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Investigation of cognitive and metacognitive strategies used by preservice science teachers exposed to explicit and peer tutoring reading strategies instruction

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Abstract

The study aimed to investigate cognitive and metacognitive strategies and products of cognitive and metacognitive processes that preservice science teachers engaged in while reading heat-temperature text after being exposed to no reading strategy instruction, explicit reading strategy instruction, and peer tutoring reading strategy instruction. This study differs from other strategy teaching studies in terms of determining the cognitive and metacognitive reading strategies used by individuals after being exposed to different types of reading strategy instruction, which can be especially used to improve conceptual understanding. This study employed holistic multiple-case study wherein preservice teachers were assigned to one of the three groups that received no reading strategy instruction (n = 9), explicit reading strategy instruction (n = 10), and peer tutoring (n = 10) based on their scores on Metacognitive Awareness of Reading Strategies Inventory and good communication among them. The content of strategy instruction included various domain-specific reading comprehension strategies used for activating cognitive and metacognitive activities that contribute to improving conceptual understanding and conceptual change. It was found that the diversity and frequency of using cognitive strategies and products of cognitive activities were the highest in the explicit strategy instruction group, and the metacognitive strategies and products of metacognitive activities were more diverse and frequent in reading strategy instruction groups compared to no strategy instruction group.

Keywords: Cognitive strategies, Metacognitive strategies, Strategy instruction, Conceptual change

Introduction

Some of the leading science educators (Norris & Phillips, 2003; Yore et al., 2004) have emphasized the role of reading science texts in raising scientifically literate individuals (Fang & Wei, 2010). Reading science texts is also supported by contemporary education reforms today. Reading science texts is seen as a powerful instrument to engage students' minds, encourage their conceptual understanding, support their questioning, and improve their scientific mental habits (Wellington & Osborne, 2001). Science text has linguistic and rhetorical features shaped by specific expectations for its genre. These prototypical features specific to the science text genre distinguish a science text from other texts of different genres (Uzun, 2001). Science texts are more objective in comparison to narrative texts, and the intensity of concepts in them is higher. They also include more words and technical terms and understanding them requires more prior knowledge (Jennings et al., 2014). Additionally, science texts contain new information, have special vocabulary, vary in terms of readability level, include abstract concepts, and the reader is expected to keep this information in mind. These properties of science texts can make reading comprehension difficult (Graesser et al., 2002; Vosniadou & Skopeliti, 2017). However, the fact that science texts are different from other text types in terms of language, meaning, and structure makes it difficult for students to understand what they read (McNamara et al., 2012). This is because reading comprehension is a complex cognitive skill that results in the reader's incorporation of information in the text into their prior knowledge and the explanation of a mental representation (Meneghetti et al., 2006). Reading comprehension is an active and

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complicated process that consists of (a) understanding the text, (b) organizing, improving, and interpreting meaningful connections from the text, and (c) using constructed meaning as appropriate to the type of text, purpose, and one's prior knowledge (Kintsch, 2013; National Assessment Governing Board [NAGB], 2012). To overcome difficulties in reading comprehension, various cognitive and metacognitive strategies need to be used (Djudin, 2017). Unfortunately, individuals are often unable to effectively use strategies (Blasiman et al., 2017; Glogger et al., 2012) and they have difficulty in changing their alternative conceptions with scientific conceptions (Dole & Sinatra, 1998). Therefore, there is a need for guidance or training on effective strategy use (Fiorella & Mayer, 2016). Students' awareness of what they know and their conscious use of strategy play a very significant role for academic success (Laskey & Hetzel, 2010; Xu et al., 2021). Additionally, metacognitive engagement while reading science texts supports monitoring and evaluating students' learning, and promotes scientific understanding (Zhang et al., 2015), and it improves students' problem-solving skills (Sandi-Urena et al., 2011). Based on this situation, in this study, it was aimed to teach cognitive and metacognitive reading strategies aimed at activating metaconceptual activities to improve conceptual understanding and eliminate misconceptions. In the teaching of reading strategies, direct instruction and peer instruction were included.

The study was based on social learning theory (Vygotsky, 1978). Teachers provide them with strategy instruction through support and modeling defined as scaffolding to occur learning within the student's zone of proximal development (Ness, 2011). In the present study, explicit reading strategy instruction and peer tutoring reading strategy instructional practices were included, and these practices are based on modeling and peer support methods.

Reading Comprehension, Conceptual Change, and Metacognition

While the reader is trying to understand and learn the concepts during reading, conceptual change occurs from time to time, because the reader's prior knowledge and the information in the text may not always be consistent. The conceptual change also includes becoming aware of the conflict between one's prior knowledge and the scientific explanation, and being able to construct a consistent and compatible conceptual understanding (Luque, 2003). High-level thinking skills need to be used for facilitating conceptual change (Sinatra & Pintrich, 2003). Metacognition, which includes an individual's awareness of one's prior knowledge and one's actively monitoring and regulating of one's cognitive processes (Hennessey, 1999), plays an active role in the individual's awareness of contradiction about scientific concepts and constructing conceptual understanding (Saçkes, 2010).

Metacognitive strategies play a significant role in improving conceptual understanding of scientific ideas (Choi et al., 2011; Nielsen et al., 2009; Wang et al., 2014) and in supporting conceptual change (Mikkilä-Erdmann & Iiskala, 2020). Moreover, metacognition allows students to question the information they have learned, think over the mistakes they have made, and become aware of their misconceptions (Quinn & Wilson, 1997). It can be said that the conceptual change process requires a learner to have metacognitive strategy knowledge and use metacognitive strategies to acquire metaconceptual awareness (Mikkilä-Erdmann & Iiskala, 2020). Conceptual change and metacognition research traditions have mostly developed separately, often without close interaction with each other (Mikkilä-Erdmann & Iiskala, 2020). Therefore, this study addresses cognitive and metacognitive reading strategies aimed at activating metaconceptual activities to improve conceptual understanding and eliminating misconceptions.

Reading in Science Education and Cognitive and Metacognitive Reading Strategies

Reading comprehension is a complex cognitive skill that results in the reader's incorporation of information in the text into their prior knowledge and explanation of a mental representation (Meneghetti et al., 2006). To comprehend science texts and interpret meaning, it is necessary to use various cognitive and metacognitive strategies (Djudin, 2017; Pilten, 2016) and be cognitively and metacognitively active while reading the texts (Yurttaş-Kumlu, 2016). Reading comprehension of science texts, especially finding, selecting, reading, monitoring, and evaluating various information sources, depends on readers' use of a variety of cognitive and metacognitive strategies (Djudin, 2017; Norris & Phillips, 2003; Wang et al., 2014; Yore, 2012).

Based on the purpose of using strategies, reading strategies can be classified into cognitive and metacognitive strategies. While cognitive strategies are needed to perform a task, metacognitive strategies are needed to understand how the task is performed (Garner, 1987). Cognitive strategies are rather important in terms of actively using mental processes to better understand the content of the text (Ahmadi et al., 2013) and learn and remember concepts (Leutwyler, 2009; Zohar & David, 2009). Metacognitive strategies are used to become aware of one's mental activities, monitor and evaluate them (Flavell, 1979; Gunstone & Mitchell, 1998), and ensure one's preregulation, direct one's attention, and selective attention and self-management while performing a task (O'Malley & Chamot, 1990; Vandergrift, 1997). Products of cognitive and metacognitive processes can be defined as verbal expressions or behaviors that are signs of cognitive–metaconceptual activities performed while reading the texts (Yurttaş-Kumlu, 2016). We cannot clearly observe the cognitive or metacognitive activity but we can infer from behavior in which the individual displays that one has performed a cognitive or metacognitive activity. These verbal expressions or behaviors are named as products of cognitive or metacognitive activities in this study.

As the term metacognition covers a wide range of mental processes, the term metaconceptual has been used to focus on metacognitive processes that are specific to concept learning (Mason & Boscolo, 2000; Wiser & Amin, 2001; Yürük, 2005). Specifically, metacognitive knowledge and activities that become active in the process of the conceptual change have been defined as the *metaconceptual knowledge* and *metaconceptual activities*, and these metaconceptual knowledge and activities have been classified as metaconceptual knowledge, awareness, monitoring, and evaluation (Yürük et al., 2009). This study focused on strategies and products of processes to activate metaconceptual activities.

