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How Does Metacognitive Knowledge Potential Impact on the Academic Success of Prospective Science Teachers?

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Abstract

Metacognition generally has two essential components: metacognitive knowledge and metacognitive awareness. Unfortunately, research that focuses on and explores the description of metacognitive knowledge and its implications for the academic success of prospective science teacher students is still rare. The current study aimed to explore (1) the baseline levels of metacognitive knowledge (MK) among prospective science teachers (PST), (2) the relationship between the extent of MK and academic success, and (3) the potential differences in MK based on gender. The correlational research with the survey method was used in the study. The study involved 206 (male: 93 and female: 113) prospective science teachers who participated in a fundamental physics course at Mandalika University of Education as a sample. Data on MK was collected using twenty items of essay tests that are valid and reliable to collect PSTs' MK. In contrast, PSTs' learning success data was collected using instruments used in mid-semester examinations and practical laboratory test results. The data was further analyzed descriptively and statistically using the ANOVA and Pearson correlation tests. The result shows that PSTs' MK is in the low category (MK<60). Additionally, male prospective science teachers demonstrated better declarative (mean: 59.247; $p < 0.05$) and procedural knowledge (mean: 64.482; $p < 0.05$) indicators, and MK positively correlates in each indicator. Based on the findings, it is evident that PSTs' MK significantly differs between males and females, the positive correlations between MK indicators, and potentially impact teaching practices and cognitive outcomes. Furthermore, future research needs to develop effective interventions, learning models, and instructional practices to enhance metacognitive skills and science learning outcomes in teacher education.

Keywords: metacognitive knowledge; academic success; prospective science teacher

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INTRODUCTION

Metacognition refers to the knowledge about and regulation of one's cognitive activities in learning processes (Veenman, 2012). In cognitive neuroscience, metacognition is divided into two main components: metacognitive knowledge and metacognitive experiences (Fleur et al., 2021). Metacognition is also regarded as a critical component of creative thinking, involving the knowledge and regulation of one's cognitive processes (Jia et al., 2019). It is a superordinate concept involving conscious awareness of cognitive performance and includes components such as metacognitive knowledge, metacognitive experiences, goals, and tasks (Hasson-Ohayon et al., 2020). Additionally, metacognition is described as cognition about cognition, encompassing knowledge, awareness, and control of one's own cognition and human cognition in general (Peteranetz, 2017).

The components of metacognition have been further detailed in the literature. These components include metacognitive knowledge, metacognitive experiences, metacognitive tasks or goals, and metacognitive strategies (Drigas & Mitsea, 2021). Moreover, metacognitive measures have been found to include self-knowledge and self-regulation components (Poll & Petru, 2023). Principal components analysis on metacognition has revealed that three metacognitive components (global metacognition, offline metacognition, and attribution to effort) explain a significant portion of the common variance (Desoete et al., 2001). Furthermore, metacognition comprises both the ability to be aware of one's cognitive processes and to manage them effectively (Mitsea et al., 2022). In summary, metacognition encompasses the knowledge and regulation of one's cognitive processes and is divided into components such as metacognitive knowledge, metacognitive experiences, metacognitive tasks or goals, and metacognitive strategies. These components play a crucial role in various aspects of learning, cognitive performance, and creative thinking.

Metacognitive knowledge is crucial to academic success, particularly among prospective science teachers. Research has shown that metacognition is significantly linked to learning, academic achievement, and cognitive development (Fleur et al., 2021). Metacognitive awareness has been identified as a significant contributor to success in learning and is considered an excellent tool for measuring academic performance (Abdelrahman, 2020). Moreover, metacognitive knowledge, monitoring, and control support students' success in academic and experiential settings (Rivers et al., 2020). In the context of science education, metacognition has been found to improve scientific literacy and practices, which are essential for prospective science teachers (Lavi et al., 2019). Furthermore, the correlation between knowledge and regulation of metacognition with students' academic performance has been demonstrated in various studies, indicating the positive influence of teaching and learning activities on academic outcomes (Hong et al., 2015). Additionally, research has shown that metacognitive awareness and regulation are related to academic success across different disciplines in university undergraduates (MacKewn et al., 2022). It has also been suggested that enhancing prospective teachers' metacognitive awareness and its constituent factors can significantly impact their academic success (Siddiqui et al., 2020).

