem-solving skills can be divided into four categories based on cognitive processes: (1) exploring and understanding information related to the problem, (2) representing the problem situation and formulating hypotheses about the factors or variables connected to the problem context, (3) planning and setting goals as well as executing them, and (4) monitoring progress and reflecting on the solutions (OECD, 2014). Another approach has been described by Jonassen (2000), stating that problem solving is related to the outcomes of the solution-generating process, which can depend on the type of problem whether it is well-defined or ill-defined. Well-defined problems have clear goals and solutions, with correct and convergent answers, whereas ill-defined problems have unclear goals and multiple criteria, present uncertainty, and require the identification of multiple concepts, principles, and creative approaches. In today's context, ill-defined problems are often used as the basis for other types of problem-solving assessments, such as complex and creative problem solving. Thus, defining problem solving becomes critical for developing pedagogical approaches to the problem-solving process, both in terms of intervention and evaluation.

Fostering problem solving should be introduced as a lifelong learning program that can be developed during both educational and professional stages. Importantly, for teachers, teaching problem solving has been emphasized in many educational systems. In Indonesia, problem solving is also suggested as one of the core competencies in the curriculum, while learning strategies such as problem-based learning are recommended for implementation during the learning process (BSNP, 2013). Consequently, educators, especially pre-service teachers, must master and be able to accommodate problem solving in their future classrooms. The ability to solve problems is also critical for designing and achieving successful learning. Identifying problem-solving abilities, especially in handling pedagogical problems, is necessary to further improve professional competencies. Indeed, administering problem-solving assessments for pre-service teachers is critical to meet the needs and evaluate the state of their pedagogical competencies.

In regards of identifying and fostering problem solving competencies, it is important to implement a specific strategies and identify factors that support problem solving processes. Thus many research conducted in Indonesia for fostering problem solving abilities for pre-service teachers (Ardian et al., 2024; Asyari et al., 2016; Najib et al., 2023; Nurjanah et al., 2019; Saputro et al., 2020; Savitri et al., 2021), supporting that the use of learning media and strategies such as problem-based learning or project-based learning can foster problem-solving competencies. However, since problem solving is a complex process, it is also important to identify the factors involved during the problem-solving process. Shin et al (2003) also suggest that metacognition plays an important role in problem solving by monitoring information and the solutions selected, elaborating plans with flexibility of action, and providing feedback on the implemented solutions. Metacognition was first defined as the knowledge of one's own cognitive processes, products, or anything related to them (Flavell, 1979). Metacognition is considered an important part of problem solving, as individuals who are likely to apply a metacognitive approach tend to enhance their problem-solving processes by connecting them with contextual thinking (Hargrove & Nietfeld, 2015). Furthermore, metacognitive monitoring helps individuals guide their problem-solving processes, making them more creative in providing solutions to the problems (Mumford et al., 1996; Urban & Urban, 2023). Indeed, identifying metacognition in the problem-solving process will provide valuable insights for efforts to foster problem solving itself.

Another cognitive component, such as reading comprehension, has been shown to support individuals' problem-solving performance (Ghahari & Basanjideh, 2015; Harangus, 2019). Boonen et al. (2016) found that students' problem solving is related to their reading comprehension ability. Reading comprehension refers to the level of understanding of a text to obtain knowledge or information from it (Peñafiel Arcos, 2018). Reading comprehension helps activate prior knowledge to make connections and inferences. This process is critical in problem solving, especially when problem solvers identify the problem, understand the context, acquire relevant knowledge, and interpret the situation. It supports cognitive processes that build comprehension and generate meaning. When the reading text is made analogous to the problem situation, it stimulates inference generation and working memory processes (Elbro & Buch-Iversen, 2013; Nouwens et al., 2017).

To support the development of problem solving among pre-service teachers, assessment and evaluation are needed. The assessment of problem solving must address critical issues relevant to the context, such as technology for education in this regard. In addition to that, it is also critical to identify influential factors that affect the regulation of problem solving, such as metacognition and reading abilities (Danesh & Nourdad, 2017; Maries & Singh, 2023; Özcan, 2016; Zhao et al., 2019). Currently, there are many studies examining the connection between metacognition and reading abilities in relation to problem solving (Shin et al., 2003; Wang et al., 2013). However, the majority of existing studies have examined this relationship in a unidirectional manner, leaving a gap in understanding the interrelationship between these predictors of problem-solving. In the present study, we examined and identified the problem-solving skills of pre-service teachers by presenting a current and contextual problem situation and comparing participants based on their levels of metacognition and reading comprehension using cluster analysis. This approach allowed us to identify which combinations of these skills contributed more strongly to problem-solving performance. Thus, the joint contribution of metacognition and reading comprehension to problem-solving is further explored.

