ACTA DIDACTICA NAPOCENSIA
Volume 19, Number 1, 2026 – DOI: 10.24193/adn.19.1.4

FEATURES OF SCIENCE METACOGNITIVE AWARENESS IN PRESCHOOL AND PRIMARY SCHOOL TEACHER CANDIDATES. AN EXPLORATORY ANALYSIS

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Abstract: Metacognition has been extensively studied over the past decade and holds a key role in teaching and learning, being a point of interest for both researchers and practitioners. In the context of the intense research on metacognition in education, this study examines the features of metacognitive awareness in a specific population of interest: preschool and elementary school teacher candidates. Using a mixed-methods research design, participants filled out the Metacognitive Awareness Inventory, two open-ended questions, and a vignette-type task related to science content. Out of 125 third-year students invited to join the study, a total of 107 accepted to participate (85.6% response rate). Data were analyzed using SPSS and ATLAS.ti software for quantitative and qualitative data, respectively. Results revealed that while teacher candidates self-reported a high level of metacognitive awareness, qualitative data indicate they have slight metacognitive competencies. In addition, this study highlights specific features of metacognition that practitioners should consider when designing and developing training programs to foster metacognitive skills in prospective pre-school and primary school teachers. Based on these findings, we discuss the integration of continuous metacognitive training in initial and ongoing teacher instruction programs.

Key words: metacognition, mixed-methods design, prospective elementary teachers, science teaching and learning

1. Introduction

Scientific literacy has been the focus of research for an extended period, and its value and importance are widely acknowledged today (Holbrook & Rannikmae, 2009; Laugksch, 2000; Ogunkola, 2013; Yasar, 2022). Snow and Dibner (2016) argue that, considering the information society in which we live, scientific literacy must be redefined to account for its economic, personal, democratic, and cultural implications. Therefore, the concept has evolved from focusing on a single domain (science) to encompassing multiple fields that should be included in the definition of scientific literacy, such as science, technology, engineering, and mathematics (STEM; National Research Council, 2014). To become scientifically literate, individuals must first be effective learners who understand and apply scientific concepts and phenomena. One approach to achieving this is through metacognitive training. Studies show that the use of metacognition in teaching and learning positively influences science comprehension and academic performance (Seraphin et al., 2012; Xie et al., 2023). Wirzal and colleagues (2022) emphasize that metacognition fosters interest in science, enhances the comprehension of scientific concepts, and supports the application of scientific knowledge in real-world situations.

Received June 2025.

Cite as: Șuteu, L. & Ciascai, L. (2026). Features of Science Metacognitive Awareness in Preschool and Primary School Teacher Candidates. An Exploratory Analysis. *Acta Didactica Napocensia,* 19(1), 50-65. https://doi.org/10.24193/adn.19.1.4

2. Metacognition in educational context

2. 1. Theoretical perspectives on metacognition

Yore et al. (1998) argue that metacognitive learning includes self-appraisal and self-management of cognition, as well as the use of various strategies such as planning, knowledge activation, monitoring, assessment, and reflection. The use of metacognitive skills enables students to search for, select, and assess information, choose and evaluate learning strategies; and recognize their strengths and weaknesses related to learning and the cognitive processes involved (Flavell, 1976; Veenman et al., 2006; Yore et al., 1998). Although metacognition has been a focus of research for a long time, debate persists regarding how it can be clearly defined, measured, and distinguished from related concepts. Veenman et al. (2006) contend that there are too many terms associated with metacognition, which contributes to the concept's ambiguity and inconsistency. Nevertheless, Flavell's (1976) definition of metacognition remains influential in the literature. He emphasizes that metacognition involves the active monitoring and regulation of cognitive processes associated with learning. Flavell proposes a two-dimensional model consisting of metacognitive knowledge and metacognitive regulation. This model has been adopted by researchers such as Schraw et al. (2012), Schuster et al. (2020), and Jacobs and Paris (1987).

The first dimension, metacognitive knowledge, refers to knowledge about how one learns (declarative knowledge), knowledge about learning strategies (procedural knowledge), and knowledge about how and when to use specific learning strategies (conditional knowledge) (Schuster et al., 2020). Schraw and colleagues (2012) define declarative knowledge as the understanding that enables learners to identify the factors influencing their learning and to recognize their strengths and weaknesses related to learning and cognitive processes. In addition to declarative knowledge, learners must possess procedural knowledge, that is, knowledge about a wide variety of learning strategies, and conditional knowledge, which allows them to select appropriate strategies depending on the context.

Many researchers agree that the second dimension, metacognitive regulation, includes strategies that enable the regulation of the learning process (Brown, 1987; Frenkel, 2014; Hartman, 2001; Schraw & Moshman, 1995). Metacognitive control refers to the deliberate use of specific learning strategies (Hartman, 2001). If metacognitive knowledge is task-specific, as Schuster and colleagues highlighted (2020), metacognitive regulation involves general skills used to regulate and monitor cognition and motivation across different learning tasks. Brown (1987) identifies planning, monitoring, and evaluating as the strategic components of metacognition. Regardless of the labels used to define metacognitive regulation strategies, Frenkel (2014) concludes that nearly all models include three main components: planning, monitoring, and evaluating. To these three components, a fourth one, debugging, may be added. Debugging occurs between the monitoring and evaluation phases.