The importance of metacognition in education has led to the development of successful learning programs translated into educational settings, emphasizing the robust relation of metacognition to learning and comprehension (Cromley & Kunze, 2020). However, it has been noted that previous research on students' metacognitive knowledge state is below standards in some empirical studies, highlighting the need for further investigation and improvement in this area (Jarrar, 2022). In the context of teacher education, the development of efficient learning designs has been linked to prospective teachers' metacognitive knowledge, including declarative, procedural, and conditional knowledge, which is crucial for their academic success (Allo et al., 2019). Additionally, the role and importance of metacognitive awareness and its components for the learning efficiency and academic self-regulation of higher education institution (HEI) students have been emphasized (Balashov et al., 2021).

Metacognitive knowledge has been a subject of interest in the context of academic success, particularly in science teacher education (Asy'ari et al., 2019). The literature emphasizes the importance of metacognition in education, highlighting its relevance to learning and academic achievement. In the specific context of science education, metacognition has been found to improve scientific literacy and practices, which are essential for prospective science teachers (Panchu et al., 2016). Furthermore, studies have examined the relationship between metacognitive awareness, regulation, study habits, and academic success across different disciplines, indicating the significance of metacognition in supporting academic achievement (Abdelrahman, 2020). Additionally, the theoretical aspects of metacognitive awareness and academic self-regulation of higher education institution (HEI) students have been analyzed, shedding light on the relevance of metacognition to academic success in higher education settings (Balashov et al., 2021). These findings collectively underscore the importance of metacognitive knowledge in the academic success of prospective science teachers. The literature provides valuable insights into the role of metacognition in enhancing learning, academic achievement, and cognitive development, particularly in the context of science teacher education.

Unfortunately, research that focuses on and explores the description of metacognitive knowledge and its implications for the academic success of prospective science teacher students is still rare. The literature on metacognitive knowledge, academic success, and science teacher education reveals several gaps and areas where further research is needed. Firstly, there is a need for more qualitative research focusing on student success, particularly in the context of science teacher education (Kirby & Amason, 2021). Additionally, further research is needed to explore the experiences of science teachers, especially those from underrepresented groups, and their relationships with students (Mensah & Jackson, 2018). Moreover, the literature highlights the importance of examining the impact of metacognitive awareness on academic achievement and the implications for curriculum delivery (Hassan et al., 2022). In the science learning subject, metacognition found in the low category (Fauzi & Sa’diyah, 2019). Unfortunately, the study was conducted in junior high school student and focused in exploring students’ metacognition awareness.

The current study aimed to full fill the gaps described above by exploring the baseline levels of metacognitive knowledge among prospective science teachers (PST). Additionally, the current study explores the relationship between the extent of metacognitive knowledge and the academic success (learning outcomes) of participants; and to explores the potential differences in metacognitive skills based on gender. The metacognition knowledge indicators involved in the current study refer to the declarative, procedural, dan conditional knowledge (Muhali et al., 2019). The impact of metacognitive knowledge on the academic success of prospective science teachers is a topic of significant importance with far-reaching implications for education, teacher training, and the improvement of academic outcomes for future science educators. Metacognitive knowledge, which encompasses an individual's awareness and understanding of their own cognitive processes, has been identified as a powerful predictor of learning (Veenman, 2012). Research has shown that metacognitive awareness and academic motivation significantly influence students' academic achievement (Abdelrahman, 2020). Therefore, understanding the relationship between metacognitive knowledge and academic success is crucial for informing effective teaching practices and supporting the development of future science educators.

Furthermore, the implications of metacognitive knowledge extend to the broader field of education, where the integration of metacognitive strategies in teaching has been shown to improve students' academic success across diverse subjects and disciplines (Stephanou & Mpiontini, 2017). Additionally, metacognitive strategies have been found to increase prospective teachers' metacognitive awareness and self-efficacy beliefs, highlighting the potential for these strategies to positively impact teacher preparation and education programs (Yıldız & Akdağ, 2017). Research has emphasized the importance of science teachers' metacognitive knowledge in promoting investigative activities in the classroom and fostering students' understanding of scientific thinking (Francisco et al., 2021). By integrating metacognitive strategies in science teaching, teachers can facilitate students' comprehension of scientific concepts and improve their academic achievement (Wagaba et al., 2016).

METHOD

The current study used the correlational research with survey method. It aimed to explore relationships between variables namely metacognitive knowledge (MK) and learning outcomes (LO). MK that involved three indicators: declarative knowledge (DK), procedural knowledge (PK), and conditional knowledge (CK). On the others hand, LO involved cognitive outcome (CO) and cognitive skills (SK). The current study combined with a survey method, this approach allows researchers to gather information on participants' opinions, behaviors, or characteristics and investigate associations between these variables (Fraenkel et al., 2012). The research data was collected from March 2023 – August 2023 involved 206 (male: 93 and female: 113) prospective science teachers who participated in fundamental of physics course in Mandalika University of Education.