The study on the connection between metacognition and reading comprehension in problem solving may potentially unlock new approaches to support instructional strategies that can foster problem solving effectively. However, previous studies have examined the association between other skills and problem solving separately, leaving a gap regarding whether two or more skills simultaneously affect problem solving in specific ways. Thus, the present study profiles and compares students' problem-solving abilities across competency clusters based on their metacognitive and reading comprehension abilities, providing new insights into how specific combinations of these skills affect problem-solving performance. There are two research questions applied in this study, which include:

1. What is the profile of students' abilities in metacognition, reading comprehension, and problem-solving skills?
2. How do problem-solving skills differ among students with varying levels of metacognition and reading comprehension?

METHOD

Participants

This study involved pre-service teachers from the Faculty of Mathematics, Science, and Information Technology Education at Universitas PGRI Semarang, including those from the first to third years students. A cluster random sampling technique was employed to select participants. This technique was used because the population (the Faculty of Mathematics and Science Education) is divided into several

clusters or study programs (Mathematics Education, Biology Education, Physics Education, and Information Technology Education). This approach ensures that all study programs are represented in the research and enhances the generalizability of the findings. The faculty consisted of sixteen classes with a total enrollment of 480 students. One class from each study program was randomly selected, and all students in the selected classes were included in the study. A total of 133 pre-service teachers from four classes was voluntarily participated in the study, with a mean age of 20.13 years (SD = 1.31), and 70.2% were female.

Instruments

The instrument used in this research is a problem-solving test that was measured based on the level of correctness of the responses. The test was self-developed based on problems related to the use of AI for educational purposes, especially in conducting the teaching and learning process, where the test takers needed to solve the problems by proposing solutions that help teachers implement AI in the teaching and learning process and reduce misalignment. The scoring procedure for the problem-solving test used rubric with a range of 0 to 4. The content validity of the test was examined by two expert reviewers, and the reliability of the problem-solving test was assessed using the intraclass correlation coefficient (ICC) based on ratings from two raters. The results indicated good reliability (ICC = .81), with a 95% confidence interval ranging from .51 to .92, $p < .001$.

The reading comprehension was measured using a reading test with the main topic of artificial intelligence. The test began with a reading passage about the benefits and drawbacks of using artificial intelligence in general sectors. Then, seven multiple-choice questions was were provided and developed based on the passage, using dichotomous scoring, with 1 point for a correct answer and 0 for an incorrect answer. The validity and reliability of the reading comprehension test were measured using Rasch analysis (Boone et al., 2014), showing that the test exhibited high item reliability as 0.93, demonstrating its internal consistency. Furthermore, the infit mean square (MNSQ) values showed that all items had acceptable ranges from 0.90 to 1.14, indicating that all items in the reading comprehension test fit the data well. In addition, the PTMA values were positive, ranging from 0.36 to 0.62, showing that the items aligned with the intended construct.

Metacognition was measured using the Metacognition for Problem Solving (MCPS) questionnaire 11 items adapted from Urban & Urban (2024). The MCPS measures metacognitive skills within problem-solving processes, mainly examining individuals' ability to plan, monitor, regulate, and evaluate their performance in cognitive processes. The scoring procedure for the MCPS follows a Likert scale ranging from 1 (strongly disagree) to 4 (strongly agree). The validity and reliability of the MCPS were assessed using Rasch analysis, showing acceptable reliability of 0.78. Furthermore, the infit mean square (MNSQ) values indicated that all items had acceptable ranges from 0.68 to 1.44, confirming that all items in the metacognition test fit the data well. However, item 2 had an infit MNSQ value of 1.64, which was slightly higher than the acceptable range but still included in the construct due to its theoretical relevance. In addition, the PTMA values were positive, ranging from 0.71 to 0.72, indicating that the items aligned with the intended construct. The distribution of the items for reading comprehension and metacognition is shown in Figure 1.

