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PHD THESIS

Metacognitive strategies that enhance science metacognitive awareness and decrease science-related misconceptions in teacher candidates

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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. Teachers are key actors in training students to use metacognition to learn science-related content and must have metacognitive skills themselves. Also, metacognition is related to how well one understands scientific concepts and to how many science misconceptions students have. Not only that metacognition is a key variable in understanding science content, but there is research showing its value and importance in generating conceptual change in science and reducing science-related misconceptions (Beeth, 1995; Gunstone & Mitchell, 1998; Wandersee et al., 1998). Considering all these, this study focuses on metacognitive awareness and science misconceptions in preschool and primary school teacher candidates. Specifically, the primarily goal of the study was to develop and test the effectiveness of a program focused on metacognitive, deep and strategic learning strategies on students' metacognitive awareness and science misconceptions. The second goal of the study is focused on testing the effectiveness of three types of texts on students' misconceptions in science: refutational texts, expository texts and textbook-based texts. To reach the first goal and identify specific characteristics of metacognition and science misconceptions in teacher candidates, several studies were conducted. This work has a strong theoretical basis which is described in the second chapter which addresses the main theories of metacognitive awareness and misconceptions of science and conceptual changes. After presenting the most important theoretical perspectives on metacognitive awareness and science misconceptions, five studies were conducted that led to the achievement of the main goal of this thesis. The current paper uses both qualitative and quantitative methodology, thus allowing in-depth data to be presented.

The first study is based on exploratory research and investigates the features of metacognitive awareness in prospective preschool and elementary school teachers. Using a mixed methods research design (concurrent/convergent design), participants filled out the Metacognitive Awareness Inventory, two open-ended questions, and a vignette-type task, related to science content. Results revealed that while teacher candidates self-reported a high level of metacognitive awareness, qualitative data show they have slight metacognitive knowledge. In addition, this study points up specific features of metacognition that practitioners should take into consideration when designing and developing training programs to foster metacognitive skills in prospective preschool and primary school teachers. Based on these findings, we bring into discussion the integration of the continuous metacognitive training in the initial and continuous teacher instruction programs.

In the second study we ran a regression analysis to test the predictive value of metacognitive awareness on science misconceptions. The study used a sample of 252 participants, of whom 107 were preschool and elementary school teacher candidates, while 145 were practicing teachers. The group of preschool and primary school teacher candidates was homogenous in terms

of age, education, and financial independence and were all students in their 3rd year of study at a well-known university in Romania. Their mean age was 22.44 years old and 51% come from rural areas while 56% from urban ones. For the group of practicing teachers, the mean age was 43.67 years, with an average teaching experience of 20.17 years. This study is adding its contribution to the first one and shows that metacognitive awareness is a significant predictor of science misconceptions. Specifically, higher metacognitive awareness skills predict lower levels of science misconceptions. Increasing students' metacognitive awareness would lead to a decrease in the level of misconceptions in science. Thus, a formative program that is focused on increasing students' metacognition in learning science should lead to low levels of misconceptions in science.

The third study analyzes the relationships between science misconceptions, deep learning strategies, strategic learning strategies and science misconceptions. We checked how these variables influence each other and how they could best be combined to have the greatest impact on the learning process. The study had a group of 211 prospective elementary teachers who completed a set of online self-rating scales, of whom 104 were enrolled in the full-time undergraduate program and 107 in the part-time undergraduate program. Data analysis indicates that deep and strategic learning strategies are significant predictors of metacognitive awareness which in turn has an impact on science misconceptions. Three models were tested in this study, using the AMOS statistical program. The best model brings significant contributions to the literature and shows that metacognitive awareness is a mediation variable between deep and strategic learning and science misconceptions. Therefore, the program developed to increase metacognitive awareness and decrease science misconceptions had been named "the Metacognitive-Deep-Strategic (MDS) instructional approach". The MDS approach promotes deep, strategic and metacognitive learning skills to increase students' metacognitive awareness and decrease their misconceptions in science. The developed program was tested in the fourth study of this paper.

The MDS program was implemented with 89 students. From these, 56 were included in the experimental group and 33 in the control one. The course took place over a period of 12 weeks, with pre-test and post-test assessment sessions. The science topics covered were photosynthesis, solar system and properties of matter. To assess science misconceptions related to the three topics, we used fourteen true-false items. To reduce the probability of random answers, students were asked to explain their choice or argue why they think the statement was true or false. Those who chose the right answer by chance were not given the score for the correct answer if their explanation was not right. The results of this study are quite promising, showing that the MDS instructional approach, which is easy to implement in ones' daily teaching, have improved students' metacognitive awareness and reduce misconceptions related to photosynthesis, solar system and properties of matter. The intervention guide has five main steps that are easy to understand and apply: (1) establish the task needed to be solved; (2) identify the knowledge, skills and resources needed to solve the task; (3) choose the most appropriate learning strategies you can use; (4) apply to chosen learning strategies and (5) evaluate the learning process. The effect size for metacognitive awareness was 0.554 and for science misconceptions we got a Cohen d coefficient of 1.705. The program reached its goal and increased students' metacognitive awareness in learning science and decrease their levels of science misconceptions.

Because using metacognition in teaching is considered time consuming by many teachers and because some teachers are not familiar with metacognition and know too little about how to introduce it in their teaching approach, in the last research we focused our attention on refutational science texts. Although there is much research showing that refutational texts are useful in decreasing science misconceptions and in generating conceptual change, in our last study we have done a comparative analysis of the impact of three types of texts on science misconceptions: refutational texts, expository texts and textbook-based texts. To our knowledge, this is the first study to test the effect of all these three types of texts in teaching and learning science. This last study focused on different types of texts proved that refutational texts have a higher impact on science misconceptions compared to expository and textbook-based texts. The highest impact of refutational texts was on photosynthesis, followed by gravitation and solar system and last by the light and vision topic. The main conclusion of this last study is that refutational science texts should be introduced in all textbooks since these materials are widely used by both teachers and students (Guzzetti et al., 1992; Mikkila-Erdmann, 2011; Tippett, 2014). Including refutational texts in science textbook would have a huge impact on students' science-related misconceptions and certainly facilitates conceptual understanding in science and hopefully increase science literacy.

KEY WORDS:

- Metacognitive awareness in science
- Science misconceptions
- Prospective preschool and primary school teachers
- Conceptual change in science
- Metacognitive, deep and strategic learning
- Refutational texts
- Expository texts
- Texts based on science textbooks

CHAPTER 1. Introduction

What is important for school children today? To learn as much content as they can or to be able to analyze information and be effective and independent learners? Being an effective learner is of high importance today, if we consider the amount of information that one can find in various environments. Students need to be effective learners to be able to cope with the huge amount of information and be able to adapt to the changes required by the information society. However, how can a student become an effective learner? There are specific ways in which one can improve his/her learning and one way is through metacognition and self-regulated learning. Learning is a complex activity that involves the use of various strategies, including planning, knowledge activation, monitorization, assessment, and reflection. In the literature, these strategies have become known as metacognitive learning strategies. Metacognitive knowledge and skills in the educational context allow us to search, select and assess information, choose, and evaluate learning strategies, know our strengths and weaknesses related to how we learn best and how our cognitive processes work. For students to be effective learners, we need to have effective and knowledgeable teachers.

1.1 Problem statement, relevance, and motivation of the study

Research indicates that, in practice, few students focus on how they learn, and even fewer use their metacognition in learning. Rather, they focus on learning by heart and learning various algorithms for problem-solving. These help them to get good scores in science and different school disciplines, but not to understand and use the scientific information they acquire in school in their everyday lives. Besides these problems, research indicates (Frenkel, 2014) that most students who drop out school, who repeat the year or who face school difficulties have low metacognitive skills and knowledge, one of their main problems being that they do not know how to effectively learn.

There is few research concerned with the impact of the programs that increase Romanian students' and teachers' metacognitive knowledge and skills in learning (Mih & Mih, 2008; Mih, 2010). As far as metacognitive learning and teaching in science is concerned, the number of the studies conducted with Romanian populations are insignificant to have conclusive results to be used in the design and implementation of an effective course on metacognition. The present paper covers this gap and focuses on testing the impact of a metacognitive intervention program on both teacher candidates' metacognitive awareness and understanding of basic science concepts.

To summarize, we believe that increasing metacognition in teacher candidates would solve, at least to some extent, the issue of scientifically illiteracy in kindergarten and primary school teachers. This is essential in developing both metacognitive and conceptual understanding in science and overcoming the issue of scientific misconceptions and illiteracy.

Given the above information, this study has a twofold purpose. First, to check the impact of a course-based intervention on teacher candidates' metacognitive awareness and science misconceptions in learning science. Second, we aim to test the effect of the well-known refutational texts on science misconceptions (compared to expository and textbook-based texts) in the specific population of Romanian preschool and elementary school teacher candidates.

The study could bring the following essential contributions:

(1) Increasing the understanding of how metacognitive learning strategies can be used to improve metacognitive awareness in science learning and reduce science misconceptions, in the context of everyday science teaching and learning.

(2) Convince policy makers that introducing metacognition into science teaching is vital to developing a deep understanding of fewer science-related subjects at the expense of superficial covering of many scientific topics.

(3) Educational policymakers can propose the explicit introduction of metacognition into the science curriculum and establish how this could be effectively delivered or put into practice.

(4) Change the existing science textbooks to introduce refutational texts that explicitly debate and explain some of the most common science misconceptions encountered in teachers.

How would it look to integrate metacognition into college science classrooms? Although there is research in this direction worldwide, it is often quite difficult for practitioners to translate and apply the results of various research into their daily teaching practice. More than often, research articles published in various journals do not present all the activities implemented to increase students' metacognition so other researchers and practitioners can adapt and use them. One the other hand, one can find with a simple google search a very great number of activities that are supposed to increase students' metacognitive awareness in science. However, there is no evidence that shows that they are in fact effective, although they might seem interesting and be student-centered. There is a greater need for studies that provide both researchers and practitioners with detailed descriptions of these programs. This study aims to overcome this limitation by presenting in detail the activities used in the training program.

1.2 Aim, objectives, and research questions

This study aims to answer the following research question: „What impact do metacognitive teaching strategies have on science misconceptions and metacognitive awareness in preschool and elementary school teacher candidates?". We hypothesize that the formative program will improve prospective teachers' understanding of scientific concepts and their metacognitive awareness.

Aim:

(1) Developing and testing a metacognitive training program to increase prospective teachers' metacognitive awareness and decrease their level of science misconceptions.
(2) Testing the effectiveness of refutational science texts on science misconceptions.

Objectives:

(1) Identify peculiarities of metacognition in pre-school and elementary school teacher candidates.
(2) Determine the most common science misconceptions in prospective preschool and elementary school teachers and their relationship with metacognitive awareness.
(3) Investigate the predictive value of three types of deep-level and strategic-level learning strategies on science misconceptions and metacognitive awareness.
(4) Design and test a metacognitive-based educational program to increase students' science metacognitive awareness and reduce their science-related misconceptions (using a cvasi-experimental design).
(5) Identify the effect of refutational texts on science misconceptions.
To offer a rich description and understanding of how the variables of our interest appear in the specific population of teachers and how they interact with each other, several demographic variables are included in the statistical analysis, such as teachers' status (pre-service versus in-service teachers) and the type of students' enrollment program (full-time versus part-time or distance learning).

Research questions:

(1) What metacognitive knowledge and skills do prospective elementary teachers have?
(2) What are the most common science misconceptions held by prospective elementary teachers (compared to the in-service ones)?
(3) What is the relationship between metacognitive awareness and misconceptions in science?
(4) What are the most effective learning strategies that develop and increase prospective teachers' metacognitive awareness in science and decrease their level of science misconceptions?
(5) What is the effect of a metacognitive teaching strategies (MTS) program on pre-service teachers' science misconceptions and metacognitive awareness?
(6) What is the effect of refutational, expository and textbooks-based texts on science misconceptions?

1.2 General research hypothesis

H1. Metacognitive awareness is a significant predictor of science misconceptions.

H2: Different learning strategies predict different levels of science-related misconceptions in teacher candidates.

H3: Prospective teachers exposed to metacognitive teaching strategies (MTS) have lower levels of science misconceptions after they attend the program.

H4: Prospective teachers who participate in the metacognitive teaching strategies (MTS) program improve their level of metacognitive awareness in science learning.

H5: Refutational texts have a higher impact on reducing teacher candidates' level of science misconceptions compared to expository texts and textbook-based texts.

H6: Expository texts have higher impact in reducing teacher candidates' level of science misconceptions compared to textbook-based texts.

1.3 Statistical analysis considerations

Dealing with educational and psychological constructs is not an easy task because these constructs are difficult to be measured directly. Most of them are latent variables which can be operationalized and measured through specific observable behaviors. In addition, most of the assessment scales used to measure psychological and educational constructs are self-reported scales, which involve that participants are rating and reporting their behaviors, attitudes and intentions. A special attention has been given to the Likert self-reported scales. Although these scales are primarily ordinal, often they have been considered and treated as interval assessment scales and processed with parametric statistical analysis. Different scales that measure constructs such as anxiety, self-esteem, beliefs, intentions, attitudes, intentions, all with applications in education and didactics, have been measured with Likert self-reported scales. Various theoretical models have been developed using instruments based on Likert-scales, which constituted the basis of various educational intervention programs. There are researchers arguing that parametric analysis can be conducted with Likert type data, being robust enough to establish scientifically valid conclusions (Sullivan & Artino, 2013; Norman, 2010). Additionally, treating Likert scales with parametric statistics is considered appropriate if there is a composite or overall score that can be calculated for the scale. With all these considerations in mind, we treated the Likert scales used in this paper with parametric statistics, where the data approximates the Gaussian or normal distribution.

1.4 The structure of the paper

The first chapter of the thesis highlights the research problem, the aim, objectives, research questions and the hypothesis of the study. To understand the concepts and the theoretical perspectives underlying them, the second chapter is concerned with the definitions, theories, classifications, and dimensions of the main constructs of the research: science misconceptions and metacognitive awareness. In the following chapters we describe the fifth major studies conducted to achieve the aim of the thesis: testing the impact of a metacognitive teaching strategies program on teacher candidates on metacognitive awareness and science misconceptions. Each chapter follows the structure of a classic research article, having a theoretical basis section, followed by the methodology, analysis, and research findings sections. Even though the structure of the chapters follows the one of a scientific article, the theoretical section is more extensive than in the case of a typical scientific article.

CHAPTER 2. Science misconceptions, conceptual change and metacognition. Essential theoretical aspects

2.1 Theoretical perspectives on science misconceptions

Science misconceptions have been the focus of research since the late 1970. With the development of constructivism, researchers started to pay attention to concepts like preconceptions, misconceptions, alternative conceptions or learning mistakes and errors. The term misconception has been used interchangeably with preconceptions, false beliefs, alternative beliefs, naive conceptions, nonscientific beliefs, intuitive knowledge. However, there is research trying to clearly differentiate between all these concepts. Smith and colleagues (1993) stated that some of the main characteristics of misconceptions are their hard-to-change character and interference with conceptual understanding. Some researchers argue that misconceptions cannot be seen just as a simple misunderstanding of concepts (Gomez-Zwiep, 2008). Instead, they are interrelated with different other concepts and form a network of strongly related basis of knowledge (Southerland et al., 2001).

Science misconceptions can be defined as incorrect explanations of scientific concepts or explanations that contradict the existing scientific evidence. They are found in almost the same form across different cultures and are used to solve and explain both academic tasks and everyday experiences. Thus, they have an important role in both children and adults' lives. Given the numerous misconceptions in science, this subchapter aimed to offer a comprehensible definition of what the concept means and to highlight some of the most well-known theoretical approaches on this topic. Although this thesis addresses specific scientific misconceptions in the following chapters, we considered essential to mention some general considerations related to science misconceptions. Science misconceptions can be approached through a process known in the literature as conceptual change.

