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DETERMINING THE FREQUENCY OF STRATEGY USE BY 8TH GRADE STUDENTS WHEN SOLVING OPEN-ENDED PHYSICS QUESTIONS

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ABSTRACT

This study aimed to identify the cognitive and metacognitive strategies used by eighth-grade students when solving open-ended physics questions and the frequency of their use of these strategies. A case study, one of the qualitative research methods, was used in the study. A total of nine students participated in the study, three from each of two private and one public secondary school in Kars province. The study data were collected using "Open-Ended Physics Questions," "Thinking Aloud Sessions Conducted with Open-Ended Physics Questions," and a "Semi-Structured Interview Form." In the study, two open-ended Physics questions were solved by the students with think-aloud protocols, and semi-structured interviews were conducted with the students after solving each open-ended question. The students' processes of solving the questions and semi-structured interviews were recorded on camera. Transcripts have been made of the data from the observation and interview processes recorded on camera. Content analyses were performed on the transcribed qualitative data. The most frequently used cognitive strategies among students attending Private Secondary School 1, Private Secondary School 2 and Public Middle School were reading while tracing words with a pen, expressing ideas in their own words, comparing the explanations in the question with the figure, following the words with a pen, taking notes next to the explanations in the question, and examining the figure. Students attending Private Secondary School 1, Private Secondary School 2 and Public Middle School most frequently employed the metacognitive strategies of re-reading, underlining clues, circling clues, re-examining the figure, re-examining the figure and taking notes next to the explanations in the question.

Keywords: Cognitive strategy, metacognitive strategy, problem solving, open-ended question.

[1]This study is derived from a master's thesis.

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INTRODUCTION

Education aims to teach individuals how to behave in formal education institutions while preparing them for life, as well as to enable them to learn problem-solving skills that will enable them to cope with the difficulties they face (Saracaloğlu et al., 2001). A problem is a situation that people have not encountered before, have no idea how to solve, and can only solve by using their knowledge and experience (Resnich & Glaser, 1976; Olkun & Toluk, 2004). A problem is a situation that captures a person's attention, is complex or unpredictable, involves explanatory questions, and requires sufficient knowledge and ability to answer the questions (Altun, 2016; Van de Walle et al., 2016). In science and mathematics education, problem-solving is as important as the problem itself (Diken, 2020). Problem solving is a comprehensive process that enables overcoming the difficulties encountered to achieve the desired goal, and it is the planning behavior that involves the time, effort, energy, and ample practice required to solve the problem (Bingham, 2004; Ünsal & Ergin, 2011). In addition, problem-solving is the entirety of cognitive processes undertaken to achieve a desired goal in situations where the solution path is unclear, for a difficult situation that the individual does not understand, and it involves high-level cognitive activities that can lead to new learning (Baxter et al., 1996; Mayer & Wittrock, 1996). In short, problem solving refers to situations that resolve cognitive confusion arising in response to a situation and lead to refreshing new outcomes (Yıldızlar, 2020). The most important elements of the problem-solving process are strategies (İsrael, 2003; Schoenfeld, 1999; Diken, 2014). It is considered that students' success in problem solving is related to their use of problem-solving strategies (Cai, 2003). Strategy is the solution that students use to carry out cognitive activities in the problem-solving stages, the tools and rules that specify when and how a process should be applied (Karaçam, 2009). Students reflect and explain the cognitive and metacognitive stages while solving problems, thereby enhancing their problem-solving skills (Ramnarain, 2014; Yazgan, 2015). The strategies used in the problem-solving stages can be classified as cognitive and metacognitive (Flavell, 1976). Cognitive strategies are the mental processes and behaviors that students use to perform a given task and achieve a set goal (Boekaerts, 1996; Pintrich, 1999). Metacognitive strategies are the knowledge that students have about their learning processes and their tendency to control these processes (Flavell, 1979). Open-ended questions are one of the types of questions that improve students' problem-solving skills and require them to use cognitive and metacognitive strategies (Han et al., 2011). An open-ended question is a question that has the possibility of having more than one answer (Hancock, 1994; Nohda, 2000; Sullivan & Clarke, 1992), is a type of question that does not restrict the student in the ways required for its solution, and makes the student use different perspectives and different strategies (Hancock, 1994). Open-ended questions allow students to find answers that suit them (Hussain et al., 2012). Open-ended questions allow students to learn in detail as well as find solutions that are suitable for them (Kahramanoğlu & Deniz, 2017). In recent years, the use of open-ended questions in educational settings in Turkey has frequently been a topic of debate (Karakelle, 2012). When we look at the questions on written exams administered in Turkish schools (especially middle schools and high schools), we see that open-ended questions are generally used. In accordance with the provisions reflected in the Ministry of National Education's Measurement and Evaluation Regulation (2024), an open-ended question system has been implemented in all secondary schools in Turkey to enable better measurement (MEB, 2024). Students must use