2. 2. Metacognition in prospective elementary teachers

The need to use metacognitive awareness to understand science-related content in greater depth has been demonstrated in numerous studies over time (Ciascai & Haiduc, 2014; Jahangard et al., 2016; Mai, 2015; Tsai et al., 2019; Wirzal et al., 2022). Furthermore, research indicates that teachers' metacognitive awareness is related to teaching practices that incorporate metacognition (Ozturk, 2018). However, it is not easy for students or teachers to become metacognitive learners, as articulating one's learning process or approach through verbalization can be difficult. When asked how students learn, teachers often relied on theories such as motivation, Piaget's developmental stages, multiple intelligences, and learning styles to describe students' learning processes (Collins, 2002). To develop awareness of how learning occurs, it is important that teachers become familiar with the concept of metacognition—both generally and specifically in science—and apply it in their own teaching and learning practices. However, Georghiades (2004) emphasizes both the importance of metacognition for in-depth learning and its absence from science education:

> "The notion of metacognition is unknown to the average science teacher. Those of them who happen to be familiar with the notion do not have the resources to facilitate implementation of metacognition in their teaching, or they do not have the authority to make such changes on

> curriculum and time allocation as to accommodate metacognition in their teaching. The current state of the literature on metacognition has already given signs of a theory–practice gap emerging, comprising extensive academic elaboration on the mechanisms of metacognitive thinking and rare attempts to bring this inside ordinary classrooms. If metacognition is to find its way into the science classroom this decision must be made by policy-making bodies, which will consequently facilitate ordinary teachers in their attempts to do so." (p. 16)

Both teacher candidates and practicing teachers must explicitly learn and teach metacognition. Research indicates that metacognitive awareness varies according to teachers' fields of study (Bars & Oral, 2016) and may also differ based on their professional status—prospective teachers versus practicing teachers (Metallidou, 2009). However, findings in this last area are inconclusive (Halamish, 2018). For instance, Michalsky (2012) conducted a study with preservice science teachers and found that teaching with self-regulated scaffolding enhances students' metacognitive skills in science. He concludes that, to increase preservice teachers' metacognitive skills, exposure to learner-centered, collaborative, and active learning environments is not sufficient. Instead, preservice teachers need explicit instruction in metacognition.

Another noteworthy study emphasizing the importance of explicitly teaching metacognition is by Halamish (2018). This research shows that neither preservice nor in-service teachers possess comprehensive metacognitive knowledge about the most effective learning strategies, and this knowledge does not improve with teaching experience. Therefore, to develop metacognitive skills to a level that can be effectively used in daily teaching, metacognition must be taught explicitly.

Explicit teaching of metacognition is a long-term approach, it must be implemented consistently and integrated into school programs for optimal results. This long-term perspective was highlighted in Fouche and Lamport's (2011) research. They argue that metacognitive strategies introduced in science classrooms are effective only if they are continuously applied and integrated into teaching practices, allowing both students and teachers to practice them regularly. Moreover, they emphasize that metacognitive strategies should be incorporated into the science curriculum to encourage students to use them consistently and to foster greater responsibility for their learning in science. Zohar (2012) contends that higher-order thinking skills, such as metacognition, should become a fundamental component of classroom instruction and be explicitly included in teachers' lesson plans. The importance of including metacognition in teachers' lesson plans was also highlighted by Randi (2004), who argues that both prospective and practicing teachers need to learn how to incorporate metacognition into their lesson planning. However, research regarding the effectiveness of metacognitive training programs for teacher candidates remains inconsistent. For example, Burcu and Semerci (2019) found that metacognitive training with preservice teachers significantly improved planning, awareness, regulation, and questioning dimensions of metacognition. It is important to note, however, that their study involved a very small sample size—only 44 participants (22 in the experimental group and 22 in the control group).

It is necessary to establish how to teach metacognition, considering different students and disciplines. However, this might be challenging if metacognitive learning and teaching are of low interest to teachers, making them almost invisible in their practice (Ben-David & Orion, 2013; Zohar, 2012). If metacognition is to become a priority for teachers, we first need to introduce it into teachers' educational and professional development training programs, as clearly emphasized by Zohar and Barzilai (2013).

2.3. Problem statement, objectives, and research questions

There is a need to explicitly teach metacognition to prospective teachers and to demonstrate how important this concept is in the learning process. To design effective programs that develop metacognition in preschool and primary school teacher candidates, it is first necessary to understand its characteristics within this specific group. Thus, this study aims to explore the perspectives of preschool and elementary teacher candidates on metacognitive awareness in learning science-related content. This study will provide a picture of how metacognitive awareness emerges among preschool and elementary school teacher candidates.

The methodological approach used is that of a mixed methods design, which allows us to obtain robust data and analysis on the topic of concern. Integrating both quantitative and qualitative methods into one study enables us to gain a detailed understanding of what metacognition means for preschool and primary school teacher candidates (Ivankova, Creswell, & Stick, 2006). Moreover, the mixed research design is the best choice because metacognition is a complex and nuanced concept explored within the complexity of educational contexts.