Conceptual change has an essential role in formal education because students come into the classroom with specific prior knowledge which can facilitate or impede learning. Students' prior knowledge can be reinforced or questioned and challenged in the classroom context. Conceptual change can be viewed as the changes that appear in the specific organization of one's own concepts.

To promote scientific literacy is crucial to address and correct misconceptions. Students need support from teachers to accurately understand scientific concepts. Diagnosing and working with students' misconceptions has been identified as a critical component of teaching effectiveness by many researchers (Seo et al., 2016). Thus, science educators are key pioneers in providing accurate, evidence-based information that also encourages the development of critical thinking. However, Stein and colleagues (2008) pointed out that in elementary school there is a high probability that students have teachers with many scientific misconceptions, despite the importance of the development of science concepts at this age. They also emphasized that teachers have a great influence on how students form their scientific understanding, especially in primary education.

Pintrich and colleagues (1993) argued that conceptual change involves more than cognitive factors and brought to researchers' attention the importance of affective factors such as students' motivation, engagement, interests and metacognition. They argue that cognition alone cannot explain the learning process as occurs in the classroom context in which emotions and relationships have a high influence on learning.

A variety of conceptual change theories developed to explain how misconceptions change to scientific conceptions. According to Goris and Dyrenfurth (2010), the most well-known theories of conceptual change are: conceptual change model (Posner et al.), alternative framework movement, Kuhn's theory, theory of gradual transformations of naive theory, theories of mental models and beliefs' revision, Piaget's theory of learning, Chi's ontological mis-categorization theory and DiSessa's perspective on misconceptions. Ronen (2017) lists several different methods that can be used for conceptual change such as predict – observe - explain (POE), dual situated learning model (DSLM), open learning environments (OLEs), and analogical models. Regardless of the strategies used to change students' misconceptions, most of them involve creating some sort of cognitive conflict. This means that the new information that a student receives must contradict his/her prior knowledge and must be difficult to integrate it into students' knowledge basis.

Pintrich and his colleagues (1993) integrated cognitive and metacognitive factors with motivational and classroom contextual factors and developed a hot conceptual change model in which volitional control, regulation, metacognitive and evaluation are indispensable. In fact, we believe that metacognition is necessary for conceptual change to occur regardless of the theoretical approach to which one adheres. Metacognition is needed even in the Posner and his colleagues' model because students must use their metacognitive skills to establish if they are dissatisfied with the current theoretical model and that the new one is plausible, fruitful and intelligible.

The inclusion of metacognition into conceptual change models has started with the four-dimensional model developed by Alsop and Watts (2000; 2002) (Kural & Kocakülah, 2016). Deep learning strategies, students' engagement, reflection and metacognitive thinking has also been included in the Cognitive Reconstruction of Knowledge Model (Dole & Sinatra, 1998). Theoretical models that explicitly include metacognition in the conceptual change models are those that focus on hot structures of cognition or on hot cognition.

Stein and colleagues (2008) emphasized that teachers have a great influence on how students form their scientific understanding, especially in primary education. To promote scientific literacy and identify and change students' misconceptions in science, teachers must first identify these misconceptions. Metacognitive engagement fosters conceptual understanding in science and thus prevents the development of science misconceptions and might help in changing them. Strategies based on metacognitive learning have been proven to be excellent approaches to change misconceptions in science (Wandersee et al., 1998). Authors like Beeth (1995), Gunstone and Mitchell (1998) and Wandersee and colleagues (1998) argue that for conceptual change to occur students must be metacognitive learners. Otherwise said, they must monitor their learning to identify misunderstandings and to use specific strategies to regulate and assess their learning. In the following subchapter we discuss the implications of metacognitive theories in learning knowledge comprehension in general and in science learning in particular.

2.2 Metacognition in the school context. Early and current conceptualizations.

The founder of the concept of metacognition is considered Flavell, who started to write about metamemory and other metaprocesses in the 1970s. Considering the roots of metacognition, the initial focus was on how children remember things and the strategies they used to become aware of their memories. Starting with concepts like memories and remembering, the term metamemory was developed. Metamemory refers to the awareness of a child about his/her own memory or, in simple words, as emphasized by Sullivan and Howe (1995), refers to beliefs about one's own memory. Flavell defined metamemory as the knowledge and awareness of a person about her own memory and developed and described a taxonomy of metamemory (1995). Besides his writings on metamemory, Flavell and other researchers (e.g., Brown) were analyzing the relationships between theory of mind and various aspects of cognitive development and metacognition, generating a strong wave of research on metacognition in the fields of developmental, cognitive, and educational psychology.

To understand metacognition, several theoretical models have been developed. A theoretical model of metacognition in education allows researchers to understand the nature and the components of this concept. The theoretical framework offers the researcher a baseline for the study, indicating what is the most appropriate research approach that the investigator should follow. As Adom, Hussein and Agyem (2018) have well emphasized, the theoretical framework has the following benefits for a researcher: frames the study in a specific philosophical, epistemological and methodological approach and guides the entire process of doing a research and writing a research paper: offer an appropriate definition of the problem and the concept under study, writing the literature review, choosing the appropriate methods to gather and analyze the data and to report the findings and integrate them into a conceptual framework. Being a topic of high interest for researchers, metacognition is the key concept of several theoretical models. To shortly present these theoretical models, we will use the Pena-Ayala and Cardenas' (2015) classification of the theoretical models of metacognition.

Pena-Ayala and Cardenas' (2015) have classified theoretical models of metacognition into two main categories: (1) classic models of metacognition and (2) declarative and procedural models of metacognition. The first category emphasizes the organization and relationships between components of metacognition and comprises: the Metacognitive Monitoring Model (Flavell), the Knowledge and Regulation of Cognition Model (Brown), the Hierarchical Model of Nelson and Narens, the Executive-Object Model and Shimamura's Model. The second category characterizes metacognition as a sequence of stages or processes which develop along with the maturation of individuals. This last category has the following nine models: Kuhn's model, the model of Alexander and Schwanenflugel, the Componential Model of Tobias and Everson, Schraw's framework, the Meta-strategic Knowledge Model of Zohar, Efklides's model (all these are categorized as descriptive models of metacognition), Veenmans' model, Zelazo conscious awareness model and Efklides's metacognitive and affective model of self-regulated learning (procedural models of metacognition).

According to Avargil and colleagues (2017), metacognitive awareness research in science involves two main categories of studies: theoretical studies and empirical ones. They divide the second category into three types of studies: (a) tools for assessing metacognition, (b) learning processes in metacognition and (c) metacognitive interventions in educational practices. Theoretical studies address topics related to defining metacognition, measuring it, or improving it in a school context. Empirical studies provide us with important information about how metacognition can be assessed in learning science-related content, what processes are involved in metacognitive learning in science, and how metacognition can be developed through specific educational practices. Studies focused on how metacognition is used in learning science-related content show that metacognition is correlated with deep understanding of scientific concepts and effective reading skills in science texts. Research focused on metacognition and science has evolved so much that specific instruments have been developed to measure metacognition in teaching and learning science. Thereby, specific instruments such as the Physics Metacognition Inventory (PMCI) and the Self-Efficacy Metacognition Learning Inventory-Science (SEMLI-S) developed. Besides these instruments developed to assess metacognition in the field of science, particular educational practices were developed for increasing metacognition for science-related content. The literature (Georghiades, 2004) mentions at least three well-known interventions of metacognition in science education: The Project to Enhance Effective Learning in Australia (PEEL), The Cognitive Acceleration through Science Education (CASE) project in UK and Georghiades' model of situated cognition.

Avargil and colleagues' meta-analysis synthesizes very well the pedagogical interventions based on metacognition in science education. They list 16 such studies that used metacognitive-based interventions in classroom settings to develop scientific skills and concepts like: inquiry skills, ecology concepts, scientific visualizations, environmental issues, conceptual understanding of electricity, causality relationships and processes, reading comprehension, general scientific literacy, understanding physics and chemistry concepts and inquiry-based biology activities.

From the wide range of models which define and describe metacognition, we chose the one developed by **Schraw and Dennison (1994),** for several reasons. First, this model has its basis in Flavell's theory of metacognition, one of the most used theories within the field of metacognitive learning. Even though many other theories have developed, some of them criticizing or supplementing this model, a brief search in the journals shows that most researchers conceptualize metacognition using Flavell's perspective. Second, even though some researchers developed theoretical models to conceptualize metacognition in a particular way, they use the instrument developed by Schraw and Dennison to measure it, thus creating a discrepancy between theoretical and practical approach. To avoid generating this discrepancy in our study, we used the theoretical approach that is supported by practical and evidence-based research, namely Schraw and Dennison's model of metacognition, considering our target group (pre-service teachers) and the particularities of this study (metacognition in a specific field: science). Literature (Cooper, Levin & Campbell, 2009; Pirrie, 2001) highlights the need to promote training programs that have been tested and proven to be effective. Thus, through this program we aim, in parallel with the purpose and objectives of the research, to reduce the discrepancy between the theory and practice existing in the educational system both at national and international level.

CHAPTER 3. Features of science metacognitive awareness in preschool and primary school teacher candidates. An exploratory analysis

Scientific literacy has been the focus of research for a long time now and its value and importance are unquestionable today, this being emphasized by many researchers (Holbrook & Rannikmae, 2009; Laugksch, 2000; Ogunkola, 2013; Yasar, 2022). Snow & Dibner (2016) argue that considering the information society in which we live in, scientific literacy must be redefined, taking into consideration its economic, personal, democratic, and cultural implications. To become scientifically literate, one must first be an effective learner who understands and uses scientific concepts and phenomena, and one way to do this is through metacognitive training. There are studies showing that the use of metacognitive awareness has positive effects on science comprehension and academic performance (Seraphin et al., 2012; Xie et. al, 2023). Wirzal and his colleagues (2022) emphasized that metacognition increases not only students' interest in science, but also the comprehension of scientific concepts and the use of science concepts in real-life situations.

3.1 Metacognition in prospective elementary teachers

The need to use metacognitive awareness to understand the science-related content in a great depth it has been shown in many studies over time (Ciascai & Haiduc, 2014; Jahangard et al., 2016; Mai, 2015; Wirzal et al., 2022; Tsai et al., 2019). Furthermore, research shows that teachers' metacognitive awareness is related to teaching with metacognition (Ozturk, 2018). However, it is not easy for students and teachers to become metacognitive learners because it can be difficult to use verbalization to describe the learning process or approach. When asked how students learn, teachers used theories like motivation, Piaget's developmental stages, multiple intelligence theories and learning styles to describe the way in which their students learn (Collins, 2002). To become aware of how learning occurs, it is important that teachers become familiar with the concept of metacognition in general and particularly in science and use metacognition in their own teaching and learning.

Both teacher candidates and practicing teachers must explicitly learn and teach metacognition. There is research that indicates that metacognitive awareness differs according to teacher candidates' field of study (Bars & Oral, 2016) and might also differ according to their professional status (future versus practicing teachers) (Metallidou, 2009). However, the research in this last direction is still inconclusive (Halamish, 2018).

Halamish's (2018) study shows that teacher candidates and practicing teachers do not have metacognitive knowledge about the most effective learning strategies. Furthermore, it appears that teaching experience alone does not have a positive impact on teachers' metacognition. So, to develop at a level that allows its use in the daily learning process, metacognition must be taught explicitly. Explicit teaching of metacognition it's a long-term approach, this means that it must be done constantly and integrated into school programs for the best results. This long-term approach of the explicit teaching of metacognition was highlighted in Fouche and Lamport's 2011 research. Fouche and Lamport argue that metacognitive strategies introduced in science classrooms are effective if they are constantly applied in school settings and integrated in effective teaching strategies to be practiced by both students and teachers. Moreover, they argue that metacognitive strategies must be included in the science curriculum if we want our students to constantly use them and to increase their responsibility for their own learning in science. Zohar (2012) argues that higher order thinking skills such a metacognition should become an important component of the class instruction and 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 pre-service and in-service teachers need to learn how to introduce metacognition in their lesson plans.

3.2 Problem statement, goals, and research questions

To design effective programs that develop metacognition in preschool and primary school teacher candidates, we need to understand its characteristics in this specific group. Thus, this study aims to identify the perspectives of pre-school and elementary school teacher candidates on metacognitive awareness in learning science-related content. This study will give us a picture of how metacognitive awareness emerges in preschool and elementary school teacher candidates. We used a mixed methods design that allowed us to get robust data and analysis about the topic of concern. There is concern in the literature that self-reported measures of metacognition have two major pitfalls. First, they are retrospective and thus might be difficult for participants to recall the specific strategies used in solving various academic tasks. Second, the Likert scales used in these self-reported measures might be difficult to analyze and interpret (Dinsmore & Zoellner, 2017).

Integrating both quantitative and qualitative designs into one study enables us to gain a detailed picture of what metacognition means for preschool and primary school teacher candidates (Ivankova, Creswell & Stick, 2006). This research design is the best choice considering that metacognition is a fussy concept explored in the complexity of educational contexts. We collected, analyzed and interpret both qualitative and quantitative data using a single-data collection session and data analysis, as suggested by Mertens (2010). Then we followed Creswell's (2009) recommendations and we first analyzed qualitative data. After analyzing the qualitative data, we moved on to quantitative data analysis. Following this line of research, 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 of prospective elementary teachers in science learning?

3.3 Methodology

3.3.1 Participants

Participants were 107 preschool and primary school teacher candidates in their final B.A. year of studies. Most of the students were 22-years-old women, coming from the urban environment, who were not financially independent (the majority received help from parents and relatives). We selected the sample of participants based on accessibility. Participation in the research was completely voluntary, but those who accepted the study invitation received a qualification bonus in the Didactics of Geography and Natural Sciences course.

3.3.2 Instruments

To find 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?” and (2) “What strategies do you use when learning in science?”. After presenting the two open-ended questions above, 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 the fourth-grade students that they will have to prepare a project in Natural Sciences. The students received 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 two days left until the deadline for the project in Natural Sciences, Andrei started doing it one day before the deadline. Because 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 he knew what he wanted to write, but he did not know how to organize them. He managed to comply with the number of paragraphs requested by the teacher but was not sure that he included everything she requested. In a hurry to finish the subject, he did not have enough time to read what he wrote before handing it over.

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 homework? (3) Do you think Andrew should have done

something different? (4) If you were Andrew, what would you do differently (assuming that you would receive this assignment in college)? (5) What difficulties do you think you would encounter?

Metacognitive awareness of teacher candidates in science was assessed through the Metacognitive Awareness Inventory (MAI) developed by Scraw, and Dennison. MAI is a fifty-two item self-assessment scale, measured on a 5-point Likert scale. The scale is available in Romanian (although it wasn't adapted on the Romanian population). The scale has two main dimensions. The first dimension, knowledge of cognition, comprises declarative knowledge, procedural knowledge, and conditional knowledge. The second one, regulation of cognition has 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 whole scale reached an internal consistency coefficient of 0.93. The MAI has good psychometric properties reported in the literature: S-B $\chi 2$ (N = 811; df = 1,220) = 2573.12, $p < .001$, *NNFI = .964, *CFI = .968, *IFI = .965, SRMR =.047, RMSEA = .040 [CI90% = .036, .043] (Gutierrez de Blume, 2024).

3.3.3 Data collection

Data were collected in the second semester of the academic year 2022. 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 of consent to take part and this 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 an online Google form document automatically recorded participant responses. The rating was not anonymous as participants filled in their names for the course bonus. However, they also had the choice to leave the name box blank if they were not interested in the bonus. One hundred and seven (107) students filled in the assessment package, of a total of 123 students enrolled in the course.

3.4 Findings

Most Romanian preschool and primary school teachers are females. Thus, this study had only one male participant while 99.1% were females. Analyzing the demographic data of this study, the typical image of the third-year student in preschool and primary education appears: 22 years old women who come from both urban and rural areas.