both their subject knowledge and their knowledge of strategies when answering open-ended questions on written exams for the courses they take at their schools and on common exams administered by the Ministry of National Education. In other words, it is important for students to use strategies while solving open-ended questions. In this regard, it is interesting to see what strategies students use when solving open-ended questions. In Turkish middle schools, open-ended questions in written exams for physics are aimed at improving students' problem-solving skills. Furthermore, open-ended questions on "The Formation of Seasons" and "Solid Pressure" in 8th-grade science courses are among the questions that 8th-grade students preparing for centralized exams tend to use a wide variety of strategies. Therefore, in this study, the cognitive and metacognitive strategies used by 8th grade secondary school students while solving open-ended questions in the Physics learning area (Eryılmaz Toksoy et al., 2016), which is a learning area in which they have the most difficulty in solving problems, and the frequency with which students use these strategies were determined. In short, this study aimed to determine the cognitive and metacognitive strategies used by students in the 8th grade of two private secondary schools in the provincial center of Kars province and a public secondary school in a village affiliated with the provincial center of Kars province when solving open-ended questions on the topics of “Formation of Seasons” and “Solid Pressure” topics in the 8th grade science course, as well as the frequency of their use of these strategies.

METHOD

Research Pattern

Case study, one of the qualitative research methods, was used in the study (Yıldırım & Şimşek, 2020). This pattern has been customized as a holistic multi-case study, as each case is compared with the other and examined within itself (Yin, 1984). The cases of this study are nine students studying at Private Secondary School 1, Private Secondary School 2, and State Secondary School. The unit of analysis of the study is the cognitive and metacognitive strategies used by the students when solving open-ended physics questions and the frequency of using these strategies.

Study group

A total of nine students formed the study group: three students from a private secondary school in the center of Kars province, three students from another private secondary school, and three students from a public secondary school in a village affiliated with the center. The students participated in the study voluntarily. When selecting students for the study, the opinions of science teachers teaching 8th-grade science courses were also taken into consideration. In the study, the names of the students were kept confidential, and these students were named as "T1, T2, T3, T4, T5, T6, T7, T8, and T9". Additionally, the names of the two private middle schools and one public middle school where the students were enrolled were kept confidential and referred to as "Private Secondary School 1," "Private Secondary School 2," and "Public Secondary School." Care was taken to select students who were successful in the 8th-grade science course. This is because successful students tend to use a greater number and variety of cognitive and metacognitive strategies when solving problems (Diken, 2024). The grade point averages for T1, T2, and T3, who are enrolled in Private Secondary School 1, are 96, 95, and 92,

respectively, for their 8th-grade science course. The grade point averages for T4, T5, and T6, who are enrolled in Private Secondary School 2, are 91, 91, and 90, respectively, for their 8th-grade science course. The grade point averages for T7, T8, and T9, who are enrolled in a Public Secondary School, are 88, 86, and 85, respectively, for their 8th-grade science course. The level corresponding to the grade point average of all students in the 8th-grade science course is "Very Good." In the Ministry of National Education Regulation on Primary Education Institutions (MEB, 2014), secondary school students with average grades between 85-100 are considered "Very Good" (MEB, 2014).

Data Collection Tools

The study data were collected using “Open-Ended Physics Questions,” “Thinking Aloud Sessions Conducted with Open-Ended Physics Questions,” and a “Semi-Structured Interview Form.”

Open-Ended Physics Questions

The first of the data collection tools used in the study was "Open-Ended Physics Questions". These open-ended questions are related to the "Formation of Seasons" subunit of the "Seasons and Climate" unit and the "Solid Pressure" subunit of the "Pressure" unit, which belong to the Physics learning area of the 8th grade science course. A total of two open-ended questions were used in the study to be solved by the students. Open-ended Physics questions have been selected from Palme Publishing's 8th Grade Science Energy Question Bank and Editor Publishing's Question Bank. To determine whether there were any scientific errors or misconceptions in the questions, these questions were checked by two faculty members who are experts in the field of Physics learning. As a result of the checks and corrections made by the faculty members on the questions, open-ended Physics questions were made ready to be used in the study.