We used the parallel form of the mixed methods design, in which both qualitative and quantitative data were collected simultaneously (Mertens, 2010). Quantitative and qualitative data were integrated in all phases of the research: data collection, analysis, and interpretation. Following Creswell's (2009) recommendations, we first analyzed the qualitative data, which were then compared with descriptive quantitative data.

Building on this approach, we sought to answer the following questions:

(1) How do preschool and primary school teacher candidates define and understand metacognition?
(2) What metacognitive strategies are used by teacher candidates in learning science-related topics?
(3) What is the level of metacognitive awareness among prospective elementary teachers in science learning?

2. Methodology

2.1. Participants

Participants were 107 preschool and primary school teacher candidates in their final year of undergraduate studies. Most of the students were 22-year-old women from urban environments who were not financially independent (the majority received support from parents and relatives). The sample of participants was selected based on accessibility and financial criteria. Participation in the research was entirely voluntary, but those who accepted the study invitation received a qualification bonus in the Didactics of Geography and Natural Sciences course. The mean age of the participants was 25 years old.

2.2. Instruments

To identify how preschool and primary school teacher candidates define and understand metacognition, we addressed the following two open-ended questions:

(1) "What do you think metacognitive learning is?"
(2) "What strategies do you use when learning in science?"

After presenting these questions, we introduced a metacognitive vignette situation with clear tasks for the participants to solve. The content of this vignette is as follows:

> The teacher announces to the fourth-grade students that they will have to prepare a project in Natural Sciences. The students receive a sheet with the requirements and deadline. After a week, Mihai asks his friend Andrew how he is managing his homework, and Andrew realizes that he has completely forgotten about it. Because he had other homework and only two days left until the deadline for the Natural Sciences project, Andrew started working on it one day before the deadline. Since it was a more complex topic, he stayed up late at night and managed to finish it without making a sketch. He had ideas and knew what he wanted to write, but he did not know how to organize them. He managed to meet the number of paragraphs requested by the teacher but was unsure whether he included everything she asked for. In a hurry to finish the assignment, he did not have enough time to read what he wrote before submitting it.

After reading this short text, we asked participants to answer the following questions:

(1) Did Andrew understand the requirements of the project?
(2) Did he use specific strategies to help himself with the homework?

(3) Do you think Andrew should have done something differently?
(4) If you were Andrew, what would you do differently (assuming you received this assignment in college)?
(5) What difficulties do you think you would encounter?

The metacognitive awareness of teacher candidates in science was assessed through the Metacognitive Awareness Inventory (MAI), developed by Scraw and Dennison. The MAI is a fifty-two-item self-assessment scale measured on a 5-point Likert scale. The scale has two main dimensions. The first dimension, knowledge of cognition, comprises declarative knowledge, procedural knowledge, and conditional knowledge. The second dimension, regulation of cognition, includes planning, information management strategies, monitoring, debugging strategies, and evaluation of learning. Internal consistency was 0.88 for the first dimension and 0.88 for the second. The overall scale achieved an internal consistency coefficient of 0.93.

2.3. Data collection

Data were collected in the second semester of the 2022 academic year. Students voluntarily completed an online assessment package and received a qualification bonus in the Didactics of Geography and Natural Sciences course. The assessment procedure followed the recommendations in the literature regarding consent to participate, which means that we asked the students for their consent to be involved in the study. We delivered the assessment package online through the Teams educational platform, and participant responses were automatically recorded via an online Google Form. The responses were not anonymous, as participants filled in their names to receive the course bonus. However, they also had the option to leave the name field blank if they were not interested in the bonus. A total of 107 students completed the assessment package out of 123 enrolled in the course.

3. Findings

The demographic characteristics of the sample are illustrated in Table 1.

Table 1. *Demographic characteristics of the sample*

Demographic characteristic		Frequency	Percent
Area of origin	Urban	56	52.3
	Rural	51	47.7
Gender	Male	1	0.9
	Female	106	99.1

The demographic data of the sample (Table 1) illustrate a general characteristic of the educational system in Romania: the fact that most Romanian preschool and primary school teachers are females. Thus, this study included only one male participant, while 99.1% were females. Of these, half are from urban areas, while the rest come from rural areas. The distribution of participants by the area of origin shows almost equal percentages between prospective pre-school and elementary teachers from urban areas (52.3%) and those from rural ones (47.7%).

To identify the specific characteristics related to metacognition in prospective pre-school and elementary teachers, we employed a qualitative research approach. This approach enabled us to collect data that captured participants' perspectives and views regarding the use of metacognition in learning science-related content. In Figures 1 and 2, we summarize the data analysis for the two open-ended questions used to explore how prospective elementary teachers define and characterize metacognition. The images below, generated using Atlas.ti software, illustrate the main words participants used to describe metacognition, and the primary codes derived from these keywords.