To get a clearer picture of the third-year students' perspectives on metacognition we asked them to offer examples of metacognitive strategies they use in learning science-related content (the second open-ended question of the study: What metacognitive strategies are used by teacher candidates in learning science-related topics?). Prospective teachers relate the strategies used in learning science-related content with information organization and management. They focus on selecting the main information using strategies like highlighting, repeating, taking notes, creation of schemes, diagrams, and sketches. The most used strategies are information organization, reading and creating sketches.

Besides the two open-ended questions illustrated above, we introduced a metacognitive vignette and asked participants to analyze it by answering to five questions. The first three questions are dichotomous ones and ask for a Yes/No answer, and the following two are open-ended questions. Table 3.5 shows the percentages distribution of the dichotomous answers to the first three questions.

Table 3.5

Participants' answers to the open-ended questions

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

Teacher candidates' conclusions about how well Andrew understood his task are quite surprising because there is not enough information to figure out with certainty the level of the task comprehension. Although 81.3% agree that Andrew understood the homework requirements, they consider that he did not used specific strategies to solve it (84.1%) and that he should have done something different (99.1%). We went further to find out what strategies Andrew should have used, according to the teacher candidates' views and addressed them two open-ended questions. The alternative learning strategies that third-year students mentioned were based on organizing the science-related information. So prospective teachers would carefully read the requirements of the task they must perform, make a summary, organize their ideas, and ask for help in case they need it. They did not mention how they would organize their ideas or what strategies they would use to carefully read the text. However, they mentioned the difficulties they might meet in solving the task. Time and stress are the key words that participants mentioned as the main difficulties they would face if they had to solve the task in the same context as presented in the vignette. Teacher candidates are aware that a complex educational task needs time to be solved properly, being aware of the importance that this variable holds in the learning process. Moreover, they mentioned that stress might be another potential issue in solving the assignment.

The qualitative data analysis allowed us to establish some of the characteristics of metacognitive awareness of teacher candidates in learning science-related content. A first characteristic that emerges is related to the importance prospective teachers place on science-related content knowledge. A second characteristic is related to their emphasis on the specific strategies to be used in dealing with science-related content. They focus on information management strategies related to science-content and place little emphasis on knowledge related to the task or to one's own strengths and weaknesses in dealing with science-related tasks. Another important result of the qualitative data analysis is related to the teacher candidates' awareness of the importance of time and perceived stress in handling science-related academic tasks.

To successfully achieve our research goals and gain a detailed picture and insight into metacognitive awareness in preschool and elementary education teacher candidates, participants filled out the Metacognitive Awareness Inventory. To markedly illustrate this tendency of teachers to claim their prominent level of metacognitive awareness in science we verify the percentages of those who "agree" and "strongly agree" with the statements that measure metacognitive awareness knowledge. Prospective teachers have an above average level of metacognitive declarative knowledge in science. Apart from the item "I am good at remembering information" which had 42.9% agreement responses, for all other items the percentage exceeded 56.10%. This means that teacher candidates report above average levels of declarative knowledge related to science content. In other words, teacher candidates have a strong knowledge base about how their own learning process occurs, according to their views.

All the four items that measure procedural metacognitive knowledge, that is knowledge about various learning strategies, have high percentage of agreement and strongly agreement that range between 58% ("I find myself using helpful learning strategies automatically") and 86.9% ("I have a specific purpose for each strategy I use"). Not only that teacher candidates have knowledge about different learning strategies, but they are so familiar with them that they manage to use them automatically, according to their own statements.

Teacher candidates report above-average levels of conditional metacognitive knowledge related to science content. This means that they know when to use specific learning strategies with which they are so familiar and apply some of them in percentages of over 80% (81.3% for "I can motivate myself to learn when I need to" and 87.8% for "I use my intellectual strengths to compensate for my weaknesses). Participants agreed that they are familiar with metacognitive strategies for planning the learning process. The agreement levels of planning the learning process are above average for all the items that measure this dimension of the metacognitive regulation process. This means that prospective teachers read instructions carefully before beginning a task, pace themselves while learning to have enough time for solving the task, think about what they must learn before beginning a task and organize their time to best carry out their goals.

While learning science-related content, teacher candidates create their own examples to make information more meaningful, make connections with prior information, focus their attention on the most important information and break the material they need to study into small chunks, according to their statements. All this information management strategies should facilitate the deep understanding of scientific concepts.

After planning and selecting specific strategies to manage information, teacher candidates use different strategies to check their comprehension. Compared to the metacognitive regulation strategies presented above (planning and information management strategies) strategies used for checking the comprehension are used is a smaller percentage. It seems that only 38.3% of teacher candidates periodically review the information to understand important relationships and 53.3% analyze the usefulness of strategies while studying. However, 84.1% consider all the options available to solve a problem and 76.4% regularly take breaks to check their comprehension.

Self-assessment strategies are essential in the learning process and teacher candidates seem to be aware of this. They do not assess only how well they understood the content but also assess whether there were better strategies they could have used. Evaluating all possible ways to solve a problem (64.4%) and trying to find an easier way to solve a task after the task has been completed (43%) are two evaluation strategies used in a high percentage by teacher candidates. To assess how well they understood the content to be learned, prospective teachers summarize what they have learned (67.2%) and check whether they have achieved their learning goals (72.9%).

The recommendation for those seeking to develop and increase metacognitive awareness in science teachers is to formally include it in the undergraduate curriculum or continuing professional development programs for teachers. Yet, we first must understand the peculiarities of it in this specific group and use the right instruments to measure metacognition in prospective and practicing teachers. This study reveals that although pre-service teachers believe they have prominent levels of metacognitive awareness, when asked to mention how they learn science-related content, they do not mention metacognitive knowledge and skills, but mainly cognitive strategies. Using self-reported scales to measure metacognition might be insufficient if our final aim is to develop and increase metacognitive awareness. Beside self-reported measures, qualitative ones should be used to identify how prospective and practicing teachers understand this concept and to develop and adapt specific intervention programs for teachers.

Chapter 4. "The sun disappears at night!" Does it? The predictive role of metacognitive awareness on science misconceptions

4.1 Science misconceptions in teachers

Research (Beeth & Hewson, 1999; Blanchet, 1952; Çelikler & Aksan, 2004; Braningan & Donaldson, 2020; Gomez-Zwiep, 2008; Hennessey, 2003; Hynd & Alverman, 2010; Karakaya et al., 2021; Kendeou & Van den Broek, 2005; Van den Broek & Kendeou, 2008; Larkin, 2012; Lubin & Ge, 2011; Vosniadou & Skopelitic, 2017) shows that there are inconclusive results regarding the relationship of metacognition with science misconceptions and the differences between them in prospective and practicing teachers. Although we tend to believe that practicing teachers have fewer misconceptions in science, studies indicate that this is not necessarily true and that misconceptions might not change or disappear as the teaching experience increases. Studies that investigate and compare misconceptions among both categories of teachers (prospective ones and practicing ones) are strongly needed to develop effective pre-service and in-service professional development programs for teachers. Given the reviewed literature, we expect that metacognitive awareness will be a strong predictor of science misconceptions. This means that we expect that high metacognitive awareness scores will predict low levels of science misconceptions.

4.2 Research hypotheses

H.1 Metacognition is a significant predictor of science misconceptions. (H0. Metacognition is not a significant predictor of science misconceptions).

4.3 Methodology

Each scale used in this research has been translated into Romanian and followed the standard procedure for instrument adaptation. This means that after the first translation from English into Romanian, the scale has been translated again into English by three professionals (two PhD candidates and the PhD's supervisor) and checked for inconsistencies. Where shortcomings were identified, items were removed. Then the scales were applied to a group of PhD students (piloted).

4.3.1 Participants

The study sample had 252 participants. Of these, 107 were preschool and elementary school teacher candidates while 145 were practicing teachers. The group of teacher candidates is quite homogenous in terms of age, education, and financial independence. Thus, the majority were not attending other undergraduate university courses and were receiving financial support from family or have part-time jobs. All participants from this group were students in their 3rd year of study at a well-known urban university in Romania and were following the training program to become pre-school and primary school teachers. Their mean age was 22.44 years old and 51% come from rural areas while 56% from urban ones. The mean age of the in-service teachers is 43.67 years old, with an average teaching experience of 20.17 years.

The in-service teachers' group was more heterogeneous in terms of demographic characteristics. Thus, they teach at different levels of pre-university education, have different ages and different specializations. Roughly all in-service teachers are females, males being underrepresented in this research (5.5%). Teaching in urban schools (76.6%) prevails compared to teaching in the rural ones (23.4%). More than half of teachers had achieved their 3rd teaching level (66.9%). A percentage of 19.30% reached the 2nd teaching level (or the 2nd grade) and 13.8% the 1st one (the highest grade in the Romanian educational system, the 1st grade). The highest percentages of participants are teaching at preschool and elementary school levels (38%) and secondary school classes (37.2%). High-school teachers are represented by 24.80%.

4.3.2 Instruments

The Metacognitive Awareness Inventory (MAI) developed by Scraw and Sperling-Dennison (1994) was used to assess pre-service teachers' metacognitive awareness. The scale and its psychometric properties were described in the first study of this paper.

The Metacognitive Awareness Inventory for Teachers (MAIT) was developed in 2011 by Cem Balcikanli and its goal is to assess the metacognitive awareness in those who already reached the teaching profession, specifically in practicing teachers. MAIT has adequate reliability coefficients (from 0.79 to 0.85) and six dimensions: declarative knowledge, procedural knowledge, conditional knowledge, planning, monitoring, and evaluating. The scale has a total of 24 items distributed into the six dimensions mentioned above, measured on a 5-point Likert scale.

Science misconceptions have been assessed through the following ten true-false statements: (1) The stars shine because of the light that is reflected from the sun. (2) On a day when the relative humidity of the air is close to 100%, it contains a larger amount of water than anything else. (3) If there were no air, all bodies would fall at the same speed. (4) Sound travels through the air faster than through any substance. (5) Solids have more particles than liquids and liquids have more particles than gases. (6) All solid bodies have a definite shape. (7) There is no space between the particles of solid bodies. (8) Materials that can be poured from one container to another are liquid. (9) Solids have volume, while liquids and gases do not. (10) Solids are rigid materials. The first four items have been collected and adapted after Rayla and Rayla (1983), but were also used by other researchers (Dunlop, 2000; Korur, 2015) and measure astronomy, atmosphere, and physical related misconceptions. Misconceptions five to ten were adapted after Tatar (2011) who identified them in a group of 227 fourth-year students who were preparing themselves to become elementary school teachers. The highest score for this scale was 10 and the lowest was 0. Higher scores mean lower lever of science misconceptions.

4.3.3 Data collection

Both sets of data were collected during the pandemic period, in the 2020-2021 academic year. Due to the restrictions imposed during the pandemic, all data was collected through online techniques. For pre-service teachers the set of the self-assessment scales was uploaded on their teaching platform (Teams) while the in-service teachers received the scales on social media (Facebook teachers' communities). All the answered questions were automatically recorded in a google forms sheet that remained open during a period of four weeks.

4.4 Findings

Teachers' answers at each science misconception items are illustrated in the table 4.1 below.

Table 4.1

Percentage of misconceptions in pre-service and in-service teachers

Misconceptions items	**Answer**	**Pre-service teachers N=107**	**Secondary & high-school teachers N=85**	**Pre-k and elementary practicing teachers N=60**
			Percent	
1. The stars shine because of the light that is reflected from the sun.	Correct	64.50	52.50	52.30
	Incorrect	35.50	47.50	47.70
2. On a day when the relative humidity of the air is close to 100%, it contains a larger amount of water than anything else.	Correct	78.50	47.50	40.90
	Incorrect	21.50	52.50	59.10
3. If there were no air, all bodies would fall at the same speed.	Correct	33.60	32.70	31.80
	Incorrect	66.40	67.30	68.20
4. Sound travels through the air faster than through any substance.	Correct	27.10	34.70	34.10
	Incorrect	72.90	65.30	65.90
5. Solids have more particles than liquids and liquids have more particles than gases.	Correct	57.90	52.50	54.50
	Incorrect	42.10	47.50	45.50
6. All solid bodies have a definite shape.	Correct	61.70	65.50	61.40
	Incorrect	38.30	34.50	38.60

7. There is no space between the particles of solid bodies.	Correct	56.10	84.20	68.20
	Incorrect	43.90	15.80	31.80
8. Materials that can be poured from one container to another are liquids.	Correct	62.60	43.60	47.70
	Incorrect	37.40	56.40	52.30
9. Solids have volume, while liquids and gases do not.	Correct	74.80	80.20	75.00
	Incorrect	25.20	19.80	25.00
10. Solids are rigid materials.	Correct	54.20	41.60	52.30
	Incorrect	45.80	58.40	47.70

Both prospective and in-service teachers had difficulties in giving correct answers to several items measuring misconceptions in science. Prospective teachers gave wrong answers in a high percentage to items like “sound travels through the air faster than through any substance” (72.90%) and “if there were no air, all bodies would fall at the same speed” (66.40%). These two items had a high percentage of wrong answers from both elementary (65.90% for the 1st item and 68.20% for the 2nd one) and secondary and high-school in-service teachers (65.30% for the 1st item and 67.30% for the 2nd item). These two misconceptions are widely spread among both pre-service and in-service teachers. Another three science misconceptions that have been found in a high percentage in prospective teachers are: “there is no space between the particles of solid bodies”, “solids are rigid materials” and “solids have more particles than liquids and liquids have more particles than gases”.

To test the predictive value of metacognitive awareness on science misconceptions a single score has been created for each variable of interest. In the case of science misconceptions, because items were similar in the difficulty level, we used the sum to get a single raw score. For metacognitive awareness scores we used the mean for the final raw score. Regression analysis results are presented below.

Table 4.2

Regression analysis: dependent variable – science misconceptions

Group	Predictor	R^2	SE B	F	t	p
ENTIRE SAMPLE (n= 252)	MA	.116	1.912	32.893	-5.735	.000
	MK	.113	1.780	31.754	-5.635	.000
	MR	.095	1.763	26.296	-5.118	.000
PE_PRESERV (n= 107)	MA	.272	2.975	39.242	-6.264	.000
	MK	.308	2.565	46.655	-6.830	.000
	MR	.202	3.039	26.556	-5.153	.000
PE_INSERV	MA	.007	2.817	.380	-.616	.540
	MK	.011	2.631	.645	-.803	.425

(n= 60)	MR	.003	2.665	.170	-.412	.682
	MA	.001	6.517	.072	-.268	.790
SEC_INSERV	MK	.002	6.072	.109	.330	.743
(n= 51)	MR	.000	5.713	.016	-.126	.900
	MA	.008	7.926	.262	.512	.612
HIGH_INSERV	MK	.000	8.764	.005	-.071	.944
(n= 34)	MR	.014	4.774	.436	.660	.514

Note: Dependent variable: science misconceptions; PE_PRESERV - Preschool and elementary school pre-service teachers; PE_INSERV - Preschool and elementary school in-service teachers; SEC_INSERV – Secondary school in-service teachers; HIGH_INSERV – High-school in-service teachers. MA – Metacognitive awareness; MK – Metacognitive knowledge; MR – Metacognitive regulation

We conducted a simple regression analysis to assess the extent to which metacognitive awareness (and its main dimensions) could predict science misconceptions in pre-service and in-service teachers. It seems that metacognitive awareness is a significant predictor of science misconceptions for the whole sample of participants ($F= 32.893$; $p < 0.000$), explaining 11% of the variance in science misconceptions scores and for preservice teachers ($F= 39.242$; $p < 0.000$), explaining 27% of the variation in the scores of science misconceptions ($R^2 = 0.272$). Because the slope of the regression line is negative, metacognitive science scores (dependent variable) will decrease when metacognitive awareness (independent variable) increases.