Teaching Reading Strategies

Most of the challenges confronted in reading comprehension of science texts can be overcome with reciprocal teaching strategies, such as teacher modeling, peer interaction, and questioning (Pilten, 2016). One of the effective and frequently used methods in reading strategies instruction is explicit reading strategy instruction (Van Keer, 2004). Explicit instruction means that the teacher clearly teaches students about a strategy by explaining and demonstrating how to implement a particular strategy, explaining the benefits of strategy use, and supporting students in strategy implementation. This is called the WWW&H rule for strategy teaching, which stands for What to Do, When, Why, and How (Veenman et al., 2006). This instruction is based on explicit explanations, modeling, and guided practice (Rupley et al., 2009). Through this teaching, teachers help students implement strategies effectively (Veenman, 2011). This instruction is used to effectively teach cognitive (Rupley et al., 2009) and metacognitive strategies (Muteti et al., 2021). Additionally, this instruction can improve students' metacognitive monitoring, learning, transferring, and motivational skills (Zepeda et al., 2015).

Another most popular and well-studied approach to teaching reading strategies is reciprocal instruction. One of the types of this instruction used is peer tutoring (Paris & Hamilton, 2009). All class members are organized in tutor–tutee pairs and these pairs work in collaboration in peer tutoring (Calhoon, 2005). Peer tutoring can be thought of as a dynamic and enjoyable method that encourages participation and offers an alternative way of learning (Alegre-Ansuategui et al., 2018). Peer tutoring makes positive cognitive, metacognitive, affective, and social contributions for the tutor and tutee (Topping, 2005) and improves self-efficacy (Van Keer & Verhaeghe, 2005). Social contributions of peer tutoring are more prominent (Bahar, 2018). Additionally, peer tutoring helps students by explaining how to properly use their metacognitive reading skills and by providing guidance and support in the classroom (Halim et al., 2020). Peer tutoring can be beneficial not only for low achieving or struggling students but also for more successful or gifted students (Love et al., 2021). Moreover, there are studies that show the benefits of peer teaching in teaching metacognitive strategies in literature (Arco-Tirado et al., 2011; De Backer et al., 2012).

Purpose and Importance of the Study

Teachers have limited knowledge of cognitive and metacognitive reading strategies used while reading science texts (Ness, 2016), and they cannot use such learning practices effectively (de Boer, Donker & van der Werf, 2014; Morehead et al., 2015; Wexler et al., 2017). Teachers need support to overcome the problems of integrating reading into science class (Fang & Wei, 2010). In the literature on the instruction of reading strategies, there are studies on identifying the effect of classroom practices on reading, identifying effective reading strategies that increase students' reading comprehension, and determining the effect of teaching of single strategy use on success (Dole et al., 2009). Moreover, students who cannot use reading strategies effectively are less likely to perform conceptual change (Dole & Sinatra, 1998). Considering this problem, it was aimed to examine how preservice science teachers' use of the cognitive and metacognitive reading strategies and products produced following cognitive and metacognitive activities while reading science texts differed according to different reading strategies instruction methods in this study. In line with this purpose, by comparing the groups who were not exposed to any

reading strategies instruction, who were taught with explicit reading strategies, and who were provided with peer tutoring reading strategies instruction, this study sought answers to the following questions:
1. What are the cognitive strategies and products of cognitive processes that preservice teachers engaged in while reading a science text?
2. What are the metacognitive strategies and products of metacognitive processes that preservice teachers engaged in while reading a science text?

How teachers can ensure effective instruction on reading science texts in the best way is an important research topic (Baker et al., 2017). Studies about new and varied strategies and their combinations to achieve students' learning goals are limited, and these kinds of studies are needed (Laskey & Hetzel, 2010). Considering that one of the important problem of science education is misconception, there are no studies in the literature on teaching cognitive and metacognitive reading strategies aiming at improving conceptual understanding that have the potential to eliminate misconceptions. This study is important in terms of creating a basic framework related to determining the cognitive and metacognitive reading strategies used by individuals after being exposed to different types of reading strategy instruction designed to teach various types of strategies, which can be especially used to improve conceptual understanding. The findings from this study can provide some insight into the effectiveness of different types of reading strategy instruction in terms of their potential to activate various reading strategies and cognitive and metacognitive processes.

Method

Research Model

In this study, there were three groups that were exposed to three different instructional situations in terms of reading strategies. These three groups were compared in terms of cognitive and metacognitive reading strategies and products of cognitive and metacognitive processes used while engaging in various cognitive and metacognitive activities performed while reading a science text. The case study, which is one of the qualitative research methods, was used and multiple cases were used in this study. These three cases are the groups that did not receive reading strategies instruction, was exposed to explicit strategy instruction, and was exposed to peer tutoring strategy. Each group was considered as a case in this study. Considering the case study research design types in holistic multiple-case studies, each case is examined holistically in itself and then cases are compared with each other (Yıldırım & Şimşek, 2008). A holistic multiple-case study was used as the research method in this study. The design of the research is summarized in Table 1.

Table 1. Information about the research design of the study

Groups	Preinstruction	In-instruction	Postinstruction
No reading strategy instruction group (n = 9) Explicit reading strategy instruction group (n = 10) Peer tutoring reading strategy instruction group (n = 10)	Metacognitive Awareness of Reading Strategies Inventory (it was used to form the groups within the scope of the study).	Strategy teaching is not provided. Only science texts have been read. Explicit teaching of cognitive and metacognitive reading strategies that activate cognitive and metaconceptual activities Peer teaching of cognitive and metacognitive reading strategies that activate cognitive and metaconceptual activities	• Reading the heat-temperature text aloud and thinking aloud (each participant in each group read the text aloud and thought aloud) • Semistructured interview to determine the purposes of using the strategies while reading the heat-temperature text (it was used to determine the cognitive and metacognitive strategies and the products of cognitive and metacognitive processes that the groups engaged in and their purposes of being engaged in them while reading the text on heat-temperature)

Participants

This study was conducted with 29 voluntary preservice science teachers who were in their third year at the science education department of a university located in Ankara; 11% of the participants are male and 89% of them are female. The GPA of the participants at the university ranged from 2.14 to 3.4. While assigning preservice science teachers to one of the three groups, attention was paid to the fact that the mean scores of each group on Metacognitive Awareness of Reading Strategies Inventory (MARSI) was administered before the instruction. The mean score of all participants from the MARSI scale was calculated as 114 and the standard deviation was 13. Information about the mean score of MARSI scale of groups is presented in Table 2.

Table 2. Mean score of MARSI scale as pretest of groups

Groups	n	$\overline{X}\overline{X}$
No reading strategy instruction group	9	111.7
Explicit reading strategy instruction group	10	113.8
Peer tutoring reading strategy instruction group	10	115.2

Table 2 shows that the mean scores of each group from the MARSI scale as a pretest were close to each other. Additionally, the maximum diversity of the purposive sampling methods was employed in the formation of the groups. Each group consisted of participants who scored at different levels within themselves, that is, they were heterogeneous. Therefore, in terms of strategy use scores, the groups were heterogeneous in themselves and homogeneous between each other. Besides, convenient sampling was used considering the communication between the participants and the time allocated for the instruction provided for the effectiveness of the instruction.

Data Collection Tools

Metacognitive Awareness of Reading Strategies Inventory Scale

MARSI was developed by Mokhtari and Reichard (2002) and adapted to Turkish by Ozturk (2012), and its reliability coefficient was calculated to be 0.93. The scale was used in this study to form the groups.

Read-aloud and Think-aloud Technique

Read-aloud and think-aloud technique, which requires them to express what they are doing and thinking while performing a task (Yoshida, 2008), enables the readers to identify different cognitive strategies and metacognitive strategies during the process of performing the task (Cromley, 2005). This feature of this te chnique was implemented in this study to obtain detailed information about the reading strategies used by the participants and the purposes of using them while reading science text. The researcher modeled by reading force–motion and electricity texts to demonstrate how this technique is implemented.