Think-aloud Protocols Conducted with Open-Ended Physics Questions

The second of the data collection tools used in the study was "Think-aloud Protocols Conducted with Open-Ended Physics Questions". The think-aloud protocol involves individuals verbally expressing their ideas and thoughts about a problem while solving it (Newell & Simon, 1972; Overton et al., 2013; Van Someren et al., 1994). The think-aloud protocol is a reliable method used in researching stages of cognitive processes (Ericsson & Simon, 1993). Before the students solved the open-ended Physics questions, the researcher informed them about the think-aloud protocol and asked them to verbally express all the mental processes they engaged in and the performance they demonstrated while solving the open-ended Physics questions. “Think-aloud Protocols Conducted with Open-Ended Physics Questions” enabled the identification of strategies students use when solving open-ended questions, the separation of these strategies into cognitive and metacognitive categories, and the determination of the frequency of use of these strategies.

Semi-Structured Interview Questions

The third of the data collection tools used in the study was "Semi-Structured Interview Questions". Semi-structured interviews were conducted with students to reconfirm whether the strategies they used to solve open-ended Physics questions were cognitive or metacognitive. "Semi-Structured Interview Questions" were developed by Diken (2014).

The interview questions are as follows.

1- While solving the question, you reread it, set up a ratio, etc. Why did you do these things?
2- Are you sure you solved the question correctly?
3- What is your reason for being sure that you solved the question correctly?

Implementation Process of the Study

To carry out the study's implementations, ethical committee approval was obtained through the decision numbered 37, item 5, dated September 22, 2022, of the "Scientific Research and Publication Ethics Committee for Social and Humanities Sciences" at the university where one of the researchers is employed. After the relevant permissions were notified to the administrators of the three secondary schools where the study will be implemented, the implementation of the study started. In consultation with the administrators of the secondary schools, the days and hours of the implementations were determined in a way that would not disrupt the class hours of the students. The tools (such as open-ended questions, blank paper, pencil, eraser, and sharpener) that the students will use while solving the questions were made available by the researcher. The administrators of the secondary schools and the students participating in the study were informed about the implementation of the study. The students participating in the study in each secondary school were informed about the think-aloud protocol. To alleviate the students' excitement, another open-ended question, different from the two open-ended questions, was solved by the students using the think-aloud protocol without recording them on camera. In this way, students were enabled to adapt to the process. Students solved open-ended Physics questions using think-aloud protocols. Thus, it is aimed to determine the cognitive and metacognitive strategies used by the students while solving the questions and the frequency of using these strategies, thanks to the think-aloud protocols. Students' question-solving processes using think-aloud protocols were recorded on camera. The camera was held by the researcher on the student's left rear side so as not to distract the student while solving the questions. Students were not interfered with in any way while solving open-ended questions; brief notes were taken by the researcher when necessary. There is no time limit for students to solve the questions. Semi-structured interviews were conducted with the students after solving each open-ended question. Semi-structured interviews with students were conducted to confirm the cognitive and metacognitive distinctions between the strategies they used to solve open-ended physics questions, as well as the frequency of use of these strategies. Semi-structured interviews with the students were also carried out under camera recording. Necessary permissions have been obtained for camera recording. Transcripts of students' think-aloud protocols

while solving open-ended Physics questions and semi-structured interviews conducted with them were computerized. The data from the observation and interview processes, for which transcripts were made, were prepared for qualitative data analysis.

Data Analysis

Content analysis was performed on the qualitative data obtained from the study. Content analysis of the data was performed using software designed for analyzing qualitative data. First, a main theme titled "Strategies" was established, with two sub-themes under this main theme: "Cognitive Strategies" and "Metacognitive Strategies." Observations of students' think-aloud sessions and the parts of semi-structured interviews related to the purpose for which the student used the strategy were coded under the relevant sub-theme to determine whether the strategies used by students at “Private Middle School 1,” “Private Middle School 2,” and “Public Middle School” were cognitive or metacognitive. Each assigned code has been named. Thus, the strategies students used when solving open-ended Physics questions were named, these strategies were categorized as cognitive and metacognitive, and the frequency of use of each strategy was calculated. After coding was completed, a faculty member who had researched cognitive and metacognitive strategies was consulted to determine and name the strategies, separate them into cognitive and metacognitive categories, and perform relevant checks on the reliability and consistency of the codes created based on their frequency of use. A dataset of a student's process of solving open-ended questions, which was coded by the researcher, was re-coded by the faculty member, who is the other coder. The consistency percentage between the two coders' data coding was determined to be 94%. The researcher and the faculty member, who had sufficient knowledge on the subject, reworked the inconsistent data sections and reached a consensus.