The results that this research revealed allow us to conclude that both practicing teachers and prospective ones face a series of science misconceptions and need specific professional development programs that target these misconceptions. Simply being exposed to the correct information does not guarantee the changing of these misconceptions, as the theories developed on this topic have already shown. That is why we need further research to identify the most suitable strategies to change misconceptions in science and to develop and maintain the correct scientific concepts that teachers can develop in their students. To change scientific misconceptions, we suggested that metacognitive awareness could be one of the best strategies that can be easily implemented in the everyday teaching context. Metacognition has been included in different conceptual change theories, already described in the second chapter of this paper. This is the reason we analyzed its relationship with science misconceptions and aimed to identify peculiarities of scientific misconceptions in both practicing or in-service teachers and teacher candidates, with a focus on kindergarten and elementary school teachers. Metacognition seems to be a significant predictor of science misconceptions, explaining 11% of the variance in science misconceptions. The predictive value of metacognition increases in the case of pre-service teachers (27%)

compared to the other categories. This means that if we increase students' metacognitive skills, their science misconceptions should decrease.

Because we cannot talk about metacognition and metacognitive awareness in the absence of specific cognitive strategies, in the following study we will test a path model that includes deep learning strategies, strategic learning strategies, metacognitive strategies and science misconceptions to understand how they can be combined for the best effects on science misconceptions. We excluded the surface learning strategies because there is much research showing that they are not a significant predictor of metacognitive awareness (Coutinho & Neuman, 2008; Liu & Long, 2019).

CHAPTER 5. Science misconceptions and learning strategies: a path analysis model

5.1 Theoretical background

Metacognition, science misconceptions and learning strategies are variables that can have a high impact on the quality of the teaching and learning process. For students to be able to understand complex scientific concepts, they need a learning environment in which teachers focus not just on the type and frequency of the strategies used by students, but also, as Dinsmore and Zoellner (2017) suggested, on patterns of learning strategies. This means how these learning strategies combine to facilitate the understanding of complex scientific concepts and phenomena, and which can be the best predictor of understanding scientific concepts and phenomena.

The interplay between cognitive and metacognitive learning strategies in specific learning models is essential and must be tested in practice so that teachers have evidence-based instructional models in science teaching. There is research indicating that both deep approach to learning and strategic approach to learning promote the development of metacognitive strategies (Pearson & Harvey, 2013) and others argue that metacognition has a mediator role in changing science misconceptions (Georghiades, 2000).

Deep processing strategies like elaboration, paraphrasing, and metacognitive comments seem to also influence the conceptual change process (Franco et al., 2012). Strategic learning involves organizing study, time management, achieving, alertness to assessment and monitoring effectiveness. On the other hand, deep learning can be characterized by seeking meaning, relating ideas, using evidence, being interested in ideas, using elaboration, organization and critical thinking (Vrugt & Oort, 2008). Both involve using effective studying strategies. It seems that deep learning strategies are used more by the students who learn in a student-centered environment (Rosario et al., 2013).

Results are inconclusive regarding the relationship of metacognitive awareness with learning strategies. Some argue that deep learning strategies increase metacognition (Elbyaly & Elfeky, 2022; Pearson & Harvey, 2013) while others believe that metacognitive strategies influence students' deep learning strategies (Bran & Balaş, 2011). Strategic learning has been less studied than deep learning. One of the studies that included metacognition, deep learning and strategic learning is the one conducted by Bran and Balaş (2011). Their study shows that using metacognitive regulation strategies in teaching increases the level of students' deep learning strategies, measured through the ASSIST scale. However, what is interesting in their research is that the strategic approach to learning had increased in both experimental and control groups, unlike deep learning strategies (which increased only in the experimental group). This supports the above statement that although strategic learning has been less studied compared to deep and surface strategies, it is important to include it in more studies to have a complete understanding of how it interacts with metacognitive and deep-level learning strategies. Valuable research on the discussed topic is the meta-analysis of Gutierrez de Blume (2022). His study shows that the effect of deep learning strategies on meta-comprehension accuracy is very high (g'= 0.782) while the one of mixed learning ones is medium (0.576). They defined the mixed learning strategies as being a combination of surface and deep learning.

5.2 Research hypothesis

The following general hypothesis were tested in this study:

H.1 Different learning strategies predict different levels of science-related misconceptions in teacher candidates.

Beside this main hypothesis, we also verified if our variables appear different according to the students' type of enrolment and different levels of science misconceptions. It is important to introduce the type of students' enrolment in our analysis because most universities offer distance or part-time enrollment courses for their students. Since distance and full-time students usually differ in their demographic characteristics, we expect to find differences between these two groups in their scores in their metacognitive, deep and strategic learning strategies and in their science misconceptions levels. Considering this, we formulated and tested the following two hypotheses:

H.2 There are significant differences in metacognition, science misconceptions, deep learning and strategic learning according to the type of student's enrollment.

H.3 There are significant differences in metacognition, deep learning and strategic learning according to students' level of science misconceptions.

5.3 Methodology

Participants

Third year students took part in this study. Out of a total of 285 students, 211 agreed to take part in our research and filled in an online self-assessment package. The response rate was 74.03%. All the participants were enrolled at the undergraduate level and were preparing to become preschool and primary school teachers, the main difference between them being the form of study: fill-time (104) versus part-time (107). A high percentage of students are women from both urban and rural areas, with a mean age of 26.04. The mean age of students enrolled in full time courses is 24.05 while of those in part-time or low frequency studies is 27.99 years old. The detailed demographic characteristics of the participants are presented in the Findings section.

Instruments

The Metacognitive Awareness Inventory (MAI) developed by Scraw, and Dennison (1994) was used to assessed metacognitive awareness of students (details about the scales has been offered in the first study of this paper).

The Approach and Study Skills Inventory for Students (ASSIST) was the second scale used in this study (Entwistle et al., 2000). There are different standardized measures for the assessment of students' learning strategies. The most common are Study Process Questionnaire, the Learning Process Questionnaire, the Inventory of Learning Process, the Approaches to Studying Inventory, and the Approaches and Study Skills Inventory for Students (ASSIST) (Wu, 2024). The ASSIST scale, one of the latest that has been developed to assess learning strategies, overcomes the shortcomings of the other scales and has been reported to have good psychometric properties. The ASSIST inventory has three main dimensions and for this study we used its second dimension. The second dimension has two main approaches of interest for us: the deep and strategic learning approaches, which means a total of 36 items divided in 20 items for the first approach and 16 items for the second approach. The deep approach to learning has five sub-scales: seeking meaning, relating ideas, use of evidence, interest in ideas and monitoring effectiveness. The strategic learning approach has four sub-scales: organized studying, time management, achieving and alertness to assessment demands. All items are measured on a five-point Likert-type scale. The scale is reported to have good reliabilities measures. The alpha Cronbach for the ASSIST scale in this study is 0.924, a high indicator that indicates good reliability. The same procedure of scale translation was followed as the one with the MAIT scale from the second study.

Science misconceptions. We assessed students' misconceptions about three major themes: solar system and earth, light and matter. This variable has been assessed using twenty true-false items listed below:

(1) The center of the universe is the Sun. (Korur, 2015)
(2) The center of the universe is Milky Way. (Korur, 2015)
(3) The sun is not a star; it is a celestial body by itself. (Korur, 2015)
(4) We see the objects around us because light travels from our eyes to the object. (Allen, 2010)
(5) Galaxies cover whole celestial bodies. (Korur, 2015)
(6) The stars reflect the incoming light from the Sun. (Korur, 2015)
(7) The Sun reflects the incoming light from the other stars. (Korur, 2015)
(8) There is no difference between Space and the universe. (Korur, 2015)
(9) There is no difference between stars and planets. (Korur, 2015)
(10) The Earth orbits the Sun once a day, producing day and night. (Korur, 2015)
(11) The Earth's orbit is highly elliptical. (Korur, 2015)
(12) There is no gravity in space. (Korur, 2015)

(13) Boiling point varies with the amount of material. (Sadler & Sonnert, 2016)
(14) Burning produces no invisible gases. (Sadler & Sonnert, 2016)
(15) Matter is not conserved. (Sadler & Sonnert, 2016)
(16) Force is always in the direction of an objects' motion. (Burgoon et al., 2010; Sadler & Sonnert, 2016)
(17) Some materials are intrinsically cold. (Sadler & Sonnert, 2016)
(18) Light travels in a straight line even when it interacts with matter. (Sadler & Sonnert, 2016)
(19) Electricity behaves in the same way as a fluid. (Sadler & Sonnert, 2016)
(20) All solid bodies have a definite shape. (Korur, 2015)

The twenty items mentioned above are true/false items and represent common misconceptions in science among prospective teachers. Responses to all these items provide the total score of the science misconception variable. For each correct answer students received 1 point and for each wrong one they got zero points. Thus, a lower score reflects a higher level of science misconceptions and a lower level of science understandings.

Data collection

The above-mentioned variables have been assessed for a group of 211 prospective elementary teachers who filled in a set of self-assessment scales during their third academic year of study. The research tools have been distributed and completed online over a period of three-weeks assessment, during which the scales could be accessed and filled in whenever the participants had time. Data were collected ensuring the confidentiality and voluntary participation of students. However, those who wanted a bonus score on their grade wrote their name in the demographic section.

5.4 Findings

5.4.1 Regression analysis

The results of the regression analysis are presented in Table 5.1.

Table 5.1

Regression analysis (science misconceptions)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	17.714	1.583		11.193	.000
	Metacognitive awareness	-2.617	.528	-.469	-4.956	.000
	Deep strategies	.276	.477	.050	.580	.563

Strategic learning	-.069	.445	-.015	-.155	.877

a. Dependent Variable: Science misconceptions
b. Predictors: (Constant), Strategic learning, Deep strategies, Metacognition

Multiple linear regression analysis was used to test if metacognitive awareness, deep strategies and strategic learning significantly predicted science misconceptions. The overall regression was statistically significant (R^2= 0.202, F(3, 207)= 17.439, p= 0.000). However, after analyzing the regression model we can conclude that predictor 1 (metacognitive awareness) is the only one that significantly predicted science misconceptions, while deep learning (predictor 2) and strategic learning (predictor 3) are not significantly predictors of science misconceptions (p= 0.563, p= 0.877). Metacognitive awareness seems to be the single variable with a significant predictive value on science misconceptions (p= 0.000) and explains 20% of the variation found in science misconceptions.

Although deep and strategic learning strategies does not seem to significantly and directly predict science misconceptions, we ran another regression analysis to check if these two variables are significant predictors of science metacognitive awareness. The results are presented in the below table.

Table 5.2

Regression analysis (metacognition – dependent variable)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	R square
		B	Std. Error	Beta			
	(Constant)	1.194	.191		6.267	.000	.569
1	Deep strategies	.280	.060	.284	4.707	.000	
	Strategic learning	.443	.050	.537	8.913	.000	

Deep and strategic learning predict 56% of metacognitive variation, which is quite a lot. Strategic learning seems to be a better predictor for metacognition, with a t = 8.913 (p = 0.000) compared to deep learning (t = 4.707, p = 0.000).

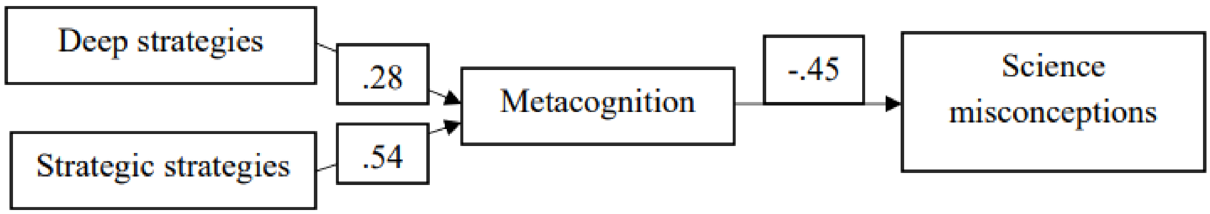
Given the results of the regression analysis, we conducted a structural equation modeling analysis to find the best fitting model to reduce scientific misconceptions using metacognitive, deep, and strategic learning. The results are illustrated below.

5.4.2 Structural Equation Modelling analysis (SEM)

Several models have been tested to check which one would best predict science misconceptions scores. All models included 3 essential variables, besides science misconceptions: deep learning strategies, strategies learning strategies and metacognitive awareness. The best model is the on presented in Figure 5.1, in which metacognitive awareness is a mediation variable between deep and strategic strategies and science misconceptions.

Figure 5.1

Structural Equation Modelling: 3rd model



In the first two model we tested the effect of deep and strategic learning strategies was very low. However, the effect of these two variables increases in the last model in which metacognition is included as a mediation variable. This means that deep and strategic learning strategies have a statistically significant effect on metacognitive awareness which in turn is a significant predictor of science misconceptions. For the identified model, as we can see in the figure above, an increase with 1 standard deviation determines a decrease with 0.45 standard deviations in science misconceptions. The Root Mean Square of Approximation (RMSEA) is 0.480, which indicates that the model has a good fit. The Goodness of Fit statistic (GFI) is 0.926 which indicates a good model while the adjusted GFI (AGFI) is 0.847.

5.4.3 Tests for group differences

Students' type of enrollment might be a variable that has some influence on metacognitive awareness, science misconception, deep learning and strategic learning. We hypothesized that we would identify significant differences in metacognitive awareness, science misconceptions, deep learning and strategic learning according to the type of student's enrollment. And this hypothesis has been partially accepted, except for strategic learning (0.523) (Table 5.3).

Table 5.3

Student t-Test: form of education and deep learning, strategic learning, metacognition and science misconceptions

Variables	t	df	Sig. (2-tailed)	Mean Dif.
Deep strategies	3.820	203	.000	.244
Strategic learning	.640	201	.523	.051
Metacognitive awareness	2.311	195	.022	.149
Science misconceptions	2.196	209	.029	.790

Except for science misconceptions where equal variances can be assumed, for metacognition, deep strategies and strategic strategies the Levene's test shows that equal variances cannot be assumed. Deep strategies seem to take different significant values in part-time students (M= 3.999 , SD= .430) compared to full-times students (M=4.243, SD= .493) (F= 4.039, p= .046) with t(203)= 3.820, p= 0.000, 95% IC[.118; .370] unlike strategic learning that seem to take the same values regardless of the group the students belong to. Significant differences were identified in metacognitive awareness in part-time (M= 4.058, SD= .410) and full-time students (M= 4.207, SD= .519), with equal variances not assumed (F=8.567; p= .004), we got t(195)= 2.311, p= .022, 95% IC[.022; .276]. For science misconceptions, for the equal variances assumed, we identified significant differences between part-time (M= 7.378; SD= 2.856) and full-time students (M= 8.163; SD= 2.332): t(209)= 2.196, p= .029; 95% IC[.081; 1.499].

We further wanted to see if metacognition, deep learning strategies and strategic learning change according to students' levels of science misconception. To set up the science misconceptions levels we used the two-step cluster analysis and obtained 3 groups with different levels of science misconceptions. Considering that a lower score on science misconceptions test reflects a higher level of science misconceptions and a lower level of science understandings (students got 1 point for each correct answer and zero points for each wrong answer / misconception answer), we got the following three groups of learners: surface learners, standard learners and deep learners. A One-Way ANOVA test was conducted to check if there are significant differences in these three groups regarding their metacognitive, deep and strategic learning according. Results are presented in Table 5.4 below.

Table 5.4

One-way ANOVA – grouping variable: science misconceptions

	Sum of Squares	F	Sig.
Metacognition	10.298	29.352	.000
Deep strategies	4.915	11.884	.000
Strategic learning	6.962	11.712	.000

We further tested which groups differ in the metacognition, deep and strategic according to different science misconceptions levels using the Bonferroni test and identified the following differences:

<u>Metacognition</u>: Metacognitive scores are different for students with different levels of science misconceptions. The significant differences were identified between the following groups:

- Students with high misconceptions level have significantly different metacognitive scores compared to the students from average and low levels of misconceptions.