Data on MK collected using twenty items of essay test that valid and reliable to collect PSTs' metacognitive knowledge (Asy'ari et al., 2018). The instrument validated by experts and declared contently and constructively valid (score > 3.6) and reliable (r: .986). Furthermore, the instrument was also empirically valid (Pearson-correlation > 0.2960) and reliable (Cronbach's Alpha: 0.944). Moreover, data on PSTs' LO collected using instrument used in mid-semester examination (CO) and practical laboratory (SK) test results.

The data further analyzed descriptively and statistically. PSTs' MK categorized based on categories provided in Table 1 that adopted from Muhali et al. (2019). Furthermore, data normality determined based on Skewness and Kurtosis scores. The type of normality test used based on the sample involved in the current study more than 100 samples (Kim, 2013). Gender different impact on PSTs' MK and LO analyzed by using ANOVA test, while the correlation between indicator explored in the current study used Pearson-correlation test. All data analysis processes were carried out with the help of IBM SPSS 23 version.

Table 1. Metacognitive knowledge criteria

Criteria	Score range
Very High	80≤MK≤100
High	70≤MK≤79
Moderate	60≤MK≤69
Low	MK<60

RESULT AND DISCUSSION

Descriptive Data Summary

The current study found that PSTs' MK is in the low category (Table 2). The finding suggests that these individuals may have limited awareness and understanding of their own cognitive processes and strategies for learning. Metacognitive knowledge encompasses the ability to reflect on and regulate one's thinking, understanding, and learning processes. Therefore, low metacognitive knowledge among prospective science teachers may indicate a lack of proficiency in monitoring and controlling their cognitive activities, as well as a limited ability to employ effective learning strategies. This finding has significant implications for the academic success and professional development of prospective science teachers. Limited metacognitive knowledge may hinder their ability to adapt their learning approaches, monitor their understanding, and regulate their cognitive processes, which are essential skills for effective teaching and learning. Additionally, low metacognitive knowledge may impact their capacity to support students' metacognitive development and academic achievement in the classroom. Furthermore, addressing the low metacognitive knowledge among prospective science teachers is crucial for enhancing their pedagogical practices and instructional strategies. Teacher training programs and professional development initiatives should consider incorporating interventions aimed at improving metacognitive awareness and knowledge among prospective science teachers. By enhancing their metacognitive skills, these educators can better support students' cognitive development, academic success, and scientific literacy.

Table 2. PSTs' metacognitive knowledge

Indicator	N	Mean	Category
DK	206	56.286	Low
PK	206	53.635	Low
CK	206	42.791	Low

The research findings indicating that prospective science teachers' metacognitive knowledge is in the low category align with existing literature on metacognitive awareness and academic success. Several studies have illustrated a strong relationship between students' metacognitive awareness skills and their academic achievement. For instance, Abdelrahman (2020) demonstrated that students with high metacognitive awareness skills achieved higher academic success, while those with poor metacognitive awareness skills had lower academic success. Similarly, Wilson and Bai (2010) highlighted that metacognitive students are successful in school, emphasizing the positive impact of metacognitive knowledge on academic achievement. These findings support the notion that metacognitive knowledge plays a crucial role in academic success. Furthermore, the literature has also explored the metacognitive awareness of prospective teachers and its implications for teaching practices. The research found that in-service teachers' declarative metacognitive knowledge of higher-order thinking skills was unsatisfactory for teaching higher-order thinking in science classrooms, suggesting that teaching experience may influence one's metacognition (Lee et al., 2010). This aligns with the research indicating low metacognitive knowledge among prospective science teachers, highlighting the need for targeted interventions to enhance their metacognitive awareness.

Additionally, the impact of metacognitive knowledge on academic success has been studied across various disciplines. Mackewn et al. (2022) examined the relationship between students' metacognitive knowledge and regulation and their academic performance, finding that metacognitive knowledge and regulation were related to students' final grades and overall GPA, serving as a predictor for college success. This underscores the significance of metacognitive knowledge in academic achievement. While the literature provides evidence of the importance of metacognitive knowledge, it also reveals areas where further research is needed. For instance, Maryani et al. (2021) found that prospective primary school teachers exhibited low-medium range metacognitive skills, indicating the need for additional research to address this gap. Similarly, Jarrar (2022) reported poor use of metacognitive awareness of learning strategies among secondary school students, emphasizing the necessity for further investigation and improvement in this area. In conclusion, the research findings indicating low metacognitive knowledge among prospective science teachers are consistent with existing literature on the relationship between metacognitive awareness and academic success. The literature also highlights the need for further research to address gaps in metacognitive knowledge among teachers and students, emphasizing the importance of enhancing metacognitive awareness to improve academic outcomes.