Semistructured Interview Form on the Reading Strategies

It was used to identify the strategies used and products produced—following cognitive and metacognitive activities—as cognitive and metacognitive and determine the purposes of using them while reading a science text. The form developed by Kumlu (2012) consists of nine items. Two of these items are related to preparations before reading the science text. One item is related to investigating the purpose of using each strategy while reading. The strategies used by the participants while reading the text were observed and notes were taken by the researcher. Six items are aimed at identifying the strategies used for mental activities performed for reading comprehension and the text section in which these strategies are used. This interview form was administered after reading in order not to affect the participants' reading process of the science text.

Heat-temperature Text

The four-page text, which was prepared by Akgul (2010), was revised and used in this study. This science text consists of the definitions of concepts, such as heat exchange, heat, temperature, heat and temperature, heat and internal energy, specific heat capacity, and heat insulation, and the scientific knowledge about the relationships between concepts, tables, formulas, symbols, and figures. An expert on science education was consulted to examine the cohesion and scientific quality of this science text written about heat-temperature.

The aim of using this text was to determine whether the participants used the strategies that are thought to facilitate conceptual change after reading strategies instruction.

The Stages of Strategy Instruction

One of the three groups in this study was not exposed to any reading strategies instruction, and they just read the science texts that are related to force–motion, electricity, photosynthesis–respiration, and the phases of the Moon and discussed the text contents after reading (nine preservice science teachers). The instruction process lasted 5 weeks in the other two groups. It was aimed to teach various general–specific and domain-specific reading strategies used to activate metaconceptual activities in strategy instruction. The teaching of strategies that are thought to contribute to improving conceptual understanding and facilitating conceptual change was also included.

Explicit Strategy Instruction

The following steps of explicit strategy instruction were prepared by considering the studies conducted by Nist and Holschuh (2000). These steps are:

(a) Explaining the definitions of cognitive and metacognitive reading strategies and exemplifying how they are used. First, the participants were informed about the importance of reading strategies, the reading strategies used while reading science texts, why strategy instruction is needed, which strategy will be effective in what situations, and how the reader can use these strategies to ensure conceptual change (becoming aware of their potential misconceptions and monitoring and evaluating their reading comprehension).

(b) Modeling of reading strategies aimed at activating potential cognitive and metaconceptual activities used while reading a force–motion text and an electricity text by one of the researchers using read-aloud and think-aloud techniques. The researcher assumed the role of a good reader who has common misconceptions about force–motion but effectively uses cognitive and metacognitive strategies to improve conceptual understanding and eliminate misconceptions in this step.

(c) Reading a photosynthesis–respiration text with a checklist. The participants were provided a checklist on which they could mark the strategies they used and purposes of using them while reading the photosynthesis–respiration text.

(d) Reading the phases of the Moon text with an evaluation form. This form consists of open-ended questions regarding the strategies they used and purposes of using them while reading.

Peer Tutoring Strategy Instruction

The following steps of peer tutoring strategy instruction were prepared by considering the studies conducted by Palincsar, Brown and Martin (1987) and Al-Hassan (2003). These steps are:

(a) Determining the tutors and tutees. The participants who scored high on the MARSI and correctly answered the concept cartoon on photosynthesis–respiration and phases of the Moon were selected as tutors, and those who scored low on the MARSI and had alternative concepts about photosynthesis–respiration and phases of the Moon were determined as tutees.

(b) Explaining the definitions of cognitive and metacognitive reading strategies and exemplifying how they are used. The first step of explicit strategy instruction was also implemented to preservice teachers who were exposed to peer tutoring reading strategy instruction.

(c) Modeling of reading strategies aimed at activating potential cognitive and metaconceptual activities used while reading a force–motion text by one of the researchers using read-aloud and think-aloud techniques. The implementation in the second step of the explicit strategy instruction was also conducted with a peer tutoring reading strategy instruction group.

(d) Training the tutors. The tutors were first informed about the contribution of this role to themselves and pairs, what to do together with pairs, and what they should pay attention to. The researcher and an expert who assumed the role of the tutee modeled the reading process together in relation to what kind of role the tutors and tutees would play while reading an electricity text. The tutors and tutees participated in this modeling process separately.

(e) Pairing the tutors and tutees. The pairing was performed by considering the selection criteria for the tutors and tutees and communication between the participants.

(f) Reading photosynthesis–respiration text and the phases of the Moon by pairs. In order for the tutors to perform their role well, they were informed about possible misconceptions about these topics. Additionally, the researchers developed reading scenarios for the texts on photosynthesis–respiration and the phases of the Moon because asking questions by peer tutors during the monitoring and correction of errors by the guides is a challenging role (Thurston et al., 2021). These scenarios prepared tutors to perform this role effectively, contained detailed information about questioning in which part of the text the tutee has misconceptions while reading the text, and if any, encouraging and guiding the use of strategy. The researchers discussed the implementation of the scenarios with the tutors. The tutor and tutee read both science texts in pairs.

In the study, while preparing these texts, attention was paid to the cohesion of texts. Besides, the researchers paid attention to the fact that these texts contain elements, such as figures, graphs, definitions, and formulas, that allow the use of different strategies. Moreover, different experts on science education were consulted to examine the cohesion of text and scientific quality of these written texts. At least two experts gave their opinions for each science text. A professor who works in the area of physics education and an associate professor who works in the area of science education for the force–motion text; a professor who works in the area of physics education and three experts (an associate professor and two assistant professors) who work in the area of science education for the electricity text; two experts (an associate professor and an assistant professor) who work in the area of biology education and three experts (an associate professor and two assistant professors) who work in the area of science education for the photosynthesis–respiration text; two experts (an associate professor and an assistant professor) who work in the area of science education and a professor who works in the area of astrophysics for the phases of the Moon text; and two experts (a professor and an assistant professor) who work in the area of physics education and two experts (an associate professor and an assistant professor) who work in the area of science education for the heat and temperature text. The experts examined the science texts in terms of clarity, cohesion, validity of the scientific content, and fluency. The texts were revised in line with the feedback.

Data Analysis

Content analysis was conducted to determine in detail the strategies and products of processes used by the participants and purposes of using them while reading the heat-temperature text. While the preservice teachers were reading the science text, video recordings were taken. These recordings were transcribed and analyzed. The steps followed while analyzing the cognitive and metacognitive strategies used and purposes of using them are as follows:

- While each participant was reading a science text, one of the researchers observed each participant and they took notes of verbal expressions or behaviors. After the reading, the researcher asked the participant questions about why they used each expression or behavior.
- The strategies used while reading were labeled. Additionally, the verbal expressions or behaviors of the participants that displayed their cognitive and metacognitive activities while reading the texts were also observed, and these were defined as products of processes.
- To code the strategies and products of processes as cognitive and metacognitive, participants' explanations about the purposes of using each strategy/product of process were examined. If the participant expressed that one used the strategy to learn, remember, and understand the concepts, the strategy was coded as cognitive (Leutwyler, 2009; Zohar & David, 2009). If a participant stated that they used the strategy to become aware of their mental activities, monitor and evaluate them (Flavell, 1979; Gunstone & Mitchell, 1998), and ensure their preregulation, directing their attention, and selective attention and self-management, it was categorized as metacognitive (O'Malley & Chamot, 1990; Vandergrift, 1997). For instance, if a participant stated that they used the strategy to make the information in the text more understandable, understand an idea in the text, activate their prior knowledge, and remember, it was classified as cognitive. If a participant stated that they used the strategy to keep in mind the information in the text, monitor understanding an idea in the text, monitor the consistency of their prior knowledge with information in the text, evaluate, draw attention, and become aware of, it was categorized as metacognitive.
- For the reliability of the observations, one participant who employed various strategies was selected first. The strategies they used, products they produced following cognitive and metacognitive processes, and purposes of using them were coded together with an expert who studied the cognitive and metacognitive strategies by examining the transcripted observation data.

- When the researcher and expert disagreed on coding, they watched the video recordings of the preservice teachers' reading process again; the literature was then reviewed and a common consensus was reached.
- The answers provided by the participants to the questions in the semistructured interview on the reading strategies regarding the use of special strategies were examined. By comparing the data obtained from this interview form with the observation data and participant's verbal expressions or behaviors, the researchers decided on the purpose of the strategies used by preservice teachers.
- Based on this coding, a table was created about the conditions and the way to use these strategies/products of processes. The strategies and products of processes that are not available in the literature were defined by considering the participant's purpose of the strategy and how it was used. The strategies and products of cognitive and metacognitive processes that other participants engaged in and purposes of using them were also coded based on this table.
- The purpose is related to performing mental activities, such as cognitive or metacognitive activity. In fact, the purpose of using strategy can be operationally defined as using the strategy to perform the cognitive or metacognitive activity. The cognitive and metacognitive activities obtained in this study are shown in Figure 1.