Procedure and data analysis

The participants completed an online test and questionnaire, beginning with a reading passage followed by a reading comprehension test. They then completed the MCPS

questionnaire and finally answered the problem-solving test, which took approximately 90 minutes. Prior to participation, the participants provided informed consent on the first page of the online survey, ensuring their voluntary and confidential participation in the study.

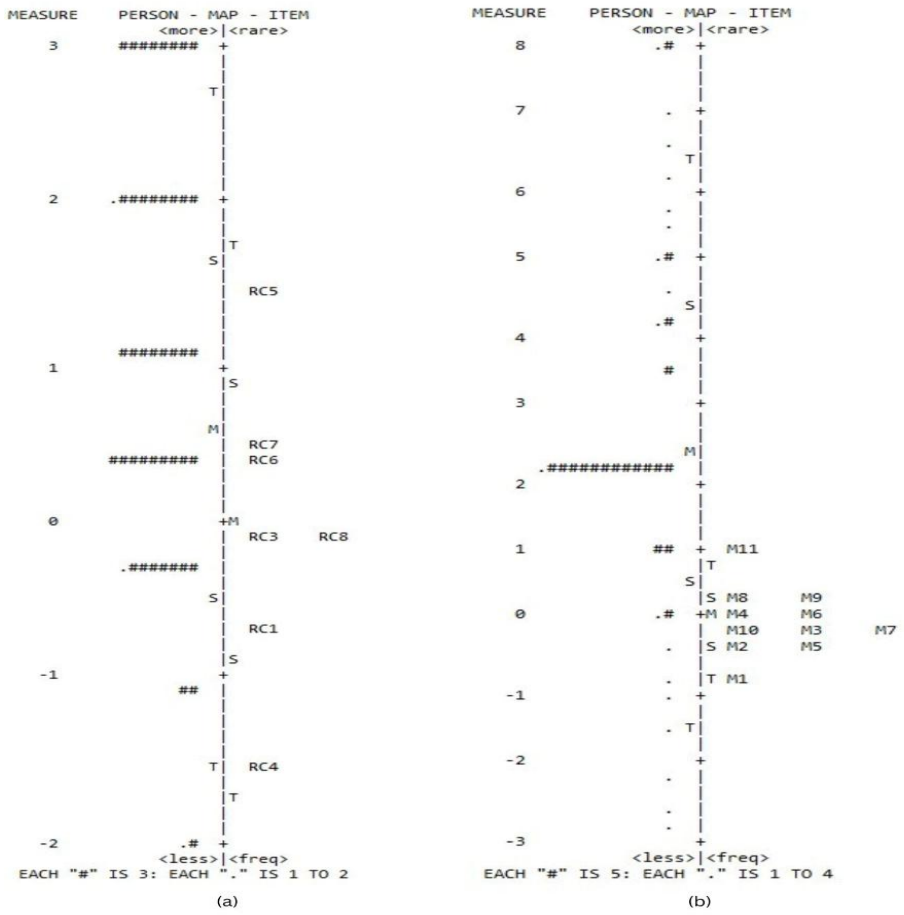

Figure 1. Wrightmap of reading comprehension test (a) and metacognition questionnaire (b).

The data collected further analyzed using descriptive statistics to profile the students' reading comprehension, metacognition, and problem-solving competencies. In this study, reading comprehension and metacognition were treated as predictor variables, and participants were clustered according to their respective levels. Subsequently, we examined whether differences in these abilities influenced problem-solving competency. A hierarchical cluster analysis was conducted using Ward's minimum variance method as the clustering algorithm, with squared Euclidean distance as the similarity measure. The optimal number of clusters was then estimated based on the distance and distribution. Finally, a comparison analysis (ANOVA) was performed to examine differences in students' problem-solving performance across clusters. Before conducting the ANOVA, skewness and kurtosis were assessed to verify the normality of the data distribution. The analysis procedures were carried out using SPSS version 25.