Data Normality

The normality of the data was assessed based on an examination of Skewness (SK) and Kurtosis (Ku) scores (Table 2). The sequential Sk and Ku values for students' cognitive learning outcomes (CO) were -0.467 and 0.208, respectively, while for practical learning outcomes (SK), the values were 0.176 and -0.636. The sequential Sk and Ku values for students' metacognitive knowledge were -0.361 and 0.566 for DK, -0.088 and -1.028 for PK, and 0.213 and -0.404 for CK. These values fall within the category of a normal distribution (±2 to ±7) (Byrne, 2010). Furthermore, the absolute z-values (Z = SK or KU/error of SK or KU) sequentially for CO were -2.7633 and 0.6172; SK was 1.0414 and -1.8872. Meanwhile, for the components of metacognitive knowledge, DK values were -2.1360 and 1.6795; PK was -0.5207 and -3.0504; and CK was 1.2603 and -1.1988. These values can be considered relatively normal for samples with a moderate size (50 < n < 300) (Kim, 2013).

Table 2. Data normality

	MK			LO	
	DK	**PK**	**CK**	**CO**	**SK**
Skewness	-.361	-.088	.213	-.467	.176

	MK			LO	
	DK	PK	CK	CO	SK
Z = SK/error of SK	-2.1360	-0.5207	1.2603	-2.7633	1.0414
Kurtosis	.566	-1.028	-.404	.208	-.636
Z = KU/error of KU	1.6795	-3.0504	-1.1988	0.6172	-1.8872

Gender Different

The finding that prospective science teachers' metacognitive knowledge significantly differs between males and females (Table 3), with male prospective science teachers demonstrating better declarative (mean: 59.247; $p < 0.05$) and procedural knowledge (mean: 64.482; $p < 0.05$) indicators, suggests a gender disparity in metacognitive awareness within this cohort. This finding implies that male prospective science teachers may possess a more comprehensive understanding of their cognitive processes and strategies for learning compared to their female counterparts. The implications of this gender difference in metacognitive knowledge are multifaceted. Firstly, it underscores the importance of considering gender-specific approaches in teacher training programs to address the observed gap in metacognitive knowledge. Tailoring interventions and instructional strategies to enhance metacognitive awareness, particularly for female prospective science teachers, can help bridge this gap and support their professional development. Moreover, the gender disparity in metacognitive knowledge among prospective science teachers may have implications for classroom practices and student outcomes.

Teachers' metacognitive awareness has been linked to their instructional effectiveness and the promotion of students' metacognitive development. Therefore, addressing gender differences in metacognitive knowledge is essential for ensuring equitable and effective teaching practices that benefit all students. Additionally, this finding highlights the need for further research to explore the underlying factors contributing to the observed gender differences in metacognitive knowledge among prospective science teachers. Understanding the factors that influence metacognitive awareness, such as educational experiences, societal expectations, and individual learning styles, can provide valuable insights for developing targeted interventions to support the professional growth of all prospective science teachers. The gender disparity in metacognitive knowledge among prospective science teachers underscores the importance of addressing this gap through targeted interventions, gender-specific approaches in teacher training, and further research to understand the underlying factors contributing to this difference.

Table 3. PTS' metacognitive knowledge overview based on gender disparity

Indicator	Gender	N	Mean	SD	f	t	p
DK	male	93	59.247	6.952	2.462	4.766	.000
	female	113	53.849	8.914			
PK	female	93	40.457	12.506	7.476	-17.466	.000
	male	113	64.482	6.879			
CK	female	93	43.279	6.011	0.481	1.103	.271
	male	113	42.389	5.554			
CO	female	93	43.817	6.141	0.001	0.679	.497
	male	113	43.230	6.193			
SK	female	93	42.325	5.116	0.267	0.317	751
	male	113	42.101	4.952			

Comparing and discussing the finding that prospective science teachers' metacognitive knowledge significantly differs between males and females with relevant research can provide valuable insights into the implications of this gender disparity. The comparison can shed light on the potential factors contributing to these differences and their impact on teacher training, instructional practices, and student outcomes. One relevant study by Duman and Semerci (2019) investigated the effect of metacognition-based instructional practices on the metacognitive awareness of prospective teachers. The research results indicated significant differences in metacognitive awareness scores at some sub-dimensions in favor of the experimental group. This finding aligns with the gender differences observed in the metacognitive knowledge of prospective science teachers, suggesting that instructional interventions may influence metacognitive awareness differently based on gender.