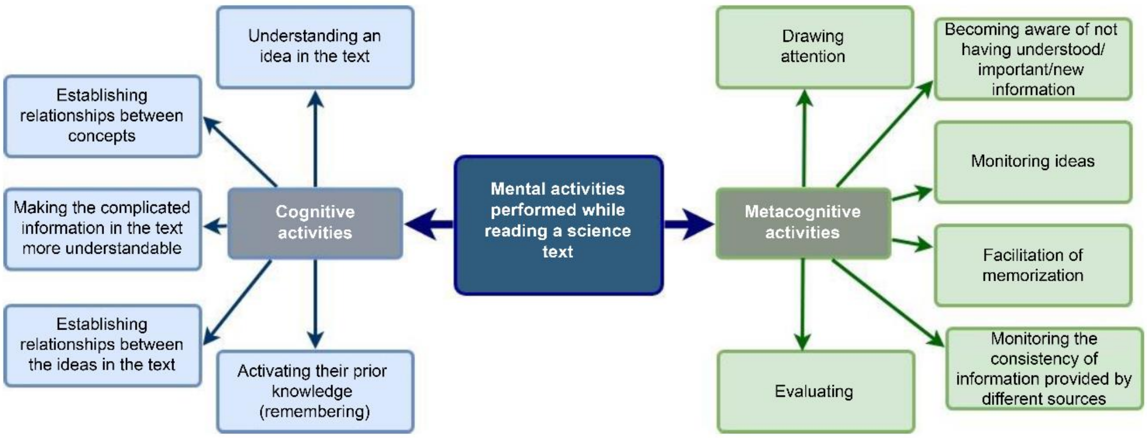


Figure 1. Activities performed while reading a science text

In Figure 1, it is seen that while reading the science text, the participants performed cognitive and metacognitive activities. The groups performed six different metacognitive activities and these submetacognitive activities are presented in Figure 2.

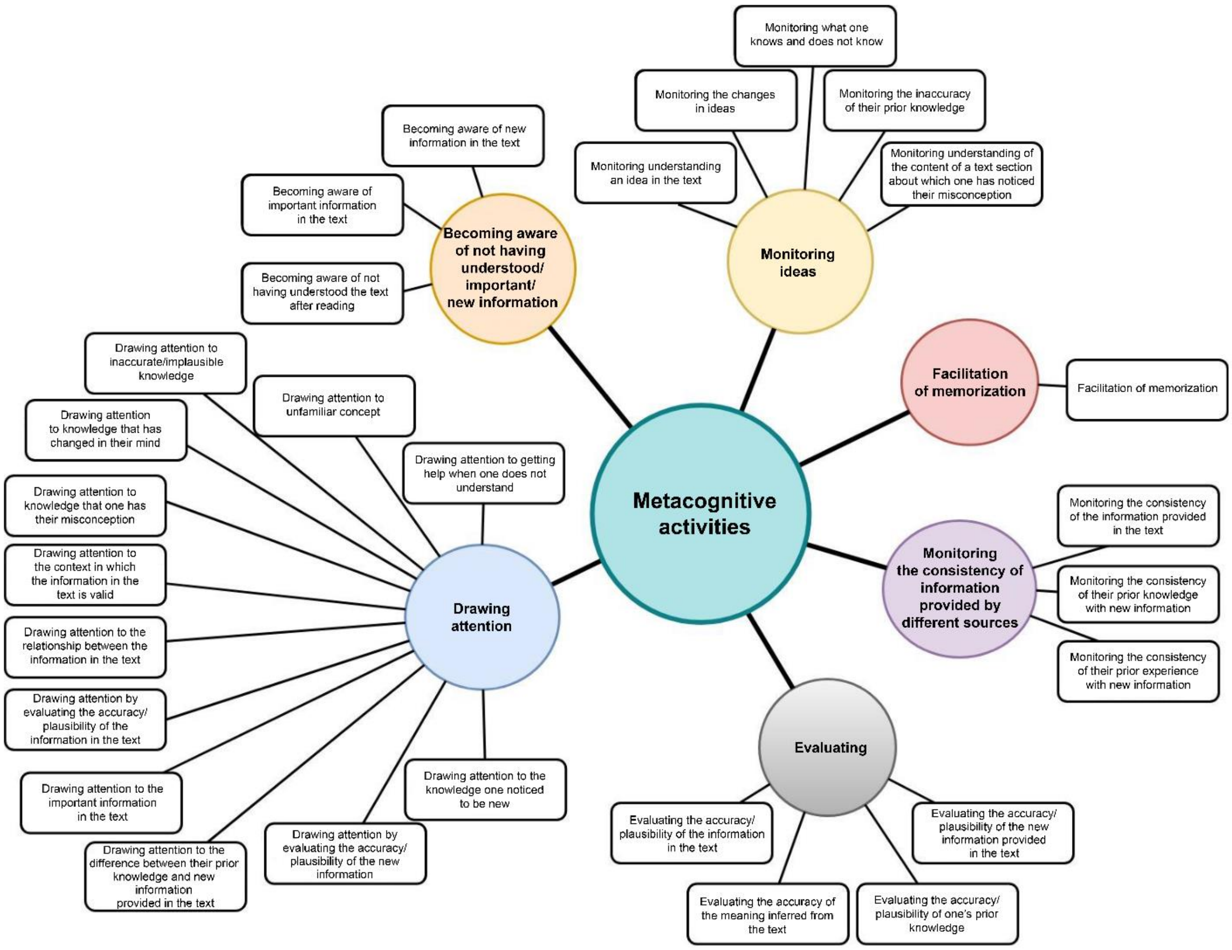


Figure 2. Submetacognitive activities performed while reading a science text

It is seen that among the metacognitive activities presented in Figure 2, the activity of drawing attention has the most variety.

The coding example for determining the strategies and products of cognitive and metacognitive processes that the participant (P6) in the peer tutoring strategy instruction group used and the purposes of engaging in them while reading the text section about the temperature concept are presented in Table 3.

Table 3. The strategies and the products produced used and the purposes of using them

Text section	Participant's expressions related to their purpose of engaging in strategies and products of processes	Strategies and products of processes that the participants engage in	Purpose of engaging in strategies and products of processes	CS/MS PCP/PMP
The faster its molecules vibrate, the higher temperature of the matter, and the slower it vibrates, the lower temperature of the matter. …	Because it seemed reasonable.	Verbally expressing the accuracy/plausibility of the concepts: Very plausible.	To evaluate the accuracy/plausibility of the information in the text	MPP
		Highlighting	To draw attention to the accuracy/plausibility of the information in the text	MS

*CS: Cognitive Strategy; MS: Metacognitive Strategy; PCP: Products of Cognitive Processes; PMP: Products of Metacognitive Processes

In Table 3, it is seen that after reading the text, P6 explained the reason for following such a path as "because it seemed reasonable" in this section of the text in the interview. The participants' explanations about the reason for using strategies and products of processes were placed in the column of "the participant's expressions related to their purpose of engaging in strategies and products of processes" of the table. P6 first engaged in the product of the process of "verbally expressing the accuracy/plausibility of the concepts" and then the strategy of highlighting. If the participant did not use any strategies to perform their cognitive and metacognitive activities while reading the text but expressed it verbally, such statements were coded as products of processes. The terms of these strategies and products of processes were provided in the column of "The strategies and products of processes that the participant engage in" of the table. A common and general purpose statement was defined for similar explanations as to why participants engaged in the strategies and products of processes. It is understood that P6 evaluated the plausibility of the information she encountered from the purpose of engaging in the product of the metacognitive process. Thus, the purpose of engaging in this product of metacognitive process was labeled "to evaluate the accuracy/plausibility of the information in the text" and placed in "the purpose of engaging in strategies and products of processes" column. P6 also highlighted this text section with a highlighter, so it can be inferred that they drew attention to this evaluation. The purpose of using this strategy was coded as "to draw attention to the accuracy/plausibility of the information in the text." Whether the strategy and product of the process used were cognitive or metacognitive was decided according to their purposes of engaging in them and coded accordingly. The product of process and strategy in this sample coding were categorized as metacognitive because they were aimed at activating evaluating and drawing attention.