- Also, students with average levels of science misconceptions significantly differ from students with low levels of science misconceptions.

Deep learning strategies: Students with different levels of science misconceptions have different levels of deep learning strategies. Interestingly, for the deep learning strategies variable statistically significant differences were identified only between the students from average misconceptions level group and the low misconceptions level group. No significant differences were found between the high misconceptions level group and the other two groups.

Strategic strategies: For the strategic learning variable, significant differences were found between the scores of the students with average levels of science misconceptions and those with low levels and from those with high levels and low levels of science misconceptions.

The main hypothesis of the study that different learning strategies (deep, strategic and metacognitive) predict different levels of science misconception in elementary school teacher candidates has been confirmed. A semantic equation modelling analysis was conducted to identify how these learning strategies interact with each other to better predict science misconceptions. The SEM analysis allowed us to develop a theoretical model that we tested during the implementation of the training program presented in the following chapter. The results regarding the predictive value of deep, strategic and metacognitive learning are in line with the results of previous research (Pearson & Harvey, 2013; Franco et al., 2012; Vrugt & Oort, 2008; Rosario et al., 2013). However, the SEM model identified is new to the literature and seems promising in reducing teacher candidates' misconceptions in science. The model used for intervention should include elements of metacognitive, deep and strategic learning strategies. THE MDS (Metacognitive – Deep – Strategic) instructional model proposed and tested in this paper integrates elements of metacognitive learning, deep learning and strategic learning. Elements of all these three learning strategies have been combined in a specific guide with prompts offered to students to solve different science-related tasks. Because teaching and learning science involves using different methods like experiments, conceptual maps, inquiry-based-learning, and problem-based learning, the guide developed and used in this study is suitable to all the previously mentioned methods. The guide is described in detail in the following chapter of the study.

CHAPTER 6. The effect of the MDS (Metacognitive-Deep-Strategic) instructional model on students' level of science misconceptions and metacognitive awareness

6.1 Theoretical model

Traditional approaches to science teaching have been criticized for generating science misconceptions and a low level of scientific literacy among students. Consequently, both students and teachers are negatively affected by this approach. Students fail in developing a deep understanding of scientific concepts and an adequate level of science-related competencies, and teachers focus rather on assessing students' reproduction of scientific information instead of science comprehension. Neither teachers nor students recognize the real value of metacognitive awareness in science learning and comprehension. Despite all these shortfalls related to traditional science teaching this approach is still in use on a large scale in different educational settings. This can be explained through the lack of financial resources for developing science labs and hands-on activities, insufficiently developed teachers' competencies in using modern and metacognitive approaches in teaching science and a curriculum far too vast and complex for the limited number of teaching hours of science.

Reviewing the impact of metacognitive strategy instruction on changing scientific misconceptions, Camarao and Monterola (2021) found that out of 20 analyzed studies all reported an overall impact of metacognitive components on scientific conceptual change. The effect size of these interventions was 0.73 within a medium to large confidence interval. Research conducted by Goren and Kaya (2023) reveals that metacognitive awareness is related to how students understand the nature of science. The correlation coefficients of metacognitive awareness and the nature of science understanding range between 0.292 and 0.347 for secondary school students. However, the authors reported the results for the entire scales although the analysis conducted on the scales' subdimensions could have revealed higher correlations.

To become competent metacognitive learners, students need the teacher's guidance, particularly in primary grades. However, often teachers do not have enough knowledge and skills to integrate metacognition into their daily teaching practices. For this reason, there is an increased amount of research focused on developing teacher's metacognition.

Metacognitive learning awareness can be enhanced by increasing deep learning strategies and strategic learning strategies (Pearson & Harvey, 2013). For this intervention we added a third type of strategies to enhance students' metacognitive awareness in science learning and decrease their science misconceptions: metacognitive learning strategies. The effect of combining cognitive and metacognitive learning strategies has been demonstrated in different research studies (Berthold et al., 2007; Hsu et al., 2017; Saks & Leijen, 2018; Samadi & Davaii, 2012). The intervention model developed in this study includes metacognitive learning strategies, deep learning strategies and strategic learning strategies. In the deep learning strategies, we included elaboration and paraphrasing, in the strategic learning we had organization, time management and monitorization and in the metacognitive learning strategies we included planning, monitoring, debugging, assessing and identifying the suitable learning strategies to solve a task (declarative knowledge) and identify which strategies are best suited to specific tasks (conditional knowledge).

The model proposed involves direct and indirect relationships between our variables. However, the main effect of the learning strategies on science misconceptions level is mediated through metacognitive awareness. We used this theoretical model, tested through the path analysis done in our previous study, to test the effectiveness of the Metacognitive – Deep – Strategic (MDS) instructional intervention program. Starting from this model, we elaborated a 5 steps intervention guide (Table 6.1). In the first step students had to choose the task they had to solve (the tsks used in this course are listed in the table at Step 1). After establishing the task, students had to identify the knowledge, skills and resources needed to solve the task (Step 2). This means that they had to write down all the requested information in step 2. Following the identification of the knowledge, skills and resources needed to solve the task, students had to choose the learning strategies they considered the best for solving the task (Step 3). After choosing the task, students were asked to apply it (and this always resulted in something written, even if the task was to understand a scientific text – Step 4). In the final stage students had to choose how they will assess their work and apply the chosen strategy (step 5) (Table 6.1).

Table 6.1

Intervention guide

(1) Establish the task:	**(2) Identify the knowledge, skills and resources needed to solve the task:**	**(3) Choose the learning strategies you can use:**	**(4) Apply the chosen learning strategies:**	**(5) Evaluate what you learned:**
a) Understand a scientific text. b) Make a conceptual map. c) Develop an experiment. d) Implement an experiment. e) Design a 5E lesson plan. f) Design a lesson plan. g) Make a demonstration.	a) Relate to prior knowledge: write what you know about the subject (**deep**). b) Write the most important information you need to solve the task (**metacognitive strategies**). c) Write what information you need to solve the task and you don't have it (**metacognitive strategies**). d) Write where you will get the needed information (colleagues, teacher, power-point, textbooks, internet, others) (**metacognitive strategies**).	a) Highlight important information (**strategic).** b) Draw pictures/diagrams to make connections (**deep**). c) Read carefully (**deep**). d) Paraphrase (**deep**). e) Break the task in the following steps (list the steps) (**strategic**). f) Generate own examples (**deep**). g) Ask questions about the task you solve (e.g. Did I understand? Am I getting the task correct? Is there another strategy to use?) (**metacognitive strategies**). h) Plan my working time (**strategic**). i) Organize information (**strategic**). j) Write down information (**deep**).	a) List the encountered difficulties (**metacognitive**). b) List the strategies used to overcome difficulties (**metacognitive**).	a) Present in front of your class. b) Ask feedback from teacher. c) Consult with a colleague. d) Check the materials provided by the teacher. e) Check other source of information (name them).

6.2 Research hypotheses

The research hypotheses tested in this study are the following:

H5: Prospective teachers exposed to a metacognitive-deep-strategic instructional approach (MDS) have lower levels of science misconceptions after they attend the program.

H6: Prospective teachers who participate in the metacognitive-based teaching strategies (MDS) program improve their level of metacognitive awareness in science learning.

6.3 Methodology

Participants

The sample of the study included 79 students in their last year of the undergraduate studies. The mean age of the participants is 21.67 years old, and they were all females. The initial sample of the study was higher and had 97 students. Although all students attended the same university, they had their courses in different cities. 56 of the participants were students at the faculty in a well-known university town (Cluj) while the rest of them (41) studied in a small urban town (Nasaud). They were all preparing to become kindergarten and elementary school teachers. Students from the well-known university town were included in the experimental group (n=56) while the second ones in the control group (n=41). Because eight students from the small rural are did not participate in the post-test assessment session and were excluded from the research. The final sample had 89 students from which n=56 in the experimental group and n= 33 in the control group.

Instruments

Metacognitive awareness. Students' metacognitive awareness was assessed using the MAI scale developed by Scraw, and Dennison (1994) (details about the scales has been offered in the first study of this paper).

Self-Efficacy and Metacognition Learning Inventory- Science (SEMLI-S). SEMLI-S measures students' metacognition and learning in science. It has 5 subscales measured on a 5-point Likert scale (1-Never; 5-always): Constructivist-connectivity (CC), Monitoring, evaluations and planning (MEP), Self-efficacy (SE), Learning risks awareness (LRA) and Control of concentration (CO). The scale has adequate psychometric properties (Thomas et al., 2008; Ajaja, 2017; Thomas, 2013). The internal consistency reported in the literature is 0.92 (Thomas et al., 2008). Considering the aim of our study, we used only the items from the constructivist-connectivity subscale (7 items – internal consistency 0.76) and from the monitoring, evaluations, and planning subscale (9 items – internal consistency 0.85).

Learning Strategies Scale for University Students (LIST). The list scale was developed by Wild and Schiefele in 1994 (Griese et al., 2011) and has three main dimensions: cognitive strategies, metacognitive strategies, and resource-related strategies. The whole scale has 77 items. For this study we selected the items that measure cognitive and metacognitive strategies and that means we had 34 items measured on a 5-point Likert scale ranging from (1) Never to (5) Always (2=Sometimes; 3=Often; 4=Very often). Being developed in 1994 the scale has been intensively used and reported to have good psychometric properties (Griese et al., 2011). The internal consistency in this study was 0.72.

Science misconception assessment. Science misconceptions were assessed using a four-tier assessment scale presented in Anex 7. The following items were used:

(1) Plants take all the substances they need to grow through their roots (Wynn et al., 2017);
(2) Plants get their energy from the soil through their roots (Wynn et al., 2017);
(3) Sunlight is useful for plants photosynthesis, but not necessary (Wynn et al., 2017);
(4) Sunlight helps plants grow by keeping them warm (Wynn et al., 2017);
(5) Soil provides food for plants (Wynn et al., 2017);
(6) The stars shine because of the light that is reflected from the sun (Rayla & Rayla, 1983);
(7) The center of the universe is the Sun (Korur, 2015).
(8) The center of the universe is Milky Way (Korur, 2015);
(9) Galaxies are constant, do not change their size (Korur, 2015);
(10) The stars reflect the incoming light from the Sun (Korur, 2015);
(11) Burning produces no invisible gases (Sadler & Sonnert, 2016);
(12) Boiling point varies with the amount of the material (Sadler & Sonnert, 2016);
(13) The Sun is the biggest planet from the solar system (Tatar, 2011);
(14) All solid bodies have a definite shape (Tatar, 2011).

Data collection and program implementation

Data collection took place in a paper-and-pencil session during the regular hours of a course in science, which was a compulsory one for the third years students enrolled in the kindergarten and elementary school teaching specialization. Students were asked for their consent to gather the data and given a bonus at their final grade of the seminar in the science teaching course. They could also choose to anonymously fill in the scales and had the choice of not completing them at all. The same scales were given in both pre-assessment and post-assessment sessions, with three-month distance between the two assessments. The order of the items and questions were changed in the post-assessment session. Afterwards, the data was introduced and analyzed in the SPSS program. Table 6.2 below summarizes how we applied the intervention guide described above and on which specific topics we focused on. The guide was implemented during the regular seminar classes conducted by the researcher. Each science seminar included a power point presentation of the specific topics of photosynthesis, solar system and properties and changes in matter. Also, each class had specific tasks for students to accomplish, like reading and understanding a scientific text, making a conceptual map, developing and implementing an experiment, design a science typical lesson plan or a 5E lesson plan or making a demonstration in science. The power point presentations had images and sketches to help students grasp the main concepts and included videos to support students' understanding of the science content. The seminar classes were conducted by the research, while the course was taught by an expert teacher in the field. All seminars have been verified by the course owner, who is a professional with a lot of experience in the field. As the seminars require compulsory attendance, students had to attend at least 80% of the seminars to sit for the final exam. Therefore, lists of those present at each seminar were drawn up. This helped to avoid losing participants and to ensure that students completed the required content.

Table 6.2

Program implementation

Timeline	**Intervention duration**	**Intervention topics**	**Intervention approach**	**Post-test**
1st meeting – students filled in the scales at the first meeting	12 hours: **2 hours** pre-assessment + **8 hours** intervention (2 hours for each	Photosynthesis	Students took part in typical seminars hours (12 per semester)	Last meeting
Written consent on the 1st page of the assessment scale	topic + 2 hours final review before the exam + **2 hours** post-assessment	Solar system	The 56 students (experimental group) from the intervention group were divided in 3 groups. The control group had 33 students. Each group had 2 hours seminar per week Initially they had to follow their alphabetical order group – but sometimes they mixed up	Written consent on the 1st page of the assessment scale
Students wrote their names to receive a 0.5 points bonus at the final grade. Those who did	TOTAL 12 hours distributed over a period of 6 weeks	Matter		Students

not want the bonus were asked to write a 4-digit number code formed from their birth.	(meetings were every 2 weeks).	(properties in matter, changes etc).	Typical seminar hours in science didactics – methods and strategies (at the course) + seminars (experiments, conceptual maps, inquiry learning) PPT for each topic with images, videos and text to read.	wrote their names to receive a 0.5 points bonus at the final grade.

6.4 Findings

6.1 Demographic characteristics

The sample of the study was homogenous and that means that all the participants were 3rd year students who were preparing themselves to become preschool and elementary school teachers, at the same faculty. The mean age of the participants was 21.67 and 58.9% come from urban areas while 41.1% from rural ones. Although all students were studying at the same faculty, the ones included in the experimental group were studying in a big urban university city while those from the control group were students in smaller town. Although the courses taken by both groups of students were the same, those in the control group had a different frequency of classes.

6.2 Pre-test / post-test - independent samples t-test analysis

The pre- and post-test analysis below (Table 6.5) shows that, overall, the intervention program proposed in this study has proven effective. The MDS instructional approach used had influence students' metacognitive awareness and science misconceptions and the study hypotheses cannot be rejected. Students who benefited from the MDS instruction (n=56) have different metacognitive awareness and science misconceptions levels compared to those who were not included in the formative program (n=33). Although initially students from experimental and control groups did not differ in their metacognitive awareness scores, after the intervention the groups had statistically significant different scores on this variable, with t=2.533 (p=0.013), a mean difference of 9.360 and an effect size of 0.554. The differences in science misconceptions scores are even higher than those on metacognitive awareness. For science misconceptions, the mean difference of students from experimental and control group is 2.944 (p=0.000) with an effect size of 1.705. Interestingly, the scores for the variable "repeating" were significantly different in the pre-assessment session and become insignificant in post-assessment. Although, there were significant differences between our two groups on metacognitive strategies in the pre-test ($t=10.519$, $p=0.000$) and post-test assessments ($t=3.670$, $p=0.000$) and on information management strategies ($t=2.099$, $p=.039$; $t=3.445$, $p=0.001$). Except for repeating, metacognitive strategies and information management strategies, there were no statistically significant differences between the groups (experimental and control) in the pre-test assessment. The groups were similar in the following learning strategies: organizing, elaborating, construct connectivity, monitoring, evaluating, planning, comprehension monitoring, and debugging strategies. Also, there were no differences in participants' declarative, procedural and conditional knowledge. In the second assessment, statistically significant differences were found in organizing, elaborating, construct connectivity, monitoring, evaluating, planning, comprehension monitoring, and debugging strategies.