Figure 1. *Word Cloud: The definition of metacognition*

Figure 1 presents a word cloud illustrating the central terms used by third-year students—prospective preschool and primary school teachers—to define metacognition. The larger a word appears in the cloud, the more frequently it was mentioned by participants. These teacher candidates commonly associate metacognition with concepts such as learning, knowledge, thinking, methods, processes, and strategies.

Figure 2 organizes these key terms into representative categories or codes, providing a clearer understanding of how participants perceive and define metacognition. This figure serves as a basis for formulating a definition of metacognition and identifying its principal dimensions from the perspective of the teacher candidates.

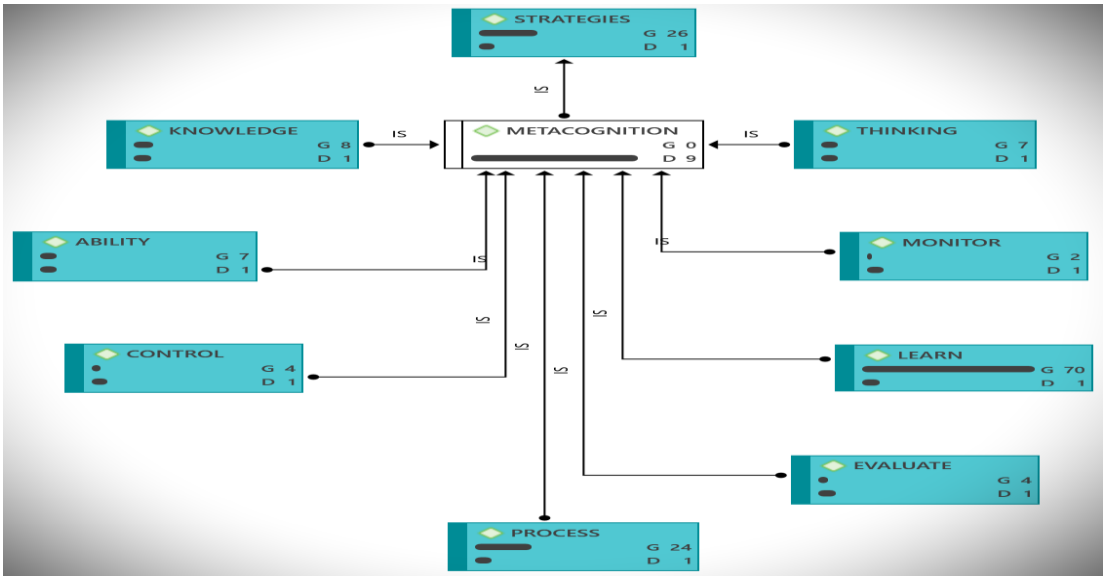

Figure 2. *Metacognition definition codes*

The main codes generated using Atlas.ti software include knowledge, process, evaluation, learning, strategies, thinking, monitor, and ability. These codes represent the primary concepts that third-year students associate with the definition of metacognition.

As shown in Figure 2, students commonly link metacognition to domains such as learning and knowledge (e.g., process, thinking), as well as to abilities and strategies (e.g., evaluation, control, monitor). In this context, the letter "G" next to each code denotes Groundedness—the number of quotations linked to a given code. Among these, *learning* is the most frequently cited code, followed by strategies and processes.

To gain a clearer understanding of third-year students' perspectives on metacognition, we asked them to provide examples of the strategies they use when learning science-related content. This question corresponds to the second open-ended item in the study: "What metacognitive strategies are used by teacher candidates in learning science-related topics?" Participants' responses are illustrated in Figures 3 and 4.

information
important
material
sketches
make
read
use
learning
organization
time
write
underline
understand
emphasize
assimilated
highlight
visual
selecting
making
organizing
colors
self
new
times
taking
study
underlining
separately
thinking
water
solving
paragraph
contents
selection
try
text
re
set
studying
repetition
like
notes
schemes
memorization
repeat
methods
diagrams
summary
schedule
note
management
markers
texts
small
motivation
focus
manage
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remember
previously
difficulty
optimization
regulation
mechanically
managing
flashcards
examples
representations
repeating
creating
proceed
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meaning
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planning
loud
logically
lecture
known
example
keywords
know
practice
techniques
playing
intuition
exercises
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main
drawings
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gradually
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images
formulate
project
several
giving
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go
connect
front
sit
many
relevant
colored
cards
focusing
original
organize
association
concentration
notions
lessons
assessment
take
friend
often
give
sheets
facilitate
limit
different
synthesizing
extract
already
ones
easily
essential
finish
connections
essays
memory
skills
words
subject
deduce
entirety
walk
reading
life
compact
practical
entire
let
clusters
drafting
just
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graphic
block
highlighting
distracts
key
acquired
select
depends
formation
crayons
concept
definition
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documentation
copying
helpful
process
appropriate
associating
anything
understanding
create
environment
deduction
easier
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personalized
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assimilation
representative
monitoring
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hard
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color
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establishing
days
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tables
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abilities
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water
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thinking
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organizers
draw
retain
outline
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difficulty
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methods
diagrams
repeat
memorization
summary
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note
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reading
life
compact
entire
drafting
clusters