We referred to the purposes of using the strategies/products of processes as cognitive and metacognitive activities performed in the findings section.

Validity and Reliability of the Study and Ethical Aspects

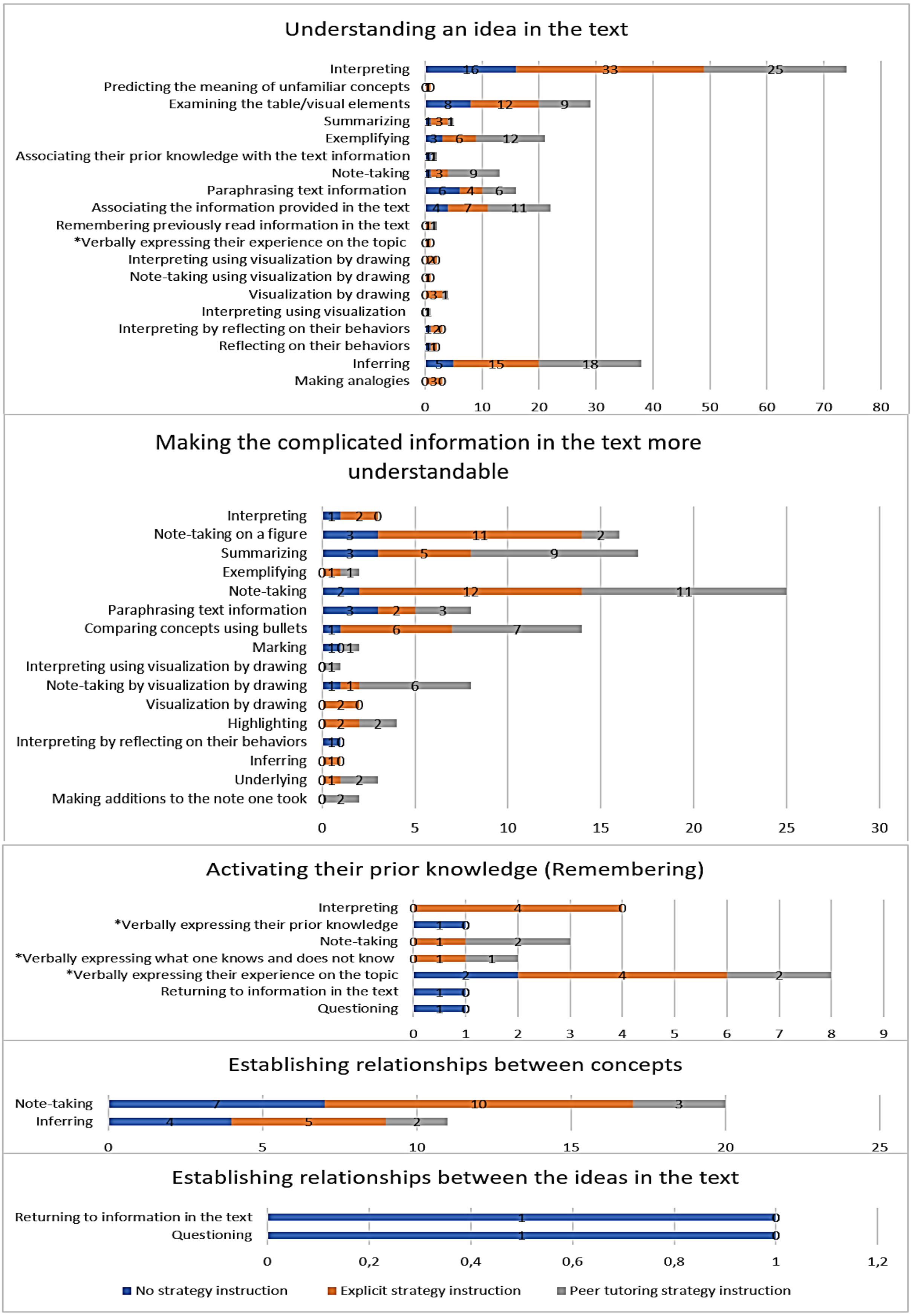
For the validity and reliability of the study, data triangulation, appropriate and adequate engagement in data collection processes, audit trail, and rich and thick description techniques (Merriam & Tisdell, 2016) were used. In data triangulation, read-aloud and think-aloud techniques were used. One of the researchers observed the strategies and products of processes that each participant engaged in while reading aloud and thinking aloud the relevant text and the researcher took notes. After reading the text, each participant was interviewed. The consistencies of the observation using read-aloud and think-aloud techniques and interview data were examined. Appropriate and adequate participation in data collection processes was provided with the number of participants and length of instruction (5 weeks). The audit trail technique, which is related to the data collection process and coding (Merriam & Tisdell, 2016), is detailed in the data collection tools and data analyses sections. Furthermore, a rich and thick dataset consisting of a 75-page document related to the table that includes the strategy/product of the process, cognitive/metacognitive, and the purpose of engaging in them was obtained. Additionally, the data obtained regarding the terms of the strategies and products of processes engaged in by three participants, their purposes of engaging in them, and whether they were cognitive or metacognitive were coded by the researchers and an expert. The intercoder consistency was found to be 79%. The coders compromised on the inconsistent codes by discussing them with another expert on conceptual understanding and reading strategies.

With regard to ethics, the names of the voluntary preservice science teachers who participated in the study were kept confidential for ethical purposes. In the coding and reporting of the data, the participants were labeled by giving the initial letter of the group they were in and a number.

Results and Discussion

Each group engaged in various cognitive strategies and products of cognitive processes to perform various cognitive activities. The frequency of using these cognitive strategies and products of cognitive processes are presented in Graphic 1.

When Graphic 1 is examined, it is seen that the variety of the strategies used to understand an idea and make the complicated information in the text more understandable was quite high compared to other cognitive activities. It is seen that the frequency of using cognitive strategy was higher in the groups which were exposed to strategy instruction—especially the explicit strategy instruction group.



**It shows that it is a cognitive process product.*

Graphic 1. Frequency of using cognitive strategies and products of cognitive processes to perform cognitive activities

When Graphic 1 is examined in terms of the variety of cognitive strategies and products of cognitive processes, it is seen that the variety of strategies and products of cognitive processes used to understand an idea by the explicit strategy instruction group was higher than the other groups. The variety of strategies and products of cognitive processes used to make the complicated information in the text more understandable was also higher in strategy instruction groups. In general, it is seen that the variety of cognitive strategies and products of cognitive processes used to perform five different cognitive activities was higher in reading strategies instruction groups compared to no strategy instruction group.

Examples from interview data on various cognitive strategies and products of cognitive processes used in these text sections are presented in Table 4.