Additionally, the study by Asy'ari and Rosa (2022) examined prospective teachers' metacognitive awareness in remote learning, viewed from cognitive style and gender. The findings indicated that based on gender differences, prospective science teachers' metacognitive awareness was not significantly different, while based on cognitive style, metacognitive awareness was significantly different on indicators of procedural knowledge and conditional knowledge. This study provides further context for understanding the gender differences in metacognitive awareness and its relationship with cognitive style, highlighting the complexity of factors influencing metacognitive knowledge among prospective teachers. Furthermore, the study by Sahoo et al. (2021) explored the metacognitive awareness of teaching and teaching competence among secondary prospective teachers. The findings revealed that the mean scores of male teachers were significantly better than female teachers when metacognitive awareness was compared with teaching and teaching competence. This study's results align with the gender differences observed in metacognitive knowledge among prospective science teachers, emphasizing the potential impact of gender on metacognitive awareness and teaching competence. In summary, comparing the findings with relevant research highlights the multifaceted nature of gender differences in metacognitive knowledge among prospective science teachers. The comparison underscores the need to consider instructional interventions, cognitive styles, and teaching competence in addressing gender disparities in metacognitive awareness. Understanding these differences is essential for developing inclusive teacher training programs and instructional practices that support equitable metacognitive development and teaching effectiveness.

Metacognitive Knowledge and Academic Success Correlation

The Table 4 shows that prospective science teachers' declarative knowledge positively correlates with procedural knowledge, procedural knowledge correlates with declarative and conditional knowledge, and conditional knowledge positively correlates with procedural knowledge and cognitive outcome suggests several important implications for the development of metacognitive knowledge among prospective science teachers. The positive correlation between declarative and procedural knowledge indicates that a strong understanding of factual information (declarative knowledge) is associated with a robust grasp of strategies and processes for learning and problem-solving (procedural knowledge). This suggests that prospective science teachers who possess a solid foundation of factual knowledge are more likely to effectively apply cognitive strategies and methods in their teaching practices and instructional approaches.

Furthermore, the correlation between procedural knowledge and declarative and conditional knowledge underscores the interconnected nature of metacognitive awareness. Prospective science teachers who demonstrate proficiency in procedural knowledge are likely to exhibit a comprehensive understanding of factual information (declarative knowledge) and the ability to adapt their cognitive strategies based on varying conditions and contexts (conditional knowledge). This suggests that a well-rounded metacognitive skill set, encompassing both procedural and declarative knowledge, is essential for effective teaching and learning practices. Moreover, the positive correlation between conditional knowledge and procedural knowledge and cognitive outcome highlights the significance of adaptive metacognitive strategies in influencing cognitive outcomes.

Prospective science teachers who possess a strong understanding of how to adjust their cognitive strategies based on different conditions and contexts are more likely to achieve positive cognitive outcomes in their teaching practices. This emphasizes the importance of fostering adaptive metacognitive skills among prospective science teachers to enhance their effectiveness in facilitating student learning and academic achievement. In summary, the identified correlations among declarative, procedural, and conditional knowledge among prospective science teachers underscore the interconnected nature of metacognitive awareness and its potential impact on teaching practices and cognitive outcomes. These findings emphasize the importance of developing a comprehensive understanding of metacognitive knowledge to support effective teaching and learning practices in science education.

Table 4. Metacognitive knowledge correlation

Indicator	N	r-table	Pearson Correlation	p	Annotation
DK	206	.1367	.285	.000	206^{PK}
PK	206		.285; .160	.000; .021	206^{DKCK}
CK	206		.160; .321	.021; .000	206^{PKCO}
CO	206		.321	.000	206^{CK}

The latest studies that explore the correlations between declarative, procedural, and conditional knowledge among prospective science teachers are still rare. The current study findings contribute a significant insight to the literature on metacognitive knowledge. On the other hands, the study by Allo et al. (2019) emphasizes the importance of metacognitive knowledge, including declarative, procedural, and conditional knowledge, in the development of an efficient learning design. This aligns with the current research findings, highlighting the interconnected nature of these metacognitive knowledge components and their potential impact on instructional practices and learning outcomes. Furthermore, the study by explored procedural learning in the context of Parkinson's disease and cerebellar degeneration, emphasizing the translation of procedural knowledge into declarative knowledge through visual input (Pascual-Leone et al., 1993). This finding resonates with the research, indicating the positive correlation between declarative and procedural knowledge among prospective science teachers, underscoring the significance of these interconnected metacognitive components.