FINDINGS

The findings obtained from the study are presented in tables below, with explanations related to the tables provided beneath them. In all tables, students are referred to by the abbreviations T1, T2, T3, T4, T5, T6, T7, T8, and T9. The grade level of students' 8th-grade science course grade averages was abbreviated as "VG" for "Very Good."

Table 1 presents the cognitive strategies employed by students while solving the first open-ended Physics question, along with the frequency at which these strategies were used.

Table 1. Cognitive Strategies Used by Students When Solving Question 1 and the Frequency of Using These Strategies

1st OPEN-ENDED PHYSICS QUESTION									
SCHOOLS	PRIVATE SECONDARY SCHOOL 1			PRIVATE SECONDARY SCHOOL 2			PUBLIC SECONDARY SCHOOL		
STUDENTS	T1	T2	T3	T4	T5	T6	T7	T8	T9
Level of Grade Point Averages	VG	VG	VG	VG	VG	VG	VG	VG	VG
ANSWER	C	C	C	C	C	C	C	C	C
COGNITIVE STRATEGIES									
Visualization	1	1	1	1	1	1	1	1	1
Reading by following the words with a pen	1		5	11	6	4	2	7	10
Reading with underlining words						3			
Reading starting from the root of the problem	1		1		1		1	1	1
Expressing in one's own words		4	3	5			5	3	2
Asking oneself questions									2
Thinking about the question						1			2
NOTE-TAKING									
Taking notes next to the explanations in the question			5		2	6		4	7
Taking notes on the Figure					6				
EXAMINATION									
Examining the Figures	1	4		1	1	1		1	1
COMPARISON									
Comparing the Explanations in the Question	1							2	
Comparing the Explanations in the Question with the Figure		4	4	6	4	4		1	4

When Table 1 and Table 2 were examined, it was determined that the grade point averages of all 8th-grade students studying in "Private Secondary School 1", "Private Secondary School 2", and "Public Secondary School" were "Very Good" and they solved the 1st open-ended Physics question correctly.

While solving the first open-ended Physics question, T1, a student at Private Secondary School 1, was found to have used the cognitive strategies of visualization, reading by tracing the words with a pen, reading from the root of the question, examining the figure, and comparing the explanations in the question. T2, a student at Private Secondary School 1, was observed to use the visualization cognitive strategy once while solving the first question, expressing in their own words, examining the figure, and comparing the figure with the explanations in the question, cognitive strategies four times each. T3, a student at Private Secondary School 1, used the visualization cognitive strategy once, reading starting from the root of the question once, expressing in one's own words cognitive strategy three times, comparing the explanations in the question with the figure cognitive strategy four times, and the reading by tracing the words with a pen and taking notes next to the explanations in the question cognitive strategies five times each while solving the 1st open-ended Physics question.

T4, a student at Private Secondary School 2, used the visualization and examining figures cognitive strategies once each, expressing in one's own words cognitive strategy five times, comparing the explanations in the

question with the figure cognitive strategy six times, and reading while following the words with a pen cognitive strategy eleven times while solving the 1st open-ended Physics question. T5, a student at Private Secondary School 2, used the visualization, examining the figure, and reading from the root of the problem cognitive strategies once each, taking notes next to the explanations in the question cognitive strategy twice, comparing the explanations in the question with the figure cognitive strategy four times, and reading while tracing the words with a pen and taking notes on the figure cognitive strategies six times each while solving the 1st open-ended Physics question. T6, a student at Private Secondary School 2, used the visualization, thinking about the question, and examining the figure cognitive strategies once each, reading while underlining words cognitive strategy three times, reading while tracing the words with a pen and comparing the explanations in the question with the figure cognitive strategies four times each, and taking notes next to the explanations in the question cognitive strategy six times while solving the 1st open-ended Physics question.