Table 2. *Students' metacognitive strengths and weaknesses*

	Percent	MAI construct
Students' metacognitive strengths		
Take proper time	48	
Summarize	34	Information management strategies
Make connections	21	
Use visual aids (schemes, diagrams, and sketches)	67	
Take notes	56	
Use strategies for remembering information	26	Declarative knowledge
Understand	21	Comprehension monitoring
Remember	43	
Plan for studying	38	Planning
Select proper learning methods and strategies	10	Procedural knowledge
Summarize	34	Evaluation
Students' metacognitive weaknesses		
Memorize, remember the lesson/information	43	Comprehension monitoring
Don't ask for help	65	Debugging
Do not mention their strengths and weaknesses	56	Declarative knowledge
Do not choose the best learning strategy depending on the learning context	63	Conditional knowledge

Most teacher candidates demonstrate familiarity with metacognitive strategies related to information management, such as summarizing, making connections, using visual aids (e.g., schemes, diagrams, and sketches), and taking notes. However, a significant proportion of prospective preschool and primary school teachers reported behaviours indicating limited metacognitive awareness: 43% stated that they frequently rely on memorization, 65% do not seek help when needed, 56% are unaware of their strengths and weaknesses, and 63% do not adapt their learning strategies to different contexts.

The data presented in Table 2 suggest that teacher candidates have limited knowledge of declarative and conditional metacognitive knowledge, as well as of comprehension monitoring and debugging strategies.

In addition to the two open-ended questions discussed above, a metacognitive vignette was introduced, and participants were asked to analyse it by responding to five questions. The first three were dichotomous (Yes/No), while the remaining two were open-ended. Table 3 presents the percentage distribution of responses to the first three dichotomous questions.

Table 3. *Dichotomous questions answers*

Questions	Yes (%)	No (%)
1. Did Andrew understand the requirements of the project?	81.3	18.7
2. Did he use specific strategies to help himself with the homework?	15.9	84.1
3. Do you think Andrew should have done something different?	99.10	0.9

An analysis of the percentages presented in Table 3 suggests that teacher candidates believe Andrew understood the requirements of his task (81.3%) but failed to apply appropriate learning strategies to complete it successfully. Their conclusions regarding Andrew's comprehension are somewhat surprising, given the lack of sufficient information to definitively assess his understanding of the task.

Most teacher candidates (84.1%) indicated that Andrew did not employ specific strategies to address the task, and almost all of them (99.1%) considered that he should have approached it differently. To further explore the strategies Andrew might have used, two open-ended questions were posed to participants. One question sought to identify the alternative strategies teacher candidates would have employed to complete the task, and the analysis of their answers is represented in Figure 5.

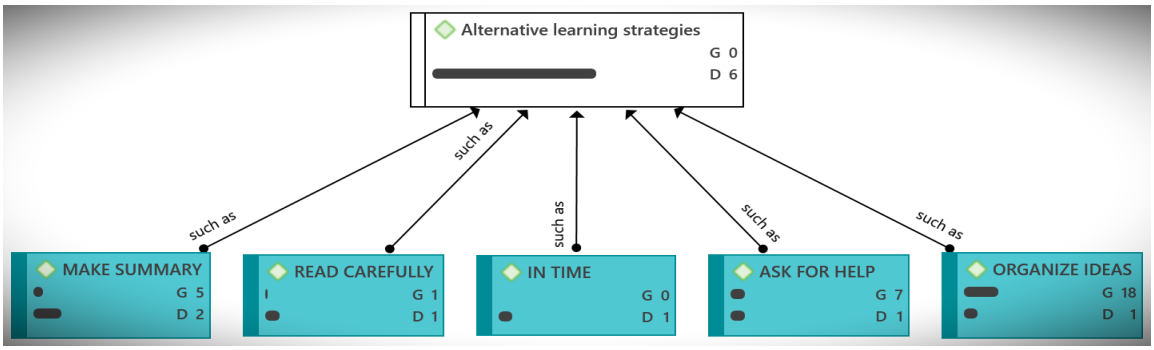
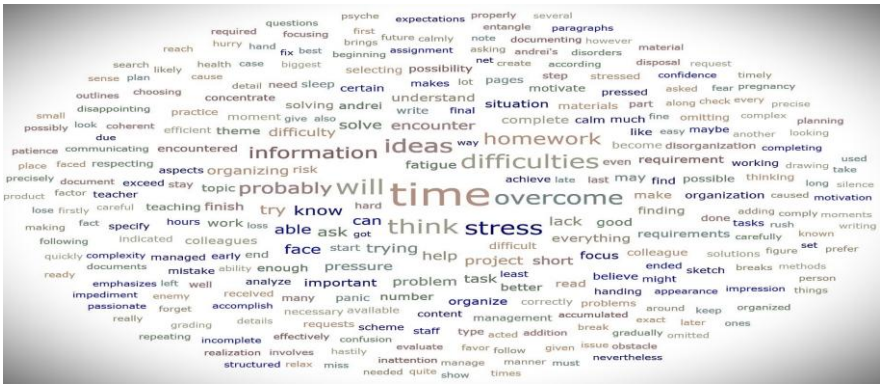