Table 6.5

Pre-test / post-test scores

		Pre-test					Post-test				
		M	SD	t	Sig	d	M	SD	t	Sig	d
Metacognitive awareness	EXPERIMENTAL	200.857	16.587	1.294	.199	.286	210.482	16.748	1.705	.013	.554
	CONTROL	196.242	15.658				201.121	16.999	2.533		
Science misconceptions	EXPERIMENTAL	7.928	2.206	-278	.782	.061	11.035	1.501	8.035	.000	1.705
	CONTROL	8.060	2.090				8.090	1.926			
Construct connectivity	EXPERIMENTAL	18.607	3.420	1.433	.155	.323	19.929	2.743	4.725	.000	1.022
	CONTROL	17.606	2.726				17.061	2.806			
Monitoring, evaluating, planning	EXPERIMENTAL	33.929	4.932	1.690	.095	.412	35.554	4.663	4.691	.000	1.029
	CONTROL	32.121	4.768				30.758	4.650			
Organizing	EXPERIMENTAL	31.143	3.956	-1.686	.095	.372	32.446	3.968	5.098	.000	.083
	CONTROL	32.576	3.725				28.394	2.936			
Elaborating	EXPERIMENTAL	26.679	4.469	-1.192	.237	.261	31.679	3.723	8.892	.000	1.932
	CONTROL	27.848	4.480				24.212	3.998			
Repeating	EXPERIMENTAL	24.732	4.837	-3.444	.001	.770	25.911	4.358	-1880	.063	.408
	CONTROL	28.212	4.174				27.758	4.671			
Metacognitive strategies	EXPERIMENTAL	13.482	2.486	10.519	.000	.618	14.768	2.587	3.670	.000	.811
	CONTROL	11.061	2.091				12.727	2.440			
Declarative knowledge	EXPERIMENTAL	31.607	3.273	1.905	.060	.418	11.036	1.501	3.007	.003	1.705
	CONTROL	30.242	3.250				8.091	1.926			
Procedural knowledge	EXPERIMENTAL	15.482	2.366	1.845	.068	.413	32.464	3.081	4.398	.000	.649
	CONTROL	14.576	2.000				30.333	3.470			

Conditional	EXPERIMENTAL	19.268	2.276	-.070	.945	.015	16.357	1.958	1.795	.076	.957
knowledge	CONTROL	19.303	2.352				14.424	2.077			
Planning	EXPERIMENTAL	27.000	3.501	.214	.831	.043	20.143	2.393	3.121	.002	.391
	CONTROL	26.848	2.706				19.182	2.518			
Comprehension	EXPERIMENTAL	24.821	3.422	.522	.603	.117	28.643	3.000	3.224	.001	.695
monitoring	CONTROL	24.455	2.785				26.667	2.677			
Information	EXPERIMENTAL	40.375	3.730	2.099	.039	.464	26.679	3.128	3.445	.001	.697
management	CONTROL	38.697	3.486				24.606	2.806			
strategies											
Debugging	EXPERIMENTAL	20.554	2.544	.141	.889	.030	41.554	3.511	2.098	.039	.757
strategies	CONTROL	20.485	2.017				38.909	3.476			
Evaluating	EXPERIMENTAL	21.750	2.881	.182	.856	.040	21.482	2.248	2.464	.016	.466
	CONTROL	21.636	2.782				20.485	2.017			
Knowledge of	EXPERIMENTAL	66.357	6.127	1.598	.114	.346	23.161	2.557	3.443	.001	.537
cognition	CONTROL	64.121	6.781				21.758	2.658			
Regulation of	EXPERIMENTAL	134.500	12.487	.933	.353	.210	68.964	6.421	3.934	.000	.746
cognition	CONTROL	132.121	9.930				63.939	7.026			

6.4 Between-subjects analysis: experimental group

Although we compared the scores between experimental and control groups, we performed a between-subjects analysis for the experimental group that received the MDS intervention to see how their scores in metacognitive awareness and science misconceptions have changed after attending the MDS classes. Results for the metacognitive awareness and science misconceptions are presented in table 6.6.

Table 6.6

Between-subjects analysis: metacognition and science misconceptions

Variable	Pre-test		Post-test		t	Sig.	d
	M	SD	M	SD			
Metacognition	200.857	16.587	210.482	16.748	4.336	0.001	0.579
Science misconception	7.929	2.206	11.036	1.501	9.619	0.001	1.285

The pre-test analysis shows significant differences in metacognitive awareness scores between the pre-test (M = 200.857; SD = 16.587) and post-test assessment (M = 210.482; SD = 16.748), at a p value lower than 0.001 with t (55) = 4.336. The effect size of the difference identified is 0.572, which is high and indicates that metacognitive awareness scores increased with 0.57 standard deviation from the pre-test assessment to the post-test assessment. This means that the differences identified due to the intervention have practical statistical significance.

Significant differences at a p value lower than 0.001 have been observed for science misconceptions scores between pre-assessment (M = 7.929; SD = 2.206) and post-assessment (M = 11.036; SD = 1.501). An effect size higher than 1 standard deviation is identified for science misconceptions scores between the pre-test and post-test assessments (d=1.285).

Table 6.7

Between-subjects analysis: construct connectivity, MEP, LIST and metacognition knowledge and regulation

	Pre-test		Post-test		t	Sig.	d
Variable	M	SD	M	SD			
Regulation of cognition	134.500	12.487	141.518	11.057	4.341	0.001	.580
Knowledge of cognition	66.357	6.127	68.964	6.421	3.144	0.001	.420
Constructivist connectivity	18.607	3.420	19.929	2.743	2.808	.006	.375
Monitoring, evaluating, planning	33.929	4.932	35.554	4.663	2.299	.003	.307
Organizing	31.143	3.956	32.446	3.968	2.754	0.001	.368
Elaborating	26.679	3.956	31.679	3.968	10.066	0.001	1.345
Repeating	24.732	25.911	25.911	4.358	2.138	0.001	.286
Metacognitive strategies	13.482	2.486	14.768	2.587	3.107	.058	.415

In the case of the experimental group, significant differences were found between all the variables included in the study. The mean scores for knowledge of cognition, regulation of cognition, constructivist connectivity, monitoring, evaluating and planning, organizing, elaborating, repeating and metacognitive strategies significantly increased after implementing the formative program. The highest difference was for the elaborating learning strategy for which the mean increased from 26.679 to 31.679 with an effect size of 1.345. The smallest differences were identified for the variable "repeating" (d= 0.286) followed by monitoring, evaluating and planning (d=0.307), organizing (d=0.368) and constructivist connectivity (d=0.375). The size effect coefficient for these variables is considered small while for metacognitive strategies, knowledge of cognition, and regulation of cognition we got a medium effects size. A large effect size was found for elaborating (d=1.345).

6.5 Students' explanations of photosynthesis, properties of matter and solar system

Because we want to understand how teacher candidates explain photosynthesis, properties and changes in matter and what they know about the solar system, they were asked to explain why they chose their answer at each true-false statement. This also helps reduce the likelihood of randomly choosing an answer. In table 6.8 we present a selection of their answers.

Table 6.8

Students' explanations of the chosen answers

Topic	Pre-test explanations	Post-test explanations
Photosynthesis	Plants get their nutrients through leaves and energy from the soil.	Through photosynthesis plants create glucose.
	Through the root, water and substances are extracted from the soil. Salts are extracted from the soil. Plants need light for development, photosynthesis helps them to develop.	Plants make their own food through photosynthesis.
	They extract their food from the soil.	
	Because the plant receives food from the soil through the roots and eats it to grow big and beautiful.	The soil supports the plant, but it produces its own food.
	Plants extract minerals and nutrients from the soil through their roots.	A plant needs carbon dioxide, light and water to make her own food. Plans are autotrophs.
Solar system	The stars are charged with energy from the Sun.	Stars have their own light.
	Stars are celestial bodies without light and heat of their own.	The Sun is a star.
	Stars reflect light from the Sun.	The Sun is a star and has its own light.

	The Sun is reflected at night by the light of the stars.	Stars are celestial bodies with their own light and heat. And the Sun is a star.
	The sun shines because it burns.	The Sun is a star, so it has its own light and heat.
Properties and changes in matter	The body can change its shape.	The molecules of solids make them have the same shape.
	Solids change shape. For example, plasticine is solid but changes its shape.	If they are solid, it means that they have their own shape.
	I am sure that not all solid bodies have a definite shape.	Solids have a definite shape, liquids do not.

The analysis of the students' answers, together with the quantitative analysis allow us to see how their answers changed. In the pre-test assessment, none of the students mentioned that plants are autotrophic organisms that make their own food. Most believed that plants get their food mainly from the soil, through their roots. Although they mentioned that light is important for plants, they didn't know to explain how light is used by the plants. In the post-test assessment, some of the students mentioned that plants are autotrophic organisms that make their own food using light, cardon dioxide, water and other minerals. They also mentioned that a plants' energy is produced through the photosynthesis process and that soil sustain a plant but it's not the source of its food. Students also understood that Sun is a star with its own energy and that stars shine because they have their own light and do not shine because they reflect the light from the Sun. Moreover, when explaining why solids have their own shape some students used the term molecules in their explanations, a term that did not appear in any of the pre-test explanations.

6.5 Discussions and conclusions

Approaching science misconceptions and metacognitive awareness in preschool and elementary school teacher candidates using a deep-strategic-metacognitive instructional model has proven to be effective. Although there is research showing that both deep and metacognitive learning strategies enhance student' deep understanding of science concepts (Camarao & Monterola, 2021; Goren & Kaya, 2023; Jing, 2006; Wagaba, Treagust, Chandrasegaran & Won, 2016), the research integrating these two strategies with strategic approach is completely lacking. To our knowledge, this is the first study to include all the three learning strategies into a coherent and easy-to-implement model that has proven its efficacy in increasing metacognitive awareness and decreasing science-related misconceptions in elementary school teacher candidates.

The metacognitive-deep-strategic (MDS) instructional model focuses primarily on increasing students' metacognitive awareness in science and secondary on decreasing their science-related misconceptions. The deep approach promotes learning strategies like relating the new information to prior knowledge, using the information in different contexts and using strategies like paraphrasing and summarizing. Strategic learning strategies are important for students because they want to make sure that their grades are high. Therefore, they are interested in how they will be assessed, what topics are to be covered for grades and what are the resources which the teacher makes available to the students. The deep and strategic learning approaches are cognitive learning strategies while metacognitive ones represent higher-order learning strategies. Both types are needed to ensure that students will be able to comprehend deeply science concepts and to use them in their everyday life or real-life problems and situations. Metacognitive strategies allow students to plan, monitor, adjust and evaluate their learning process and the learning results.

In this study we used several scales to assess metacognition in students. Among these were the MAI, the LIST and 2 dimensions of the Self-Efficacy and Metacognition Learning Inventory- Science: construct connectivity and monitoring, evaluating and planning. Although all these are self-reported scales, we are highly confident that they were the best choice for assessing metacognition in teacher candidates. The assessment of science misconceptions through true-false items, although questionable by some researchers, was a suitable assessment scale in which we introduced open ended items that asks students to explain their choices, to reduce the percentages of random selection. Thus, those who chose true as an answer but did not offer the correct explanation were rated as false/wrong answers.

The MDS instructional program proposed here seems to have a high impact on students' misconceptions in science, with a big effect size of 1.705. The science topics covered through the MDS program are photosynthesis, solar system and matter properties. It is important to mention that the science misconceptions targeted in this study are easy-to-change misconceptions. This means that to modify these misconceptions students had to change or eliminate links between their knowledge and not to restructure the knowledge base around new principles (Dunbar et al., 2007). This might explain the high effect size that the program had on students' science misconceptions.

For future research, it is recommended to focus on higher samples of students, from different universities, and cover a wider range of topics and some hard-to-change science misconceptions. In addition to these recommendations, it would be suggested that multiple-choice or problems tests should be used to offer a more detailed comprehension of science misconceptions.

Metacognitive strategy-based instruction could be a challenge in the context of the current educational system. This is because the science curriculum is vast and contains many topics that need to be covered in a relatively short time. And teaching with metacognition takes time. In addition to time, it could be a difficult task for some teachers who find it difficult to introduce metacognition into their daily teaching. Because teaching science involves using a wide variety of methods, it can be difficult to find a single, simple way to teach with metacognition. And this might be one of the reasons why metacognition is not considered in science teaching. Given these shortcomings, in the following chapter we proposed and test the effect of refutational texts on science misconceptions, a strategy that can be easily implemented in any science classroom and with students of different ages.

CHAPTER 7. The impact of refutational texts, expository texts, and textbook-based texts on science misconceptions and understanding

7.1 Theoretical framework

7.1.2 Photosynthesis misconceptions

The concept of photosynthesis is related to many misconceptions because is counterintuitive to believe that plants make their own food from several resources (Mikkila-Erdmann, 2001). Photosynthesis misconceptions in both children and adults have been widely documented. If not treated appropriately, these misconceptions that develop in small school children will be found in college students as well. In short, photosynthesis can be considered as the conversion of water and carbon dioxide into oxygen and a plant's food. However, the process is not easy to understand, because it involves matter in different states of aggregation. Driver and her colleagues (1994) point out that what students must understand is that the solid matter of carbon is presented in the carbon dioxide (a gas) that is converted into sugar by plants (solid, but solution). The process of carbon dioxide conversion into sugar involves hydrogen (gas), water (a liquid) and sunlight (light energy). Photosynthesis is somehow a counterintuitive process since the idea that plants get their food from the soil is widespread. This might be because individuals used soil for seeds planting because it was the most accessible way. However, with technological development, it could be easily observed that plants and seeds grow in water and wadding as well. The heterotrophic view of plants feeding still exists although both children and adults have experience with seeds and plants that grow in water or wadding and despite the formal teaching and education. It is more intuitive to believe that plants take their food (water, minerals) from the soil and that these directly contribute to the photosynthesis process. Despite of using guided discovery strategy in teaching photosynthesis, Barker and Carr (1899a; 1998b; 1998c) show that 42% of students aged 13-18 years old believe that photosynthesis is the process of making-food, 19% argued that photosynthesis is a process of producing carbohydrates and a slight of 3% consider it as a process of storing energy.

There are a series of common misconceptions regarding photosynthesis. When looking at how children define food, researchers (Roth et al., 1983) found that they consider water and fertilizers as being food for plants. However, neither water nor fertilizers are food for plants because they do not directly provide energy. Another common misconception of photosynthesis is that plants get their food from the soil through the roots. Although water, nitrates (for the synthesis of protein) and magnesium (to produce chlorophyll) which are taken from the soil are vital for a plant's food production, they are not the food itself.

Canal (1999) and other researchers (Anderson et al., 1990; Dimec & Strgar, 2017; Haslam & Treagust, 1987; Käpylä et al., 2009; Radanovic et al., 2015; Svandova, 2014) identified the most common misconceptions of plant nutrition in primary school children are: (1) Plant nutrition means the process of plant feeding; (2) Plants feed themselves through the water and minerals taken from the soil; (3) The plants' health depends on the sunlight; (4) The breathing process in plants means air inhalation and exhalation.

7.1.2 Solar system and earth-related misconceptions

Given the fact that even physics students hold misconception about how seasons are formed, we would expect to also find them in kindergarten and elementary school pre-service teachers. Dunbar and colleagues (2007) offer the well-known example of physics students in Harvard who consider that season are formed because of the earth's distance from the sun and of the highly elliptical orbit of the Earth around the Sun. As Jelinek (2021) emphasized, the idea of a flat Earth forms based on children's everyday life experiences. However, with exposure to the correct information, this wrong conception about the earth's shape should change. Although this happens and children learn that the Earth has a spheric shape, it is hard for them to understand why humans do not fall from the Earth (the gravity concept). Jelinek emphasized that although misconceptions of gravity and Earth shape change with children's age, they persist in 10-year-old children.