RESULTS AND DISCUSSIONS

In this study, we investigated pre-service students' problem-solving performance alongside their levels of reading comprehension and metacognition. The details of students' problem-solving, reading comprehension, and

metacognition are described in Table 1. Within our sample, students' problem-solving and reading comprehension levels were categorized as moderate, with M_{PS} = 2.86 (SD = 0.80) and M_{RC} = 0.68 (SD = 0.23) respectively, while metacognition was categorized as high (M_{MCPS} = 3.10, SD = 0.36). There was no significant correlation among problem-solving, reading comprehension, and metacognition. However, the latent variables of metacognition showed high and significant intercorrelations, supporting their internal consistency. Additionally, all data showed a normal distribution, with skewness and kurtosis values within the acceptable range of −2 to 2.

Table 1. The result of descriptive and correlational analysis between variables

	M(SD)	Skewness (SE)	Kurtosis (SE)	1	2	3	4
Reading comprehension (1)	0.68 (.23)	-.28 (.21)	-.74 (.42)	-			
Metacognition							
Monitoring and regulating (2)	3.13 (.37)	.57 (.21)	1.60 (.42)	.008	-		
Planning (3)	3.08 (.43)	.04 (.21)	1.66 (.42)	-.018	.769**	-	
Evaluating (4)	3.03 (.46)	.20 (.21)	0.96 (.42)	-.012	.635**	.711**	-
Problem solving (5)	2.86 (.80)	-.81 (.21)	1.02 (.42)	-.001	.110	.092	.164

Note: **significant at p < .001

The examination of the cluster analysis using a squared Euclidean distance of 10 suggested a three-cluster solution based on students' metacognition. Cluster 1 (n = 68) included students with high reading comprehension and moderate metacognition. Cluster 2 (n = 16) consisted of students with moderate reading comprehension and high metacognition, while Cluster 3 (n = 49) comprised students with moderate reading comprehension and metacognition. The descriptions of each cluster are presented in Table 2 and Figure 2.

Tabel 2. Descriptive results of cluster based on reading comprehension and metacognition

	Mean (SD)			F	*p*
	Cluster 1	Cluster 2	Cluster 3		
Reading comprehension	0.85 (.13)	0.57 (.26)	0.48 (.13)	95.27	< .001
Metacognition	3.07 (.19)	3.84 (.16)	2.88 (.25)	130.05	< .001

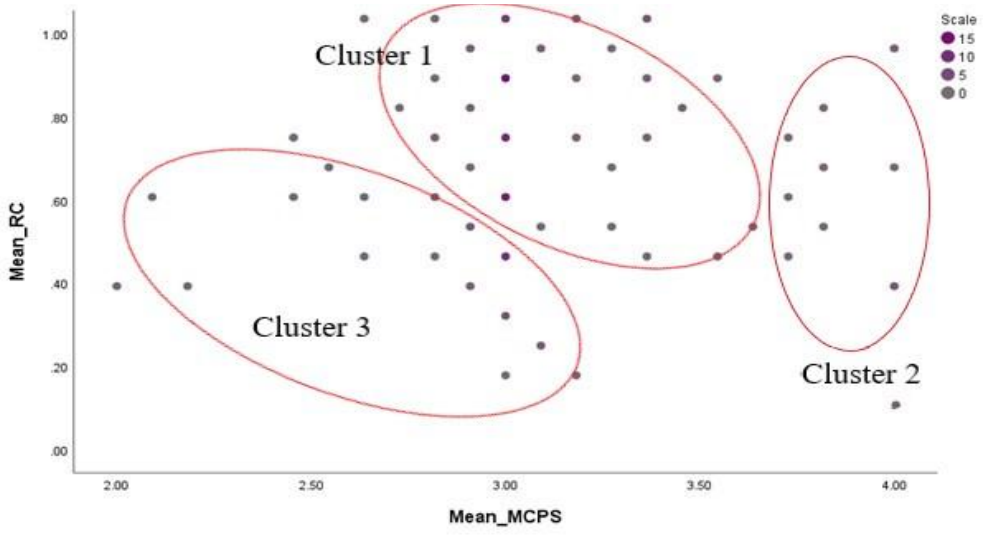

Figure 2. Scatterplot of cluster analysis based on students' metacognition and reading comprehension (MCPS = metacognition; RC = reading comprehension)