T7, a student at Public Secondary School, used the visualization and reading from the root of the question cognitive strategy once, reading by tracing the words with a pen cognitive strategy twice, and expressing in one's own words cognitive strategy five times while solving the 1st open-ended Physics question. T8, a student at Public Secondary School, used the visualization, reading from the root of the question, examining the figures, and comparing the explanations in the question with the figure cognitive strategies once each, comparing the explanations in the question cognitive strategy twice, expressing in one's own words cognitive strategy three times, taking notes next to the explanations cognitive strategy four times, and reading by following the words with a pen cognitive strategy seven times while solving the 1st open-ended Physics question. T9, a student at Public Secondary School, used the visualization, reading from the root of the question, and examining the figures cognitive strategies once each, expressing in one's own words and asking oneself questions cognitive strategies twice each, comparing the explanations in the question with the figure cognitive strategy four times, taking notes next to the explanations cognitive strategy seven times, and reading by following the words with a pen cognitive strategy ten times while solving the 1st open-ended Physics question.

The metacognitive strategies students used while solving the first open-ended Physics question, and the frequency with which they used these metacognitive strategies, are shown in Table 2.

Table 2. Metacognitive Strategies Used by Students When Solving Question 1 and the Frequency of Using These Strategies

1st OPEN-ENDED PHYSICS QUESTION									
SCHOOLS	PRIVATE SECONDARY SCHOOL 1			PRIVATE SECONDARY SCHOOL 2			PUBLIC SECONDARY SCHOOL		
STUDENTS	T1	T2	T3	T4	T5	T6	T7	T8	T9
Level of Grade Point Averages	VG	VG	VG	VG	VG	VG	VG	VG	VG
ANSWER	C	C	C	C	C	C	C	C	C
METACOGNITIVE STRATEGIES									
Re-reading			2	6					4
Increasing reading speed	1								
Underlining clues	1		3	2	1	4	1	7	2
Circling clues	8		1	3				5	
Reading with underlining words	1								
Backtracking			1						
Checking the solution process	1	1		2				1	1
MARKING									
Marking the Figure in the Question			1	2					
Marking the explanations in the Question	1								
NOTE-TAKING									
Taking notes next to the explanations in the question	4	8		8			6		
Reviewing the Figure				6	4	4		4	4

Table 2 shows that while solving the first open-ended Physics question, T1, a student at Private Secondary School 1, used the increasing reading speed, underlining clues, reading while underlining words, checking the solution process, and marking explanations in the question metacognitive strategies once each, taking notes next to the explanations in the question metacognitive strategy four times, and circling the clues metacognitive strategy eight times. T2, a student at Private Secondary School 1, used the checking the solution process metacognitive strategy once and taking notes next to the explanations in the question metacognitive strategy eight times while solving the 1st open-ended Physics question. T3, a student at Private Secondary School 1, used the circling the clues, going back, and marking the figure in the question metacognitive strategies once each, re-reading metacognitive strategy twice, and underlining the clues metacognitive strategy three times.

T4, a student at Private Secondary School 1, used the underlining the clues, going back, and marking the figure in the question metacognitive strategies twice each, circling the clues metacognitive strategy three times, re-reading and re-examining the figure metacognitive strategies six times each, and taking notes next to the explanations in the question metacognitive strategy eight times while solving the 1st open-ended Physics question. T5, a student at Private Secondary School 2, used the underlining the clues metacognitive strategy once and the re-examining the figure metacognitive strategy four times while solving the question. T6, a student at Private Secondary School 2, used the underlining the clues and re-examining the figure metacognitive strategies four times each while solving the question.

T7, a student at Public Secondary School, used the underlining the clues metacognitive strategy once and taking notes next to the explanations in the question metacognitive strategy six times while solving the 1st open-ended Physics question. T8, a student at Public Secondary School, used the checking the solution process metacognitive strategy once, re-examining the figure metacognitive strategy four times, circling the clues metacognitive strategy five times, and underlining the clues metacognitive strategy seven times while solving the question. T9, a student at Public Secondary School, used the checking the solution process metacognitive strategy once, underlining the clues metacognitive strategy twice, and re-reading and re-examining the figure metacognitive strategies four times while solving the question.

When Table 1 and Table 2 are examined, it is seen that students studying at Private Middle School 1 and Private Middle School 2 used a greater number and variety of cognitive and metacognitive strategies than students studying at State Middle Schools. Furthermore, it was determined that students studying at Private Middle School 1, Private Middle School 2, and State Middle School used cognitive strategies more frequently than metacognitive strategies when solving the first open-ended Physics question from the "Seasons and Climate" subunit.

The cognitive strategies students used while solving the second open-ended Physics question, and the frequency with which they used these cognitive strategies, are shown in Table 3.