7.1.3 Light-related misconceptions

Explaining light-related phenomena in scientific terms seem to be hard for both students and teachers. Uzun and colleagues (2013) showed that 8th grade students, 11th grade students and student teachers offered incorrect explanations related to light and vision. Moreover, they had similar wrong explanations, and this indicates that in general misconceptions remain unchanged from primary to university school levels. Identifying students and teachers' misconceptions related to light has a variety of advantages. Two of these benefits have been emphasized by Pompea and colleagues (2007) who argued that light-related misconceptions could be useful in designing instructional materials and teacher professional development programs. Analyzing the relevant literature on light and optics misconceptions, Pompea and colleagues described how the Hands-On Optics National Science Foundation was developed starting from the following misconceptions identified in students: (a) light reflects off mirrors and smooth surfaces; (b) black objects do not reflect any light, that is why they are black; (c) to see your entire body in a mirror you need a five-foot tall mirror if you are five feet tall; (d) the further you move from a mirror, the more you can see yourself in a mirror; (e) light doesn't travel, it stays in a mirror during reflection; (f) the image you see in the mirror forms on its surface; (g) when light shines on an object, we can see it; (h) mirrors reflect all light that shines on their surfaces; (i) light always travels in a straight line; (j) light travels very fast; (k) to magnify objects as much as you want, you can use a telescope; (l) the focal point of the lens is the place where an image is always formed; (m) polarizing filters are only dark plastic or glass; (n) all radiation is harmful; (o) lasers emit tight, parallel beams of light.

Djanette and Fouad (2014) identified a series of misconceptions hold by life sciences and nature students related to light found. They used concept maps to identify them and among the most relevant misconceptions related to light were: (a) we see objects because light travels from the eyes to objects; (b) light illuminates the object so we can see them; (c) light travels to the eyes and that is how we see. While light-related misconceptions can be found in approximately the same form across different cultures, as indicated in Fetherstonhaugh and colleagues' study (1987), the effective reconstruction/modification strategies should be tested with students from different grades, specializations and with different demographic characteristics.

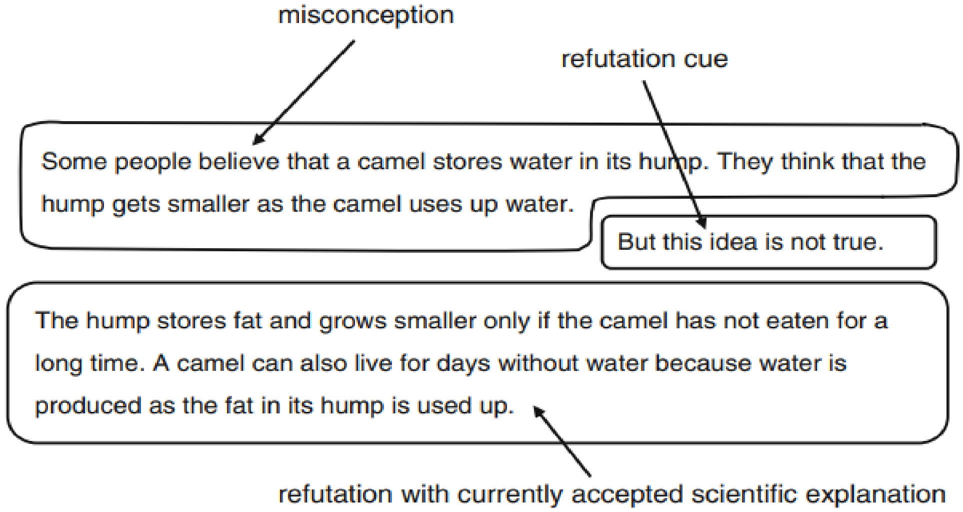
Blizak and colleagues (2009) investigated light-related misconceptions in a high sample of Algerian 1st year university students (246 students). Their study revealed that only 45% of the students had developed an adequate scientific concept about light. Although the authors used a high sample and mentioned that participants were 1st year university students who studied optics in their secondary school years, it would have been useful to mention their field of specialization.

7.1.4 Refutational texts, expository texts and textbook-based texts in science

Refutational expository texts are often successfully used to change wrong concepts in science-related topics. These types of texts involve presenting a science misconception, refuting it and describing an alternative explanation so the misconception can be overcome. Otherwise said, a refutational expository text presents common science students' misconceptions and brings arguments that sustain the scientific or the alternative scientific perspective (Hynd, 2001). Hynd (2001) argues that the refutational text-based perspective involves the intentional reorganization of knowledge and it's in line with different theoretical perspectives found in literature (Carey, 1992; Chi, 1992; Thagard, 1992). Although some authors use refutational texts and conceptual texts interchangeably, Tippett (2010) argues that there is a difference between these two terms. While refutational texts include specific misconceptions, a clear statement that these are not in line with accepted scientific explanations and they offer alternative explanations to these misconceptions, conceptual texts offer scientific information that might be or not related to specific science misconceptions. He offers a schematic definition of what refutational texts look like, presented in the below figure.

Figure 7.8

Tippett' refutational texts components (Tippett, 2010, p. 953)



The research conducted by Will and colleagues (2019) shows that undergraduate students included in a refutation-text condition offer more and accurate explanations of different scientific concepts and process. The science topics included in the Will and colleagues' study are similar to those included in our study, like "Seasons are caused by the Earth being closer to the Sun in the summer than in the winter" or "If you drop two balls of the same size but one weighs twice as much, the heavier ball will hit the ground first". Will and colleagues offer detailed descriptions of the refutational, and expository texts used in their study, an asset given the fact that most studies did not include in their published articles all these details.

Given the contradictory results of some studies, the effect of refutational texts on science misconceptions needs to be further investigated. The misconceptions found in our study are like those found in the literature on photosynthesis (Driver et al., 1994; Haslam & Treagust, 1987; Roth et al., 1983), light (Aydin et al., 2012; Blizak et al., 2009; Djanette & Fouad, 2014; Pompea et al., 2007), and Earth and gravitation (Dunbar et al., 2007; Vosniadou & Brewer, 1990). Using three types of science texts, our aim is to check the effectiveness of these texts on reducing science misconceptions. This study is one of the few ones that uses these three types of texts and a mixed-research design to identify and change science misconceptions in prospective preschool and primary school teachers.

7.2 Research hypotheses

The research hypotheses tested through this study are the last ones of this thesis:

H1: Refutational texts have a higher impact on reducing teacher candidates' level of science misconceptions compared to expository texts and textbook-based texts.

H2: Expository texts have higher impact in reducing teacher candidates' level of science misconceptions compared to textbook-based texts.

7.3 Methodology

Participants

Prospective kindergarten and elementary school teachers were included in this research. We had 72 students in the Light topic classes, 76 in the Gravitation theme and 80 in the Photosynthesis theme classes. Students were in their last year of undergraduate studies (3rd year), on the last semester, preparing to become teachers in either kindergarten or elementary school. Their mean age was around 21 years old, all being females. We didn't have any male student included in this research (which is quite typical for the specialization of pre-service kindergarten and elementary school). All the students were from the same university but most of them studied in the same big urban area. In one intervention group (the textbook-based group) were included students from a different urban area who were following the courses of the same university. The intervention lasted the same for these students although they attend a 4-hours class three time during the semester.

The participants were divided into three groups based on their family name and the first group comprised students from A to D (30 students), the second group from D to M (31 students) and the last one from N to Z (30 students). Although the main rule of dividing students into the three groups was their family names, some of them changed their groups because of real reasons. Those students who did not have either the pre-test or post-test assessments were excluded from the study. From all 91students enrolled in the 3rd year of study, some did not attend the science course at all, although it is a compulsory one, and some were excluded from data analysis because they attended only the final examination and did not participate in the intervention. The final sample had 72 students for the light topic, 80 for photosynthesis and 76 for the gravitation and solar system topic.

Instruments

The instruments used to measure students' misconceptions in both pre-test and post-test are synthesized in the table below.

Table 7.2

Pre-test and post-test assessment scales

Pre-assessment	Items	Measurement scale
1.Light assessment test	5 items	Multiple-choice
2. Photosynthesis assessment test	10 items	True-false and multiple-choice items

3.Solar system and gravitation test	10 items	True-false and multiple-choice items
Post-assessment	**Items**	**Measurement scale**
All topics	10 items	Multiple-choice questions

It is important to mention that higher scores on each test indicate higher levels of understanding in the topic being assessed and lower levels of science misconceptions. So, the lower the score on the scientific topics tests the higher are the scores of science misconceptions. All the assessment instruments are found in the Annexes. The final scores for photosynthesis and gravitation pre-assessment tests and the one of the final post-tests were computed by adding the scores of each item. Students received 1 point for each correct answer and the maximum score they could get was 10, while the minimum one was 0. For the light pre-assessment test students got 2 points for choosing the right answer from the ten options they had and another 8 points for choosing the right answer at four items (2 points for each correct answer).

Data collection

Knowing that student's attendance at classes is not constant, we chose to assess and teach each theme during one teaching session. This way we avoided losing participants. This means that we firstly assessed students' misconceptions about light and then started the light topic classes. Then we assessed and approached misconceptions related to photosynthesis and last ones those with solar system and gravitation. Every test and task done in the class was rated and students received points for each task they solved at seminars. They had three tasks on each of the three topics included in the study (including the pre-assessment tests) and each task was graded with 1 point (they automatically received 1 point which was added to the 9 final points for the laboratory tasks).

The 4 hours intervention for each topic is illustrated below.

Table 7.3

Intervention program implementation

Duration	**Program implementation**
2 hours	❖ <u>Light pre-assessment test.</u> ❖ Reading different types of texts about light (refutational, expository or textbook). ❖ Demonstrations using a light pointer. ❖ Conceptual map on light and vision.
2 hours	❖ Students had to fill in a conceptual map based on the text they read a week before. They had access to the text to remind them the information.
2 hours	❖ <u>Photosynthesis pre-assessment test.</u>

	❖ Reading different texts about photosynthesis (refutation, expository and textbook-based) and discuss about the information from the texts.
2 hours	❖ Students had to present a conceptual map and apply the 5E learning cycle on the photosynthesis topic, based on the text they read a week before. They had access to the text to remind them the information.
2 hours	❖ Gravitation pre-assessment test. ❖ Reading different texts about light and discuss about the information from the texts
2 hours	❖ Conceptual map on gravitation and a lesson plan on gravitation and solar system.
1-hour post-assessment test	❖ This was taken in the examination session of students.

7.4 Findings

7.4.1 Pre-test / post-test analysis

The whole sample of the students who attended the **light-related topic lessons** was made up of 72 students. The descriptive statistical indicators used to describe the sample are the mean, standard deviation, standard error of the mean, and the minimum and maximum scores. Descriptive statistics is illustrated for each group included in the study. Because the sample is homogenous, the demographic information includes only age and the city where the students study. The sample has 72 students divided into three groups and the textbook-based text group had 15 students who were studying the same specialization at the same university but in a different town. All the participants had the same tutors/instructors during the entire research. The mean age of the sample is 22.26 years. From the textbook-based group, 17 students were studying in another city, although in the same university and the same specialty and their mean age was 23 years old.

The entire sample of the **solar system and gravitation** topic included 76 students, from which 14 students studying in a different city. The mean age for the refutational texts group was 22.12 years old, for expository texts group 21.46 years old while for the textbook-based texts group the mean age was 23.16.

Pre-test – post-test ANOVA

Table 7.6

Pre-test and post-test ANOVA analysis

Topic of study	**Time of testing**	**F**	**Sig**
Light	Pre-test	.451	.639
	Post-test	12.238	.000
Photosynthesis	Pre-test	.491	.614
	Post-test	54.582	.000
Gravitation and solar system	Pre-test	.281	.756
	Post-test	25.744	.000

Light pre-test scores do not significantly differ between the three groups, with a p value of 0.639. this means that all three groups have similar knowledge about light before we implemented the intervention. The results of the post-test analysis for the light scores shows that at least two groups got different scores on the light assessment test, with F=12.238 at the p level of .000.
No significant differences were identified in the photosynthesis scores between the three groups in the pre-test assessment session, with F (2;77) = [0.491] and a p value of 0.614. In the post-test assessment, ANOVA shows statistically significant differences in the mean photosynthesis scores between at least two out of the three research groups (F (2, 77) = [54.582], p = 0.000).
The pre-test ANOVA shows no significant differences between the scores of the three groups included in the analysis: F (2;73) = 0.281, p = 0.756. After the intervention, at least two groups had statistically significant different scores, with the F (2;73) = 25.744, P = 0.000.
We further ran the multiple comparisons analysis to identify if all three groups have significantly different scores.
The multiple comparison analysis shows no significant differences in the light scores between the expository and textbook-based scores with a p value of 0.452. Light scores in the post-test assessment are significantly different between the students from refutational text group compared to expository and textbook-based groups. The eta square which tests for the practical significance of the identified differences show is 0.261, which means that the identified differences are of large sizes.
All groups differ significantly between their post-test scores in the topic of photosynthesis. The mean difference between refutational and expository texts was 1.355, p=0.000 and CI = [0.754, 1.956]. A higher difference was identified between refutational and textbook-based texts groups of 2.586, p = 0.000 and CI = [1.979, 3.193]. The lowest difference was between expository and textbook-based texts: 1.231, p = 0.000, CI = [0.607, 1.854]. Although it is important that we got significant differences between the different groups, we also checked if these differences have

practical significance. Thus, we calculated the eta squared coefficient using an online calculator (statology.org) and we got a value of 0.58. This means that the ANOVA analysis using the type of text as an independent variable explains 58% of variability in the scores of students, which is a very large effect size.

In the post-test, all groups got significantly different scores in the gravitation theme, with the higher difference being identified between the refutational and textbook-based groups.

The eta squared for the ANOVA above is 0.41 which means that 41% of the variability in the scores of students regarding gravitation are explained by our independent variable, more exactly by the type of texts used in the instruction.

7.4.2 Between-groups comparisons

The mean scores for each type of texts have changed between pre and post-test assessments, as can be seen in the tables below.

Table 7.8

Paired-samples t test

Topic	Type of text	t	Sig. (2 – tailed)	Cohen d coefficient
Light	Refutational	-9.294	.000	-1.938
	Expository	-7.333	.000	-1.189
	Textbook-based	-3.978	.000	-.812
Photosynthesis	Refutational	-10.039	.000	-1.864
	Expository	-6.062	.000	-1.189
	Textbook-based	-1.789	.086	-
Gravitation and solar system	Refutational	-9.684	.000	-2.019
	Expository	-7.169	.000	-1.355
	Textbook-based	-2.784	.011	-.568

Light topic results. Mean differences in the light scores of the students from the refutational group significantly differ between the pre-test assessment session (M = 5.043; SD = 1.186) and the post-test assessments (M = 8.130; SD = 1.140): t(22) = 9294, p = 0.000 and IC [3.776; 2.398]. The mean differences of the scores is 3.087, which is quite high. The effect size of the differences identified is illustrated below. The effect size of the identified difference is large, with a Cohen’s d coefficient of 1.938 (anything above 0.80 is considered a large effect size). This means that there is a difference between the pre- and post-test scores of almost 2 standard deviations. Significant differences can be observed between pre-test and post-test scores in the group of students who learned using light expository texts. Differences in the expository text-based group in the pre-test (M = 5.280; SD = 1.021) and post-test assessment (M = 7.760; SD = 1.127) are significant with a t = 7.333, p = 0.000 and a mean difference of 1.760. In the following we will check if the identified differences have practical significance by calculating the effect size. The Cohen's d value for the expository text group is 1.189 which, as for refutational group, is large and indicates that the score difference is slightly higher that 1 standard deviation. The differences in the textbook-based text scores between pre-test (M = 5.333; SD = 1.129) and post-test (M = 6.583; SD = 0.974) are significant, as illustrated in the below table. For the textbook-based text group we obtained the following results: t = 3.978, p=0.001. The effect size coefficients are illustrated below. The practical significance of differences between the pre- and post-test assessment of the students from the textbook-based text group is lower compared to the other two intervention groups, but still large (d = 0.812).