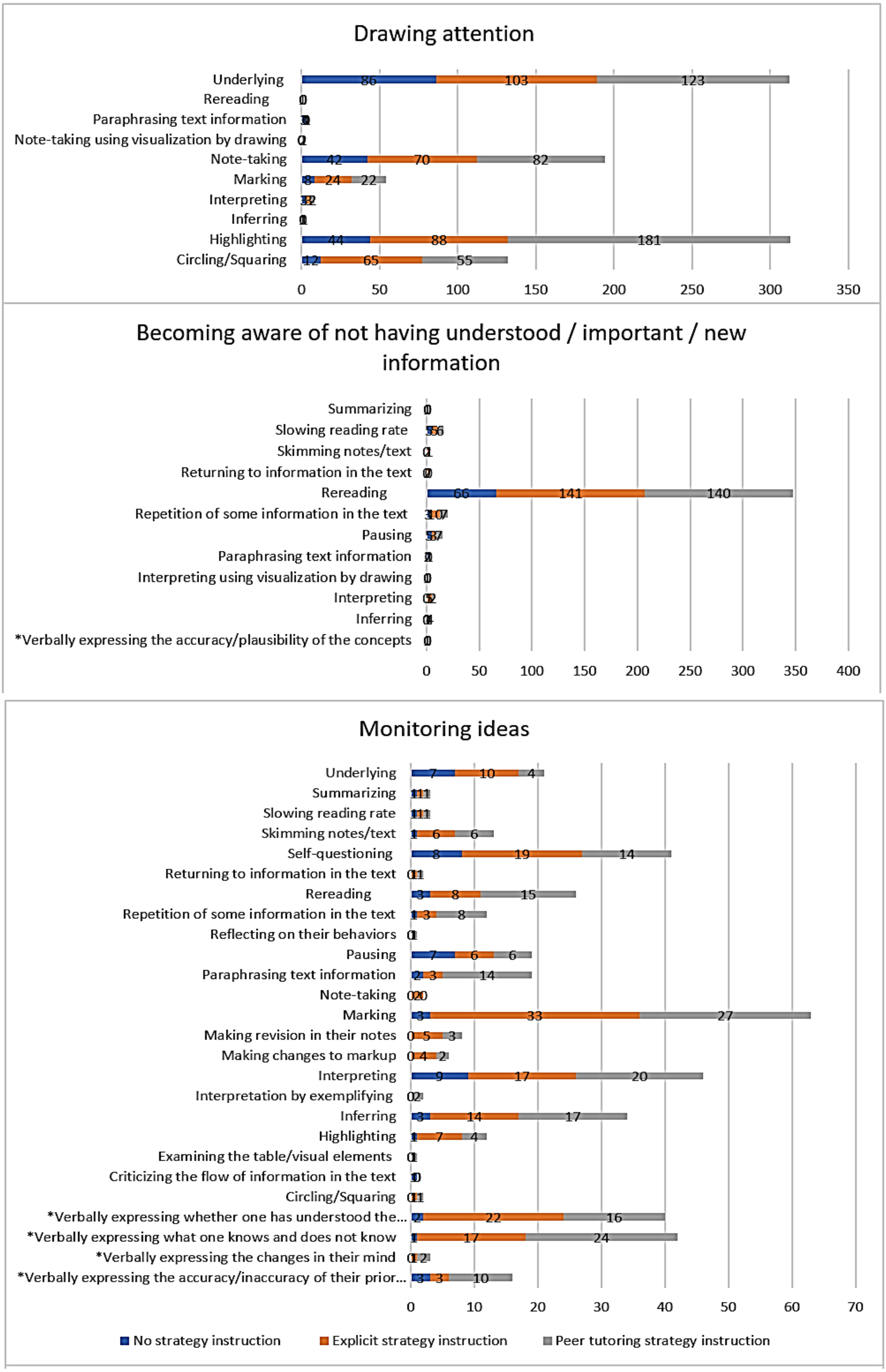
Table 4. Examples from interview data on various cognitive strategies and products of cognitive processes used in these text sections

Kinds of cognitive activity	Strategies and products of cognitive processes engaged in	Text section where strategies and products of cognitive processes were engaged in	Examples from interview data
Establishing relationships between concepts	Note-taking	Substances with higher specific heat have a lower heat transfer speed.	R: After reading the text section, you wrote *Specific heat ↑ transfer speed ↓*. Why? N6: To understand the relationship between the concepts.
Make the complicated information in the text understandable	Note-taking	Substances in the same environment for a long time are at the same temperature, even if they differ in size and the materials from which they are made.	R: After reading the text section, you wrote *Different substances in the same environment are at the same temperature* on the text. Why? E8: Just to summarize.
Understanding an idea in the text	Inferring	For example, the temperatures of tables made of the same material of different sizes that have been in the same room for a long time are equal to each other.	R: After reading the text section, you said *In other words, the temperatures of two substances made of the same material with different masses are equal, here, the temperature does not depend on mass*. Why? P4: To understand better.

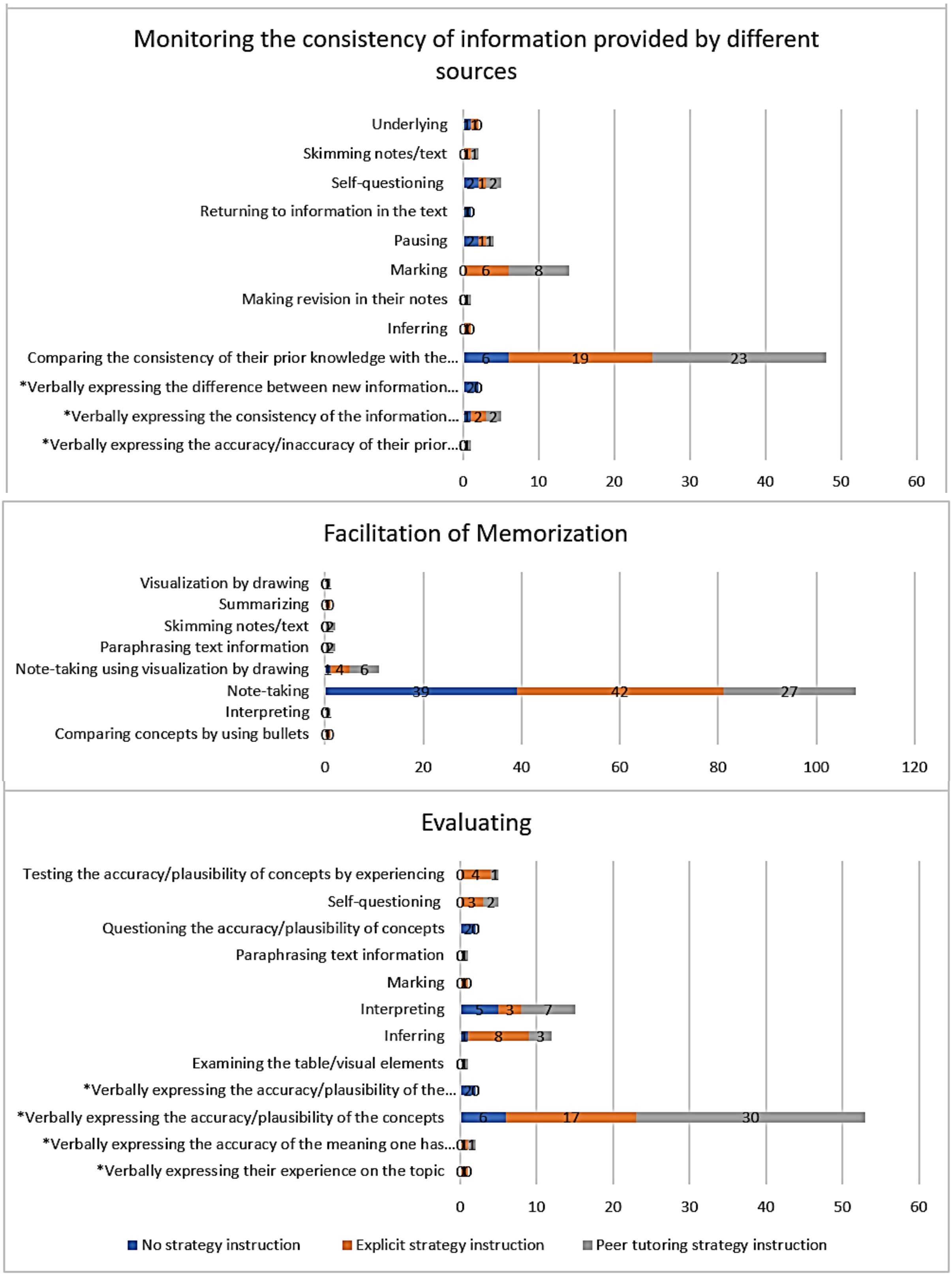
Findings of the metacognitive strategies used to perform metacognitive activities by each group are presented in Graphic 2.

When Graphic 2 is examined, it is seen that the variety of the strategies and products of metacognitive processes used for monitoring ideas was quite high compared to other metacognitive activities. This is followed by becoming aware of not having understood/important/new information, monitoring the consistency of information provided by different sources, evaluating, drawing attention, and facilitation of memorization activity. When each metacognitive activity is examined, the variety of the metacognitive strategy used to perform drawing attention activities was higher in the group without strategy instruction groups and the peer tutoring strategy instruction group. The frequency of using strategies and products of metacognitive processes strategy used to perform drawing attention activities was higher in the strategy instruction groups that were exposed to strategy instruction—especially in the peer tutoring strategy instruction group—compared to the group without strategy instruction.

The variety of metacognitive strategies and products of metacognitive processes used to perform becoming aware of not having understood/important/new information was equal in the three groups. The frequency of using metacognitive strategies and products of metacognitive processes used to perform becoming aware of not having understood/important/new information was higher in the strategy instruction groups compared to no strategy instruction group.