The ANOVA results show that there is no significant difference in students' problem-solving abilities among the clusters, $F_{(130)}$ = 1.023, p = .363. This result implies that students with moderate to high levels of reading comprehension and metacognition tend to perform at a similar level in problem solving. Moreover, Cluster 2, which consists of students with higher metacognitive skills, shows the highest problem-solving competency (M = 3.13, SD = 1.15, $CI_{95\%}$ = [2.51, 3.74]), followed by Cluster 1, which includes students with higher reading comprehension and moderate metacognition (M = 2.85, SD = 0.80, $CI_{95\%}$ = [2.66, 3.05]). Finally, Cluster 3, consisting of students with moderate levels of both reading comprehension and metacognition, shows the lowest problem-solving competency (M = 2.80, SD = 0.68, $CI_{95\%}$ = [2.60, 2.99]; see Figure 3).

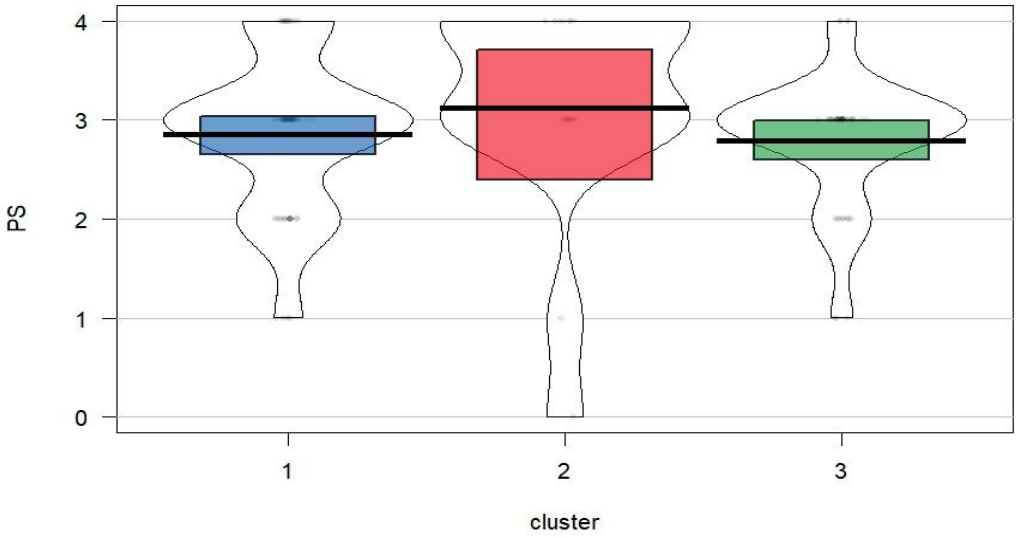

Figure 3. Distribution of students' problem-solving abilities across clusters (PS = problem solving)

The results within the sample show that the level of students' reading comprehension was at a moderate level, meaning that the majority of students were able to obtain information from the text and develop some understanding and inferences from it. For the metacognition level, we found that students had generally high metacognitive skills. The sample students gave positive responses, indicating that they were able to make novel plans when solving problems, monitor and regulate their progress, and evaluate the solutions or the results of their work. Since metacognition was aligned with problem-solving activities, the students were fully aware of their abilities (strengths and weaknesses) to select appropriate strategies to solve the problems. This was reflected in the solutions they produced when solving the given problems, where most students provided appropriate answers, and on average, they demonstrated a moderate level of performance. The majority of students' problem-solving solutions showed novel approaches to handling the given issues, but they did not comprehensively provide deeper explanations about their solutions.

Further analysis was conducted by clustering students based on their metacognition and reading comprehension. In the given sample, three clusters were identified: students with high reading comprehension and moderate metacognition, students with moderate reading comprehension and high metacognition, and students with moderate levels of both reading comprehension and metacognition. There were no students who fell into the category of low reading comprehension and metacognition. Among these three groups,

there was no significant difference in their problem-solving skills. However, higher problem-solving performance was found in the group of students with higher metacognition, followed by those with higher reading comprehension, and lastly, students with moderate levels of both metacognition and reading comprehension. These results suggest that metacognition potentially contributes to fostering students' problem-solving skills, along with their reading comprehension. Metacognition has long been suggested to play a supportive role in effective problem solving (Kim & Lim, 2019; Kim et al., 2013; Liu & Liu, 2020; Özcan, 2016; Zhao & Saleh, 2025). It helps students make judgments and decisions about problem solutions that enable them to reach specific goals. Additionally, monitoring and regulating activities effectively help students implement strategies that facilitate the achievement of their goals (Maries & Singh, 2023). Moreover, individuals with higher metacognitive skills usually take more time to represent the problems, generate solutions, and check their work (Zhao & Saleh, 2025). Indeed, metacognition plays a critical role in supporting students' problem-solving skills. This may explain the non-significant results observed in the study, as participants exhibited relatively high and homogeneous levels of metacognitive ability, potentially limiting variability in problem-solving outcomes.