Photosynthesis topic results. Significant differences were found between the pre-test and post-test scores for the photosynthesis topic scores (t(28) = 10.039, p = 0.000, IC[3.321; 2.196]). Cohen's d coefficient is nearly 2 (1.864) which means a high effect size or a practical significance of the results. A difference of almost 2 standard deviations of the scores was identified between the pre- and post-test for students who were instructed using light refutational texts. The scores of the students who were instructed with expository texts in the photosynthesis topic differ significantly between the pre- (M = 5.615; SD = .941) and post-test assessments (M = 7.231; SD = .951): t(25) = 6.062, p=0.000 and CI[2.164; 1.067]. We've got a smaller effect size coefficient in the photosynthesis expository group scores (d = 1.189). No significant differences were identified between the scores of the textbook-based texts group between the pre-test and post-test (p = 0.086).

Gravitation and solar system. The students included in the refutational text group had statistically significant differences in the gravitation scores between the pre- (M = 5.130; SD = 1.180) and post-test assessments (M = 8.565 ; SD = 1.161): t (22) = 9.684, p = 0.000. The difference in students' gravitational scores between the pre-test and post-test is 2 standard deviations, which is considered a large effect (d = 2.019). Expository text group students got different scores in the pre-test (M = 5.429; SD = 1.168) and post-test assessments (M = 7.464; SD = 1.138) and this differences are significant at a p value of 0.000 with t(27) = 7.169. The effect size analysis shows that the differences of the gravitation scores in the expository text group between the pre-test and post-test are above 1 standard deviation (d = 1.355). The pre-test (M = 5.417; SD = 1.100) – post-test (M = 6.333; SD = .963) scores differ at a significance level of 0.011 with a t value of 2.784. However, the differences are much smaller compared to the ones identified in the other two groups (refutational and expository). Students' gravitational scores increased with 0.568 after the intervention, for the textbook-based text group.

CHAPTER 8. General conclusions and discussions. Original contributions. Limits and future research directions

8.1 Theoretical implications. Conclusions.

Metacognitive awareness and science misconceptions are two essential variables in science teaching and learning and should be considered by both researchers and practitioners. Although there is research showing that increasing metacognitive awareness in students leads to increased performance in science and an increased level of science understanding, the results are scarce for specific populations like preschool and elementary school teacher candidates. Moreover, few evidence-based models exist that are sufficiently detailed to be used in real educational settings by different practitioners teaching science in elementary school. This paper overcomes these shortcomings in the literature and provides a detailed analysis of the intervention procedures used, so that they can be adapted and applied by different researchers and practitioners, in other training programs.

Although metacognitive learning and metacognitive awareness has been a topic of debate for many years, the well-known model developed by Schraw and Dennison (1994) is still largely in use. Firstly, this is the case because it is a well-known model easily understood by both researchers and practitioners. Secondly, it has practical support through the very good operationalization of the model in the Metacognitive Awareness Inventory scale. Even though the MAI is a self-reported Likert-type scale, it allows researchers and practitioners to easily assess metacognitive learning behaviors and knowledge in the classroom context. And this involves being able to apply assessment measurements to large number of students in a short amount of time. These are the main arguments why the current study uses this model. The two main dimensions of metacognitive awareness and their implications on learning have been extensively studied, but little is known about their relationship with specific science misconceptions. Particularly, little is known about how metacognitive awareness relates to different levels of science misconceptions in preschool and elementary school pre-service teachers. And this research brings valuable knowledge within the field of metacognitive awareness and misconceptions in photosynthesis, properties of matter, light, and solar system and gravitation in teacher candidates. All the above-mentioned topics are essential in being able to explain a variety of daily experiences and use scientific knowledge in everyday life.

Conceptual development in science is an important research topic from several points of view. First, research can help practitioners to understand how they can facilitate science conceptual development and understanding in common educational settings. This means during typical teaching classroom hours with a high number of students (and sometimes limited materials to be used). Second, research can offer insightful explanations about why some students fail to develop correct concepts in science. Third, research into how science misconceptions can be overcome in practice is vital for teachers and for educational decision makers. Lastly, evidence-based research results and formative or training programs can be made available to practitioners (with detailed descriptions of these programs). In this study we cover most of these points related to the importance of studying conceptual development in students. We first briefly describe some theoretical perspectives on conceptual development. Then we explain why some students fail to develop correct concepts on specific scientific topics, addressing the theme of misconceptions in science. Along with the description of the general theories on science misconceptions we present several theoretical models that explain how science misconceptions are changed or overcome. Otherwise said, how conceptual change occurs. Although there are many theories explaining how conceptual change occurs and how science misconceptions are changed or overcome, there seems to be two main perspectives in which conceptual change theories can be divided: one that involves only cognitive dimensions of conceptual change (cold-based theories) and one that included emotions as well (hot-based theories).

All studies included in this paper bring their contributions to the development of the final MDS model tested here. The **1st study**, which was based on mixed-design research shows us that teachers tend to overestimate their metacognitive knowledge and skills when ask to fill in self-reported scales. However, when faced with a task that involved a vignette in which specific metacognitive impairments were presented, they had difficulty identifying these impairments. Moreover, they seem to equate metacognition with metacognitive regulation and have limited knowledge about the metacognitive knowledge dimension of metacognition. The **2nd study** brings valuable information about the predictive value of metacognition on science misconceptions. The results of this study indicate that metacognition can and should be used to decrease science misconception in teacher candidates. Increasing metacognitive knowledge would lead to a decrease in science misconceptions. The **3rd study** brings essential theoretical contributions to the literature showing how deep, strategic and metacognitive learning strategies interact to influence the level of science misconceptions. The analysis that included these variables revealed that although deep and strategic learning strategies have a slight direct impact on science misconceptions, their indirect impact is much higher when metacognition is included in the analysis. Otherwise said, deep and strategic learning strategies have a high impact on metacognition which has a strong impact on science misconceptions. When analyzing the impact of deep and strategic learning strategies on science misconceptions we can conclude that their effect is almost insignificant. However, when we introduce metacognition in the analysis as a mediator variable, we would see that the deep and strategic learning strategies influence science misconceptions through metacognition. In the **4th study** we tested the effectiveness of a formative program on science misconceptions of the elementary school teacher candidates. The results of this intervention are promising and reveal that cognitive and metacognitive strategies can be effective in reducing science misconceptions. Including metacognition in teaching might be sometimes a difficult decision because it has an impact on the number of topics that can be covered during a school year. Otherwise said, a smaller number of topics can be covered when teaching with metacognition. This shortcoming is overcome by the interventions focused on refutational texts, described in the **5th study**. Introducing refutational texts in science teaching does not influence the number of the topics covered and it can be easily introduced in the daily teaching of science. The impact of refutational texts on changing science misconceptions is quite hard, even on misconceptions hold with strong confidence. Compared to expository and textbook-based texts, refutational ones have a high impact on science misconceptions. The results of this study are in line with the ones found in the literature.

8.2 The Metacognitive-Deep-Strategic learning theoretical approach.

The model proposed and used in this research involves specific cognitive and metacognitive teaching and learning strategies. The path analysis conducted revealed that the best model that describes the relationships between metacognitive awareness, deep-learning strategies, strategic-learning strategies and science misconceptions is the one in which metacognitive awareness is a mediator variable. This means that although deep and strategic-learning strategies have a direct impact on science misconceptions, this is insignificant. However, when metacognitive awareness is included in the analysis, it seems that deep and strategic learning have a high impact on metacognitive awareness which in turn is an adequate predictor of science misconceptions. Using the statistical results of the path analysis, we developed an applicative model to reduce misconceptions levels related to photosynthesis, properties of matter and solar system and gravitation in teacher candidates. The proposed model includes specific deep-level, strategic-level and metacognitive-level learning strategies for teacher candidates to use in learning science-related content. The deep-level strategies involve connecting the new information with the old one to generate a meaningful understanding of the new information, using inferential and paraphrasing skills, and using the new acquired knowledge in different contexts. The strategic-level strategies ask students to use time management skills, study strategies skills, an effective cover of the syllabus and the use of specific strategies that ensures academic success. Metacognitive strategies focus on identifying and defining the task that needs to be solved, but also on monitoring, regulating and evaluating one's own learning and study results. This model was named MDS (Metacognitive-Deep-Strategic) and used in our intervention approach. Although one might think that using deep-level learning strategies contradicts with the use of strategic-level learning, this is not the case. Deep learning helps students to focus on understanding the information they need to and generate conceptual understanding. To acquire conceptual understanding and deep comprehension, deep-level strategies like paraphrasing, prediction, inferential skills and the application of knowledge to various contexts can be use. However, students are generally focused on their grades, meaning that they are interested in how they will be assessed, what topics the science course covers, and which topics need to be covered for their final evaluation. Therefore, we consider that is essential to introduce strategic-level learning strategies in our intervention approach since it is suitable for this specific group of interest: pre-school and primary school teacher candidates. As Biggs emphasized (1988), focusing on strategic learning means to focus on time management skills and study strategies that assure students that they are well-prepared for the final exam of the course. Thus, we made sure that the exam topics were covered effectively. Strategic-level strategies help students identify specific topics they need to get familiar with, but also specific strategies needed to approach those topics, like conceptual mapping, learning through inquiry (5E learning cycle), projecting and doing an experiment, planning a lesson or doing a demonstration. After ensuring that students are familiar with techniques like paraphrasing, predicting, applying knowledge to real-life situations (deep-level strategies), and they also know how they will be assessed and what topics they need to cover (strategic-level strategies), we instruct our students to plan, monitor, regulate and assess their learning. Otherwise said, we introduced metacognitive learning strategies. The model, although new to our knowledge, is not a revolutionary one. But because it improves metacognition and reduces science-related misconceptions, it deserves to be applied and introduced in the teaching preschool and elementary school teacher candidates. The model is described in detail and the intervention guide can be easily adapted and applied to preschool and elementary school teacher candidates in different years of study and even to beginning practice teachers in need for training programs on science teaching. The metacognitive, deep and strategic strategies introduced in this intervention program are easily to be used by teachers and students in the context of everyday science classes. It considers the specific methods used to teach science in elementary school (or the didactics of science) and specific elementary school science topics. Covering all the topics that teachers are expected to teach at pre-school and elementary school levels would be impossible. The reason of choosing topics such as solar system and gravity, photosynthesis, and matter properties is related to the frequency of misconceptions on these topics, documented in the literature. Understanding what photosynthesis is and how it occurs, or how can we explain the formation of the seasons is not difficult if we use the MDS model proposed in this paper. The misconceptions associated with these topics can be overcome using the metacognitive, deep and strategic learning skills described in this study.

8.3 Practical implications. Conclusions.

There are many strategies and methods that can be used in science teaching, and they can be find with a simple search on the internet and in various materials focused on science teaching. However, some of these strategies and methods have not been tested to see how much they contribute to the in-depth understanding of scientific concepts. Some are considered interesting by students and easy to use by teachers. However, the reality revealed by various national and international scientific assessments shows us that there is a high degree of illiteracy in science. Students have difficulties in understanding complex scientific concepts and applying them to various situations in their everyday lives. Increasing students' understanding of science-related concepts and process is a goal of every science curriculum and the integration of metacognition in science teaching is necessary. The intervention program developed and tested in this study proved to be effective in changing science misconceptions in preschool and elementary school teacher candidates. The program is described in detail, it is easy to be implemented in the everyday teaching of science with undergraduates' students and can be easily adapted to different science topics, not just the ones they were tested on. In the first step of the program, the one that focuses on establishing the task needed to be solved, teachers can add various tasks if they closely follow the formative guide for the next steps. The introduction of any additional elements in this program should be argued and tested. The introduction of any additional elements in this program should be argued and the program tested to see if it is effective after the operated changes. The intervention guide developed and tested in this research asks students to engage in learning science-related content and allows teachers to introduce videos, photos, graphics, power point presentations and any other useful materials of the platforms they find useful into their teaching approach.

The use of science refutational texts in teaching and learning, although proven to be effective in developing students' understanding of science concepts, usually becomes difficult to apply, and the main reason is the lack of such texts available to teachers. The content of science textbooks does not include refutational texts. In fact, many science misconceptions can be found in typical science textbooks. Although so far there is no real reason not to include refutational texts in science textbooks, they are sorely lacking. This is either because the textbook developers are not aware of the research in the field, or because they find it difficult to develop such texts and include them in the textbooks. However, considering their practical implications and effectiveness in reducing science misconceptions, they should be included in all science textbooks.

Although the literature documents the existence of many strategies and methods that are effective in decreasing science misconceptions, it seems that students still have many science misconceptions and difficulties in understanding science concepts. Science textbooks have many misconceptions despite their widespread use by both teachers and students. Other effective strategies in reducing science misconceptions might not be consistently used by teachers and this can be due to several factors. Among this, is the lack of teachers' familiarity with these strategies, or the difficulty of applying them because of the wide topics they must cover during a school year. Including refutational texts in science textbooks could be an easy and effective method to overcome the above-mentioned shortcomings. Enriching these refutational texts with metacognition might be even more effective in increasing students' understanding of scientific concepts. Moreover, the MDS intervention program proposed in this study should be tested with elementary school students and if effective, included at the end of different chapters and used to stabilize and deepen knowledge.

8.4 Limits and directions for future research

One of the limitations of the study relates to the control group used in testing the effectiveness of the MDS intervention program. It is recommended that in future research larger control groups to be used. In addition, it would be useful to test the effectiveness of the program with preschool and elementary school practicing teachers. The intervention program and guide should also be tested with different science misconceptions, apart from those proposed here.

Several comments should be made about the scales used to assess the variables included in this paper. Except of the science misconceptions scales used, which is an interval one, all other scales are Likert-type ones which are ordinal scales. Using parametric statistics with such scales is considered inadequate by some researchers. However, other argue that data gathered through Likert-type scales can and should be analyzed with parametric statistics especially when they have a composite final score. There is research showing that treating Likert-type data as ordinal and analyze it using non-parametric statistics does not offer results different from parametric analysis and may even lead to the loss of valuable statistical conclusions. Of course, using interval and ration scales would be recommended but this might be impossible or very difficult for measuring constructs such as deep learning, strategic learning and metacognitive awareness. A note is also needed regarding the tests used in the assessment of misconceptions. In further studies, true-false tests can be replaced by more efficient ones. However, this will increase the time needed for the pre- and post-assessment sessions. But it might bring valuable information.

The practical effects of the intervention program tested in this study might have been much bigger if we have used an experimental design instead of a cvasi-experimental one. However, for the topic treated in this study, using the cvasi-experimental design is of higher value because we showed how the program works in a real-educational setting, where a rigorous control of all variables is impossible (using a randomized sampling for instance). In real-life educational contexts, sometimes don’t even have access to a control group. However, we do not underestimate the value of purely experimental or laboratory research. On the contrary, their value is indisputable because they could help us better understand why some science misconceptions are extremely difficult to change and what are the mechanisms behind these hard to change concepts. Thus, this constitutes one of the future directions in which research on misconceptions in science should go: identifying the mechanisms behind conceptual change and translating them into effective teaching practices. So far, the results of such research are few and have not been tested in everyday teaching practice. Therefore, it becomes difficult for teachers to use them in their daily teaching practice.

For the intervention that used different types of texts to change students’ misconceptions in science the results indicated high effects of refutational texts, compared to expository and textbook-based ones. The lowest effect on changing science misconceptions was of the textbook-based texts. These results reveal the low impact of textbook-based texts on science misconceptions, despite the wide use of science textbooks, especially by beginning teachers. Research clearly indicates that teachers use textbooks to make their science lesson plans or to prepare themselves for teaching science, although they might not be the most effective resources. Several science misconceptions can be encountered even in science textbooks, and this makes hard the process of conceptual change. An effective alternative method for decreasing science misconceptions is the use refutational science texts. However, since metacognition is also essential in understanding science concepts and decreasing misconceptions, a future direction of research is to add metacognition in refutational texts. Creating refutational-metacognitive science texts could be an effective strategy to reduce misconceptions in science and one that can be easily applied in the context of everyday science teaching in the classroom.

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