Drawing attention
Underlying
Rereading
Paraphrasing text information
Note-taking using visualization by drawing
Note-taking
Marking
Interpreting
Inferring
Highlighting
Circling/Squaring
Becoming aware of not having understood / important / new information
Summarizing
Slowing reading rate
Skimming notes/text
Returning to information in the text
Rereading
Repetition of some information in the text
Pausing
Paraphrasing text information
Interpreting using visualization by drawing
Interpreting
Inferring
*Verbally expressing the accuracy/plausibility of the concepts
Monitoring ideas
Underlying
Summarizing
Slowing reading rate
Skimming notes/text
Self-questioning
Returning to information in the text
Rereading
Repetition of some information in the text
Reflecting on their behaviors
Pausing
Paraphrasing text information
Note-taking
Marking
Making revision in their notes
Making changes to markup
Interpreting
Interpretation by exemplifying
Inferring
Highlighting
Examining the table/visual elements
Criticizing the flow of information in the text
Circling/Squaring
*Verbally expressing whether one has understood the...
*Verbally expressing what one knows and does not know
*Verbally expressing the changes in their mind
*Verbally expressing the accuracy/inaccuracy of their prior...
No strategy instruction
Explicit strategy instruction
Peer tutoring strategy instruction



Graphic 2. Frequency of using metacognitive strategies and products of metacognitive processes

It is seen that the variety and the frequency of using strategies and products of metacognitive processes to perform monitoring ideas activities were higher in the reading strategies instruction groups—especially in the peer tutoring strategy instruction group—compared to no strategy instruction group. The variety of metacognitive strategies and products of metacognitive processes used to perform monitoring the consistency of information provided by different sources was equal in the three groups. The frequency of using metacognitive strategies and products of metacognitive processes to perform the activity of monitoring the consistency of information provided by different sources was higher in the strategy instruction groups. It is also seen that the variety of metacognitive strategies used to perform the activity of facilitation of memorization was higher in the peer tutoring strategy instruction group. The frequency of using the metacognitive strategies of the explicit strategy instruction group to perform the activity of facilitation of memorization was quite high compared to the other groups.

The variety of metacognitive strategies and products of metacognitive processes used to perform evaluating activities were notable in both strategy instruction groups. It is seen that the frequency of using the metacognitive strategies and products of metacognitive processes was higher in the strategy instruction groups—especially in the peer tutoring strategy instruction group.

Examples from interview data on various metacognitive strategies used in these text sections to perform the kinds of metacognitive activities are presented in Table 5.

Table 5. Examples from interview data on various metacognitive strategies and products of metacognitive processes used in these text sections

Kinds of metacognitive activity	Strategies and products of metacognitive processes engaged in	Text section where strategies and products of metacognitive processes were engaged in	Examples from interview data
Drawing attention to inaccurate/implausible knowledge	Underlying	Heat is energy transfer between two objects in contact to reach thermal equilibrium due to the difference in their average kinetic energies.	R: After you read this text section, you underlined it. Why? N3: I underlined it because it was silly.
Drawing attention to knowledge that has changed in their mind	Highlighting Note-taking	In other words, to keep our food warm or to keep our coke cold, it will be sufficient to insulate the container with *woolen fabrics* that are heat insulators.	R: After reading the text section, you highlighted it and wrote *warm and cold*. Why? E7: To forget my previous knowledge.
Drawing attention to knowledge that one has their misconception	Highlighting	Since heat is not property owned, we cannot define the energy of hot and cold objects as heat.	R: After reading the text section, you highlighted. Why? P6: I became aware of my misconception, I highlighted it because I had a misconception. I knew that it had heat
Drawing attention to the difference between their prior knowledge and new information provided in the text	Highlighting	For example, iron and wood that are in the same environment for a long time are at the same temperatures.	R: After reading the text section, you said *Ooh, we always said they were differen*t. Why? E1: I knew it differently. I did not know like that. It is different from what I know, so I highlighted it.
Becoming aware of not having understood the text after reading	Rereading	Heat is energy transfer between two objects in contact to reach thermal equilibrium due to the difference in their average kinetic energies.	R: After reading the text section, you read it again. Then, you asked *So, does it say that if there is no object in contact, there is no heat?* Why? N3: I usually read it again if I do not understand something, and I understand it somehow with my own interpretations and my own knowledge.

Table 5. *(Continued)*

Kinds of metacognitive activity	Strategies and products of metacognitive processes engaged in	Text section where strategies and products of metacognitive processes were engaged in	Examples from interview data
Becoming aware of important information in the text	Rereading Interpreting	*Air space in the matter prevents the transmission of heat through vibration.* For example, the benefit of using two blankets is to prevent heat transmission with the help of an air layer between them.	R: After reading the text section, you read it again from the phrase *air space in the matter* and said *What's up with the air, it's blocking it*. Why? E5: Because it is even more important.
Monitoring the changes in ideas	Interpreting	In other words, to keep our food warm or to keep our coke cold, it will be sufficient to insulate the container with *woolen fabrics* that are heat insulators.	R: After reading the text section, you said *We could use wool not only to keep warm but also to keep it cold*. Why? E7: We associate woolen *fabrics* with the winter. When I think of wool, I always think of warmth, we can even use it for cold.
Monitoring understanding of the content of a text section about which one has noticed their misconception	Inferring Rereading	Since heat is not property owned, we cannot define the energy of hot and cold objects as heat.	R: After reading the text section, you said *Then, heat is transmitted, the temperature is not* and reread it. Why? P6: I became aware of my misconception; I knew that it had heat.
Monitoring the inaccuracy of their prior knowledge	*Verbally expressing the accuracy/inaccuracy of their prior knowledge	In this respect, there can be no definition of the amount of heat contained in an object.	R: After reading the text section, you reread it and said *I knew it as the amount of heat; what I knew is wrong*. Why? E7: A question mark arose in my mind. I underlined that what I knew was wrong, so that my misconception would be corrected.
Facilitation of memorization	Note-taking using visualization by drawing	For example, the temperatures of tables made of the same material of different sizes that have been in the same room for a long time are equal to each other.	R: After reading the text section, *you drew two boxes ▫ □, wrote the table in the boxes, → their temperatures are equal.* Why? P7: So that it could remain in my mind.
Monitoring the consistency of the information provided in the text	*Verbally expressing the consistency of the information provided in the text	There is a reciprocal relationship in the definition of heat: if two objects are at the same temperature, even if they interact with each other, there is no heat transfer between them.	R: After reading the text section, you said *it was mentioned on the previous page.* Why? E10: To establish relationships between the paragraphs in the texts.

Table 5. *(Continued)*

Kinds of metacognitive activity	Strategies and products of metacognitive processes engaged in	Text section where strategies and products of metacognitive processes were engaged in	Examples from interview data
Monitoring the consistency of their prior knowledge with new information	Comparing the consistency of their prior knowledge with the text information	Heat is energy transfer between two objects in contact to reach thermal equilibrium due to the difference in their average kinetic energies.	R: After reading the text section, you said *I knew that heat is the total kinetic possessed by the molecules of a substance, but here it says average kinetic energy. What is heat actually? Substances in contact want to reach thermal equilibrium, heat is their average kinetic energy they spend on this.* Why? P6: A definition is given here; I also had a definition in my mind. I interpreted it using my prior knowledge, and then I compared it with the information in the text.
Monitoring the consistency of their prior experience with new information	*Verbally expressing the difference between new information and their prior experience	For example, iron and wood that are in the same environment for a long time are at the same temperature.	R: After you read the text, you said *Whereas I expect the iron to be colder, but they are at the same temperature because they have been in the same environment for a long time.* Why? N8: I used my prior experiences.
Evaluating the accuracy/ plausibility of the information in the text	Testing the accuracy/ plausibility of concepts by experiencing	Substances in the same environment for a long time are at the same temperature, even if they differ in size and the materials from which they are made.	R: After reading the text section, you said *Pencil and pencil sharpener, they have the same temperature, then do they have different heat? But pencil sharpener is like colder*. Why? E10: I used materials to confirm the correctness of the knowledge.
Evaluating the accuracy/ plausibility of the new information	*Verbally expressing the accuracy/ plausibility of the concepts	Heat is energy transfer between two objects in contact to reach thermal equilibrium due to the difference in their average kinetic energies.	R: After reading the text section, you said *Does heat necessarily have to be transferred? I think this is a very silly definition.* Why? N3: I thought the knowledge was wrong.