Furthermore, reading comprehension has been reported to have a positive influence on problem solving (Boonen et al., 2016; Danesh & Nourdad, 2017; Ghahari & Basanjideh, 2015; Harangus, 2019). It supports problem solving by providing context and prior knowledge that help individuals understand the problems (Wicaksono & Korom, 2025). In relation to problem solving, reading comprehension can provide conceptual and factual knowledge that helps problem solvers identify the problems. This knowledge supports the understanding of variables and their connections within the problem situation. It also reinforces prior knowledge to build problem schemas that allow individuals to organize a collection of problems into categories, making them easier to identify and analyze (Mayer, 2016; Milbourne & Wiebe, 2018). In our sample, each cluster exhibited distinct levels of reading comprehension. Cluster 3, which had the lowest reading comprehension, also showed the lowest problem-solving performance. Although Cluster 1 demonstrated the highest level of reading comprehension, its problem-solving scores were lower than those of Cluster 2 (moderate reading comprehension). This pattern may be influenced by the high metacognitive levels observed in the clusters.

Indeed, the combination of metacognitive treatment and reading comprehension has been reported to contribute to successful problem-solving activities. In this study, we particularly grouped students based on their metacognitive treatment and reading comprehension abilities. The findings indicate that when students have at least a medium level of these abilities, they tend to solve problems more effectively. Thus, we recommend that students develop medium to high levels of metacognitive treatment and reading comprehension in order to solve problems effectively. Furthermore, future research is needed to investigate the effects of metacognition and reading comprehension on problem-solving performance across different settings and research designs, allowing a more comprehensive examination of each variable's contribution to problem-solving ability.

Additionally, this study must be interpreted in light of several limitations. First, the problem used in this study was related to the implementation of Artificial Intelligence (AI) in connection with teaching and learning practices for pre-service teachers. Second, we measured these abilities only among mathematics and science students, so students from other fields of study may show different performances or responses related to problem solving, metacognition, and reading comprehension. Therefore, we recommend increasing the

sample size in future studies to include students from different majors. It is also important to consider the roles of metacognition and reading comprehension in efforts to promote problem-solving abilities. Third, the limited number of reading comprehension items in the research instrument may have reduced the measurement's sensitivity to detect differences in problem-solving performance. Furthermore, intervention-based studies are needed to more clearly examine the effects of metacognitive instruction and reading comprehension on problem-solving outcomes.

CONCLUSION

This study profile students' problem-solving abilities and compares it based on their reading comprehension and metacognitive levels. In this sample, cluster analysis was performed to group students based on their reading comprehension and metacognitive levels, resulting in three groups: students with high reading comprehension and moderate metacognition, students with moderate reading comprehension and high metacognition, and students with moderate levels of both reading comprehension and metacognition. There were no significant differences in problem-solving skills among students across the three groups based on the ANOVA results ($F_{(130)} = 1.023$, $p = .363$). This may suggest that similarly high levels of metacognition, which reflect a ceiling effect, contributed to reduced variability in problem-solving performance. Thus, the findings imply that achieving at least a moderate level of both reading comprehension and metacognition may be required to support problem-solving performance. Moreover, these findings highlight the importance of integrating reading comprehension and metacognitive components into learning processes to enhance students' problem-solving performance, while taking into account several limitations, particularly that the research was conducted within a specific domain and involved only pre-service teachers, which may limit the generalizability of the findings to other samples and populations, as well as the possibility that the instruments used in this study may not fully capture variations in reading comprehension, metacognition, and problem-solving skills in different settings. Therefore, further research is recommended, particularly studies that implement strategies accommodating both reading comprehension and metacognition to support problem-solving.

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