Figure 5. *Alternative problem-solving strategies*

The alternative learning strategies mentioned by third-year students primarily focus on organizing science-related information. Prospective teachers reported that they would carefully read the task requirements, summarize the content, organize their ideas, and seek help if needed. However, they did not specify how they would structure their ideas or what strategies they would use to read the text attentively. Participants also identified potential difficulties they might encounter while completing the task. These perceived challenges are represented in the word cloud shown in Figure 6.


time
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hastily
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timely
stressed
step
pages
makes
lot
certain
need
sleep
detail
outlines
choosing
disappointing
practice
moment
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andrei
write
final
way
fatigue
even
requirement
aspects
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teacher
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Table 4. *Descriptive statistics of MAI scales*

	N	Min	Max	Mean	Std. Error	Std. Deviation	Variance
Declarative knowledge	107	22.00	40.00	31.60	.37	3.78	14.32
Procedural knowledge	107	11.00	20.00	15.93	.23	2.33	5.44
Conditional knowledge	107	14.00	25.00	20.70	.25	2.54	6.44
Planning	107	19.00	35.00	28.62	.34	3.55	12.63
Comprehension monitoring	107	18.00	35.00	26.59	.36	3.76	14.13
Information management strategies	107	30.00	50.00	41.41	.43	4.44	19.70
Debugging strategies	107	15.00	25.00	20.83	.27	2.76	7.61
Evaluation	107	15.00	30.00	23.13	.31	3.25	10.55

Responses to the Metacognitive Awareness Inventory (MAI) items ranged from 1 (strongly disagree) to 5 (strongly agree), with all items positively worded; thus, reverse scoring was not required. Analysis of the data presented in Table 4 indicates that prospective teachers perceive themselves as possessing an above-average level of metacognitive awareness in science. This suggests that they consider themselves to have elevated levels of both metacognitive knowledge and metacognitive regulation skills.

To further illustrate this trend, we examined participants' answers to each dimension of metacognitive awareness in science learning. Table 5 summarizes the answers related to the metacognitive knowledge dimension.

Table 5. *Metacognitive Knowledge Dimension (agreement & strong agreement answers)*

Items	Agreement percentage
Declarative knowledge	
I understand my intellectual strengths and weaknesses.	84.1
I know what kind of information is most important to learn.	72.9
I am good at organizing information.	72.9
I know what the teacher expects me to learn.	93.4
I am good at remembering information.	42.9
I have control over how well I learn.	56.1
I am a good judge of how well I understand something.	73.8
I learn more when I am interested in the topic.	95.4
Procedural knowledge	
I try to use strategies that have worked in the past.	86
I have a specific purpose for each strategy I use.	86.9
I am aware of what strategies I use when I study.	77.6
I find myself using helpful learning strategies automatically.	58
Conditional knowledge	
I learn best when I know something about the topic.	59.8
I use different learning strategies depending on the situation.	60.8
I can motivate myself to learn when I need to.	81.3
I use my intellectual strengths to compensate for my weaknesses	87.8
I know when each strategy I use will be most effective.	57.9

Except for the item "I am good at remembering information" (Table 5), which received 42.9% agreement, all other items received agreement levels exceeding 55%. This suggests that teacher candidates report above-average levels of declarative, procedural, and conditional metacognitive knowledge. They appear to know what to learn, recognize their strengths and weaknesses, apply previously effective strategies, and select strategies based on specific purposes. Moreover, they report being able to motivate themselves when necessary and to use their cognitive strengths to compensate for areas of weakness. Participants also believe they can identify the most important information to learn and are effective at organizing information.

An analysis of the data on metacognitive regulation strategies reveals a pattern like that observed in teacher candidates' metacognitive knowledge. Descriptive data on metacognitive regulation are presented in the figures below, with agreement and strong agreement responses shown for each subscale of metacognitive regulation.