Conclusion

In this study, four conclusions were reached. First, the cognitive and metacognitive strategies and products of cognitive and metacognitive processes used to perform various cognitive and metacognitive activities were found to be various. Since such texts include intense scientific information and elements such as tables, figures, formulas, and symbols, it is necessary to use various reading strategies to comprehend what one reads (Djudin, 2017). It was found that the diversity of metacognitive strategies and products of metacognitive processes used is mostly seen in performing the activity of monitoring understanding an idea in the text. This is because individuals need to use different strategies to monitor their comprehension (Pourhosein-Gilakjani & Sabouri, 2016). There are also studies in the literature that show that metacognition improves students' ability to monitor reading comprehension from scientific publications (Michalsky 2013; Wang et al., 2014).

Second, the variety and frequency of using cognitive strategies and products of cognitive processes to perform various cognitive activities were the highest in the explicit strategy instruction group. Cognitive strategies were used in most of the studies (Duffy et al., 1987; Ghavamnia, 2019) in the literature in which explicit strategy instruction was implemented to better understand the text and conceptually understand scientific information (Dole et al., 2009). Therefore, it can be said that explicit strategy instruction is effective in teaching cognitive strategies.

Third, it was determined that the metacognitive strategies and products of metacognitive processes and the purposes of using them were more diverse and frequent in the reading strategies instruction groups compared to the no strategy instruction group. The variety of metacognitive strategies and products of metacognitive processes used to perform the activities of becoming aware of not having understood/important/new information and monitoring the consistency of information provided by different sources by the three groups was close to each other. However, the frequency of using metacognitive strategies and products of metacognitive processes was higher in the strategy instruction groups in comparison to the no strategy instruction group. While the variety of metacognitive strategies and products of metacognitive processes used to facilitate memorization was higher in the peer tutoring strategy instruction group, the frequency of using them was the highest in the explicit strategy instruction group. We can say that only one strategy teaching or two different strategies teaching can be used in the acquisition of the skill of using metacognitive strategies and products of metacognitive processes to perform some metacognitive activities. There are studies in the literature that show that both strategy instructions were effective (Van Keer, 2004). With explicit strategy instruction, strategies are clearly taught to students and students learn how to choose the appropriate strategy (Ortlieb, Norris, & Christi, 2012). Furthermore, this strategy instruction can help students monitor and develop their understanding of the text (Nietfeld & Schraw, 2002). Therefore, it can be said that this instruction is effective in using various metacognitive strategies and products of metacognitive processes. The variety and frequency of using strategies were the highest in the peer tutoring strategy instruction group. It can be said that peer tutoring strategy instruction is effective in strategy use. The reason for this can be explained by the fact that the tutor and tutee have more opportunities to practice the use of reading strategies in the peer tutoring strategy instruction (Spörer et al., 2009). In general, the use of both teachings is required for teaching the use of different strategies for different purposes.

Fourth, when the strategy instruction groups were compared between themselves, it was determined that the metacognitive strategies and products of metacognitive processes were more diverse and frequent in the peer strategy teaching group. De Backer et al. (2012) concluded in their study that the peer tutoring strategy instruction was effective in the use of metacognitive and self-regulation strategies. The variety of metacognitive strategies and products of metacognitive processes used by the peer tutoring strategy instruction group, especially for (a) drawing attention, (b) monitoring ideas, and (c) facilitating memorization was quite high. The frequency of using metacognitive strategies and products of metacognitive processes of this group was also notable in performing the activities of (a) drawing attention (especially highlighting strategy), (b) monitoring ideas (especially interpreting and marking strategy), (c) monitoring the consistency of information provided by different sources (especially comparing the consistency of their prior knowledge with the text information strategy), and (d) evaluating (especially the product of the metacognitive process of verbally expressing the accuracy/plausibility of the concepts and interpreting strategy). The reason why the peer tutoring strategy instruction group used various strategies can be explained as follows: in peer tutoring strategy instruction, students perform the reading activity in pairs. The student who is more well-informed in terms of strategy use and text content and assumes the role of the tutor first tries to understand what the tutor has read and uses various strategies to ensure that the tutor's peer also understands what they have read from the science text. Thus, peer tutoring strategy instruction helps to improve the tutor's strategy use and content knowledge. In the process of reading together, the tutor supports and guides the tutor's tutee in the learning process by questioning and explaining (Roscoe & Chi, 2008). After the modeling of reading strategies used, pairs continue to read science texts and then students become independent readers in peer tutoring strategy instruction. In the explicit strategy instruction, conversely, students become independent readers after the modeling process. The stages of the strategy instruction provided within the scope of this study were conducted in the same way. Besides, in peer tutoring strategy instruction, the tutors provide support to the tutees in strategy practice, immediate error correction, pacing, and immediate feedback (Johnson & Zabrucky, 2011). In this process, peer interactions potentially increase the tutees' awareness of their learning (Choi et al., 2005). Additionally, peer interaction can guide and facilitate performing metacognitive activities (Palincsar et al., 1987). When the tutees encounter different perspectives or questions from their peer's explanations, they may try to justify their own knowledge or revise their prior knowledge. When the tutees express the deficiencies in their knowledge, they can actively look for new information to fill in these deficiencies. These verbal interactions are considered to be the most effective way of peer interaction in structuring new information (Palincsar, 1986; Webb, 1989).

Researchers claim that metacognition is a fundamental feature in lifelong learning and science education, and that metacognitive involvement is the key to developing a deeper conceptual understanding of scientific thinking (Choi et al., 2011; Wang et al., 2014). Activities of drawing attention, monitoring ideas, monitoring the consistency of information provided by different sources, and evaluating often performed by peer teaching overlap with the conditions in the conceptual change model proposed by Posner et al. (1982) (Yıldız, 2008). Considering that the effective use of reading strategies is closely related to metacognitive skills (Carrell, 1998), it can be said that the strategies that can activate metaconceptual activities are important in terms of contributing to the students' conceptual change.

Recommendations

This research is limited to a four-page science text containing information about heat-temperature, and to the strategies and products of cognitive and metacognitive processes that 29 preservice science teachers used while reading the text aloud and thinking aloud. Similar studies can be conducted again with science texts containing different content and textual elements. Additionally, there is also a need to conduct the research with students from different education levels, such as elementary and middle school. This study is about determining how the strategies used and the purposes of using them (performing an activity) are similar and different according to the strategy instruction method. Besides, considering that conceptual understanding and change are important in science education, studies can be conducted to examine the effect of strategy use on developing conceptual understanding and achieving conceptual change. It may be suggested to conduct studies on how different combinations of cognitive and metacognitive strategies vary according to different strategy instruction and its effect on conceptual understanding.

Practitioners should pay attention to the fact that (a) the group in which they practice strategy instruction is not crowded, (b) the length of the text in reading activities where the reading aloud and think-aloud protocol will be used, and (c) the use of cognitive and metacognitive strategies while modeling the process of reading science texts in strategy instruction. Additionally, while modeling the reading process, the practitioners should show how an individual with all possible alternative concepts related to a science topic uses strategies to eliminate alternative concepts.

Learners can use the strategies they have learned not only while reading a science text but also while studying, learning, listening, or writing new information. Thus, they also contribute to the development of their own self-regulation skills. While the researcher is modeling the reading science texts process in strategy instruction, learners can use items that encourage the use of strategies, such as checklists, so that learners can observe the researcher well. They should realize that it is important for learners to learn from their peers as well, and they should look warmly to cooperation efforts.

Author (s) Contribution Rate

First author performed conceptualization, methodology, formal analysis, investigation, data curation, writing-original draft preparation, visualization preparation, project administration. The first author's contribution rate is 50%.
Second author performed conceptualization, methodology, validation, resources, data curation, writing - review & editing preparation, proof-reading. The second author's contribution rate is 50%.

Conflicts of Interest

The authors declare that they have no personal and financial conflict of interest associated with this publication to disclose.
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Ethical Approval

This manuscript was produced from doctoral dissertation of first author.

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