Additionally, the study by Hallett et al. (2010) examined individual differences in conceptual and procedural knowledge when learning fractions, highlighting the contradictory conclusions drawn from previous research on children's understanding of fractions. This study provides context for understanding the complexity of conceptual and procedural knowledge, shedding light on the multifaceted nature of metacognitive awareness among learners, including prospective science teachers. Moreover, the study by Schneider et al. (2011) investigated the relations among conceptual knowledge, procedural knowledge, and procedural flexibility, emphasizing the stable bidirectional relations between these components. This finding aligns with the current research, indicating the positive correlations between declarative, procedural, and conditional knowledge among prospective science teachers, underscoring the interconnected nature of metacognitive awareness.

Future Direction

Further investigation to deepen understanding and address constraints in the current study could involve exploring the impact of metacognitive interventions and learning models on science learning, particularly in the context of science teacher education. The potential issues related to learning model development and intervention in science learning can be addressed through comprehensive research that considers the development of learning model that suitable and explicitly promote metacognitive knowledge and improving instructional practices in science education (Rahman et al., 2021; Saragih et al., 2018; Zorlu & Sezek, 2019). Additionally, further examining the metacognitive awareness and experiences of prospective primary and secondary school teachers, particularly in the context of research-based teaching and continuing education. This research could provide valuable insights into the metacognitive knowledge and pedagogical understanding of prospective teachers, contributing to the development of targeted interventions to enhance their metacognitive awareness and teaching competence (Francisco et al., 2021; Maryani et al., 2021; Sahoo et al., 2021).

Investigating the potential impact of metacognitive skills packages on achieving gender equity in science classrooms is also needed. This research could explore the effectiveness of metacognitive interventions in addressing gender disparities in science learning and promoting equitable academic achievement among students (Ozoji et al., 2022). In addition, the investigation on examining the metacognitive awareness of prospective science teachers in remote learning environments, considering cognitive styles and gender differences. This investigation could provide insights into the challenges and opportunities associated with remote learning and the development of metacognitive skills among prospective teachers (Asy’ari & Rosa, 2022). Moreover, the exploration of the perspective science teachers on the use of indigenous knowledge in promoting metacognitive awareness and instructional practices could shed light on the potential integration of indigenous knowledge and metacognitive strategies in science education, contributing to culturally responsive teaching practices (Mudau & Tawanda, 2022).

CONCLUSION

Based on the research findings, it is evident that prospective science teachers' metacognitive knowledge significantly differs between males and females, with male prospective science teachers demonstrating better declarative and procedural knowledge indicators. This gender disparity in metacognitive knowledge among prospective science teachers highlights the need for targeted interventions and support to enhance metacognitive awareness, particularly among female prospective science teachers, to ensure equitable professional development and pedagogical practices. Additionally, the positive correlations between declarative, procedural, and conditional knowledge underscore the interconnected nature of metacognitive awareness and its potential impact on teaching practices and cognitive outcomes. These findings emphasize the importance of developing a comprehensive understanding of metacognitive knowledge to support effective teaching and learning practices in science education.

RECOMMENDATION

Based on these findings, it is recommended that teacher training programs and professional development initiatives should consider incorporating interventions aimed at improving metacognition among prospective science teachers, with a specific focus on addressing gender disparities in metacognitive knowledge. Additionally, further investigation into the impact of learning models, metacognitive interventions, and the experiences of prospective science teachers could deepen understanding and address constraints in the current study. These research directions have the potential to inform the development of effective interventions, learning models, and instructional practices to enhance metacognitive skills and science learning outcomes in teacher education. Furthermore, exploring the integration of metacognitive skills and strategies into science learning devices and curriculum materials could provide valuable insights into the impact of integrating metacognitive components into these materials on enhancing concept mastery and cognitive outcomes among prospective science teachers. Overall, addressing gender disparities and promoting comprehensive metacognitive development among prospective science teachers is essential for fostering equitable professional development and enhancing instructional practices in science education.

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