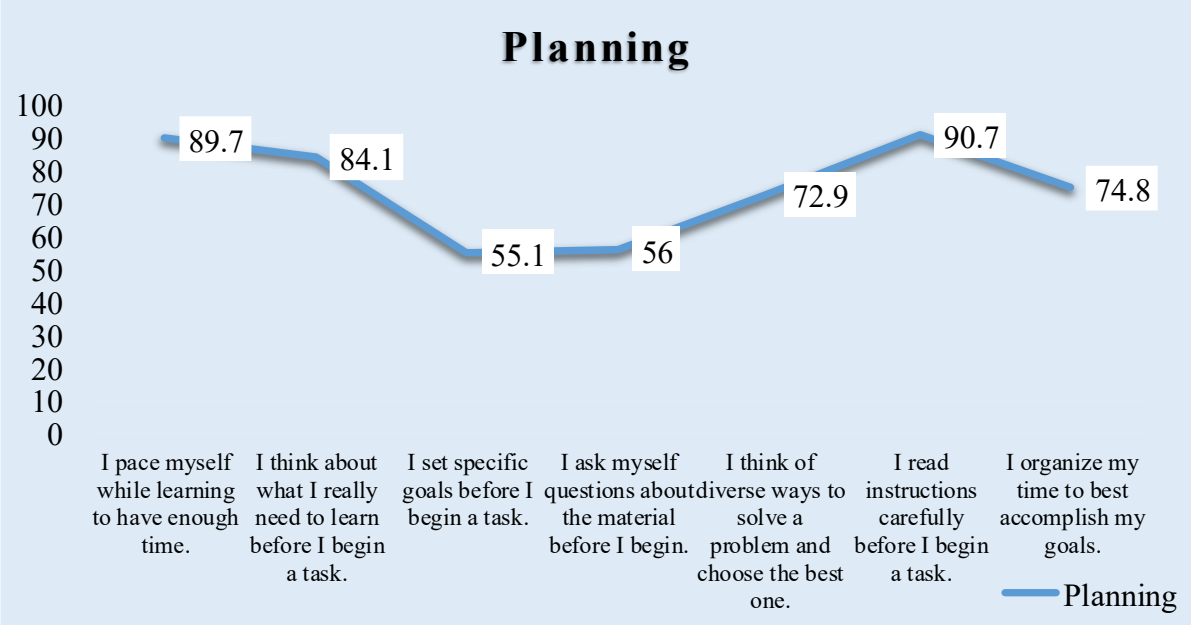

Figure 7. *Metacognitive Regulation - Planning*

Teacher candidates report a strong familiarity with specific metacognitive strategies related to planning their learning processes. As shown in Figure 7, levels of agreement with items measuring this dimension of metacognitive regulation are above average. Prospective teachers indicate that they engage in effective planning behaviors, such as carefully reading instructions before beginning a task, pacing themselves to ensure sufficient time for learning, considering learning objectives in advance, and organizing their time efficiently to achieve desired outcomes.

Information management strategies play a critical role in effective learning and are key predictors of academic success. Table 6 summarizes the primary strategies employed by teacher candidates when engaging with science-related content, highlighting how they organize, process, and retain information during their learning experiences.

Table 6. *Information management strategies (agreement & strong agreement answers)*

Items	Agreement percentage
Information management strategies	
I slow down when I encounter valuable information.	75.7
I consciously focus my attention on valuable information.	82.3
I focus on the meaning and significance of the latest information.	80.4
I create my examples to make information more meaningful.	88.8
I draw pictures or diagrams to help me understand while learning.	71.1
I try to translate the latest information into my own words.	86
I use the organizational structure of the text to help me learn	87.9
I ask myself if what I am reading is related to what I already know.	85.9
I try to break studying down into smaller steps.	78.5
I focus on the overall meaning rather than specifics.	57

Overall, the data presented in Table 6 reflect a high level of engagement with effective learning techniques, though some areas could be strengthened. The most used strategies are creating personal examples (88.8%), using text structure (87.9%), rephrasing in one's own words (86%), and making

connections with prior knowledge (85.9%). These patterns are mirrored in their use of metacognitive regulation strategies as well (see Table 7), suggesting a consistent and strategic approach to learning. (Table 8).

Table 7. *Metacognitive Regulation – Comprehension monitoring*

Items	Agreement percentage
Comprehension monitoring	
I ask myself periodically if I am meeting my goals.	65.4
I consider various alternatives to a problem before I answer.	64.6
I ask myself if I have considered all options when solving a problem.	84.1
I periodically review to help me understand important relationships.	38.3
I find myself analyzing the usefulness of strategies while I study.	53.3
I find myself pausing regularly to check my comprehension.	76.4
I ask myself questions about how well I am doing while learning something new.	74.8

While many learners demonstrate strength in real-time comprehension monitoring and reflective thinking, fewer consistently engage in evaluating the effectiveness of their strategies or analyzing relationships between concepts. These practices are critical for adapting learning approaches and developing deep conceptual understanding. This suggests a need for greater emphasis on post-learning reflection and strategic review in educational settings.

If comprehension monitoring is inadequate, learners are unlikely to employ effective debugging strategies when they encounter difficulties. Table 8 presents learner agreement percentages for debugging strategies, the techniques used to identify and correct misunderstandings during the learning process.

Table 8. *Metacognitive Regulation - Debugging*

Subscale	Agreement percentage
Debugging strategies	
I ask others for help when I do not understand something.	71.1
I change strategies when I fail to understand.	73
I re-evaluate my assumptions when I get confused.	80.4
I stop and go back over the latest information that is not clear.	86
I stop and reread when I get confused.	88.8

High percentages with statements like "*I stop and reread when I get confused"* (88.8%), *I stop and go back over unclear information"* (86%), and "*I re-evaluate my assumptions when I get confused*" (80.4%) indicate that most learners are proactively correcting comprehension issues, a core part of effective metacognitive regulation. Learners show strong engagement with self-corrective strategies**,** particularly in rereading, reviewing unclear content, and reassessing assumptions. These behaviors are essential for overcoming learning obstacles. While strategy shifting and help-seeking are present, encouraging more openness to collaboration and diverse strategies could enhance overall learning effectiveness.

The final key category of metacognitive regulation strategies involves the evaluation of learning. Table 9 presents the strategies participants use to assess their learning processes and outcomes.

Table 9. *Metacognitive Regulation - Evaluation*

Subscale	Agreement percentage
Evaluation	
I know how well I did once I finished a test.	86.9
I ask myself if there was an easier way to do things after I finish a task.	43
I summarize what I have learned after I finish.	67.2
I ask myself how well I accomplish my goals once I finish.	72.9
I ask myself if I have considered all the options after I solve a problem.	64.4
I ask myself if I learned as much as I could have once, when I finish a task.	63.5

Table 9 provides self-reported evaluation strategies after completing a learning session, reflecting how they assess their performance and learning outcomes. These strategies help individuals reflect on their achievements and identify areas for improvement. Learners show strong post-learning reflection, especially in evaluating their test performance and measuring goal accomplishment. High self-awareness (86.9%) reflects good confidence in knowing how well they did. The tendency to summarize learned material (67.2%) also suggests that learners are consolidating their knowledge.

However, there's room for improvement in strategies that promote continuous learning improvement. The lower percentages for considering easier ways to complete tasks (43%) and evaluating full learning potential (63.5%) indicate that learners might not consistently seek opportunities for refining their learning approaches or ensuring they've optimized their potential.

4. Discussion and conclusions

Research indicates that it is no longer sufficient to develop students' subject matter knowledge and pedagogical content knowledge in science alone (Michalsky, 2012). In today's complex learning environments, students must also acquire metacognitive skills that enable them to plan, monitor, and evaluate their learning processes. Teachers play a critical role in fostering these skills. This means they must be proficient not only in metacognition but also in effectively modeling and teaching metacognitive strategies. This shift highlights the need for teacher education programs to include a strong focus on metacognitive training—an area that policymakers must urgently address.

Educational policies should explicitly support the development of teachers' metacognitive competencies. This includes advocating for the inclusion of structured courses and workshops that introduce the concept of metacognitive awareness and metacognitive competencies, exploring their role in teaching and learning, and offer practical guidance on how to embed metacognitive strategies into instructional design. Such training should go beyond theoretical understanding. It should offer hands-on experiences where teachers reflect on their thinking, examine real classroom scenarios, and collaboratively design metacognitive interventions for their students.

However, before implementing these professional development initiatives, it is essential to understand the specific characteristics and needs of teachers as adult learners. Teachers bring diverse experiences, beliefs, and levels of metacognitive awareness to the learning process, which necessitates a differentiated approach to training. Programs should be tailored to address varying levels of prior knowledge and provide opportunities for self-assessment, peer collaboration, and continuous feedback. Moreover, sustained support through mentoring, coaching, and reflective practice is vital to ensure the long-term integration of metacognitive principles into teaching routines.

Ultimately, preparing teachers to be metacognitively skilled educators is a critical step toward fostering more independent, self-regulated learners in science education. By embedding metacognitive training in teacher preparation and ongoing professional development, educational systems can ensure that both teachers and students are equipped to navigate the cognitive demands of modern science learning.

This study reveals a notable discrepancy between the perceived metacognitive awareness of prospective elementary teachers and their actual level of metacognitive awareness. While participants report high levels of metacognitive awareness, as measured by the Metacognitive Awareness Inventory (MAI), their descriptions of learning practices primarily reflect the use of cognitive strategies tied to information management, such as underlining, summarizing, sketching, and organizing content into schemes. These techniques, although valuable, largely reflect surface-level engagement with content rather than deeper, self-regulated learning processes.

Notably, participants seldom mentioned or demonstrated essential metacognitive strategies such as setting explicit learning goals, monitoring their comprehension, using debugging strategies to overcome difficulties, evaluating the complexity of learning tasks, or identifying and using their strengths to solve specific tasks. This indicates a superficial understanding of metacognition, where awareness does not necessarily translate into meaningful or consistent application. These finding echoes prior research by Ben-David and Orion (2013) and Georghiades (2004), who found that

metacognition remains largely invisible in science classrooms and that a gap persists between theoretical awareness and practical implementation among teachers.

The disconnect between self-perception and actual practice suggests that prospective teachers may conflate general learning efforts with metacognitive engagement, overestimating their ability to regulate their learning. This phenomenon could stem from a lack of explicit instruction and guided practice in metacognitive processes during teacher education. Moreover, the reliance on cognitive rather than metacognitive strategies may reflect the dominance of content-focused instructional approaches in science education, where procedural and factual knowledge often take precedence over reflective learning practices.

These findings have significant implications for teacher education programs. They underscore the urgent need to provide future educators not only with theoretical knowledge of metacognition but also with structured opportunities to develop, apply, and reflect on metacognitive strategies within authentic learning contexts. Embedding metacognitive instruction into science methods courses, incorporating reflective teaching assignments, and modeling metacognitive dialogue in teacher training can bridge the gap between awareness and practice.

Ultimately, supporting teacher candidates in becoming metacognitively skilled learners and practitioners is essential for fostering the same capabilities in their future students. As science education increasingly emphasizes inquiry, critical thinking, and problem-solving, teachers' ability to model and teach metacognitive strategies becomes a foundational component of effective instruction. Addressing this gap in teacher preparation is therefore critical to advancing both teacher quality and student learning outcomes in science.

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