Table 3. Cognitive Strategies Used by Students When Solving Question 2 and the Frequency of Using These Strategies

2nd OPEN-ENDED PHYSICS QUESTION									
SCHOOLS	PRIVATE SECONDARY SCHOOL 1			PRIVATE SECONDARY SCHOOL 2			PUBLIC SECONDARY SCHOOL		
STUDENTS	T1	T2	T3	T4	T5	T6	T7	T8	T9
Level of Grade Point Averages	VG	VG	VG	VG	VG	VG	VG	VG	VG
ANSWER	C	C	C	C	C	C	C	C	C
COGNITIVE STRATEGIES									
Visualization	1	1	1	1	1	1	1	1	1
Reading by following the words with a pen			1	3	3	2		3	2
Reading with underlining words	3				1				
Reading starting from the root of the problem	1	1	1				1	1	1
Expressing in one's own words	1	9	1	7	4	1	1	2	
Proportioning							1	1	2
Digitizing Visual Information			4						
Doing Division			1						
NOTE-TAKING									
Taking notes next to the explanations in the question	4	4	9	4	4	4	6	4	7
Examining the Figures	1	4	1	4	4	4	4	4	4
COMPARISON									
Comparing the Explanations in the Question with the Figure	1	4			1	4			
Comparing the Figures in the Question						4			
DRAWING									
Drawing Figures									2

When Table 3 and Table 4 were examined, it was determined that the grade point averages of all 8th-grade students studying in "Private Secondary School 1", "Private Secondary School 2", and "Public Secondary School" were "Very Good", and they solved the 2nd open-ended Physics question correctly.

As can be seen in Table3, T1, a student at Private Secondary School 1, used the visualization, reading starting from the root of the problem, expressing in own words, examining the figures, and comparing the explanations in the question with the figure cognitive strategies once each, reading with underlining words cognitive strategy three times, and taking notes next to the explanations in the question cognitive strategy four times while solving the 2nd open-ended Physics question. T2, a student at Private Secondary School 1, used the visualization and reading from the root of the problem cognitive strategies once each, taking notes next to the explanations in the question and comparing the explanations in the question with the figure cognitive strategies four times each, and expressing in own words cognitive strategy nine times while solving the 1st open-ended Physics question. T3, a student at Private Secondary School 1, used the visualization, reading by following the words with a pen, reading starting from the root of the problem, expressing in own words, dividing, and examining the figures cognitive strategies once each, converting visual information into numbers cognitive strategy four times, and taking notes next to the explanations in the question cognitive strategy nine times.

T4, a student at Private Secondary School 1, used the visualization cognitive strategy once, the reading by following the words with a pen cognitive strategy three times, examining figures and taking notes next to the explanations in the question cognitive strategies four times each, and expressing in own words cognitive strategy seven times while solving the 2nd open-ended Physics question. T5, a student at Private Secondary School, used the visualization, reading with underlining words, and comparing the explanations in the question with the figure cognitive strategies once each, reading by following the words with a pen cognitive strategy three times, and expressing in own words, taking notes next to the explanations in the question, and examining the figures cognitive strategies four times each. T6, a student at Private Secondary School 2, used the visualization and expressing in their own words cognitive strategies once each, reading while tracing the words with a pen cognitive strategy two times, taking notes next to the explanations in the question, examining the figures, comparing the figures in the question, and comparing the explanations in the question with the figure cognitive strategies four times each while solving the question.

T7, a student at Public Secondary School, used the visualization, reading starting from the root of the problem, expressing in own words, examining the and comparing the explanations in the question with the figure cognitive strategies once each, reading with underlining words cognitive strategy three times, and taking notes next to the explanations in the question cognitive strategy four times while solving the 2nd open-ended Physics question. T8, a student at Public Secondary School, used the visualization, reading starting from the root of the problem, and establishing proportions cognitive strategies once each, expressing in own words cognitive strategy twice, reading by following the words with a pen cognitive strategy three times, and taking notes next to the

explanations in the question and analyzing figures cognitive strategies four times while solving the question. T9, a student at Public Secondary School, used the visualization, reading starting from the root of the problem cognitive strategies once each, reading by following the words with a pen, establishing proportions, and drawing figures cognitive strategies twice, examining the figures cognitive strategy four times, and taking notes next to the explanations in the question cognitive strategy seven times while solving the question.

The metacognitive strategies students used while solving the second open-ended Physics question, and the frequency with which they used these metacognitive strategies, are shown in Table 4.

Table 4. Metacognitive Strategies Used by Students When Solving Question 2 and the Frequency of Using These Strategies

2nd OPEN-ENDED PHYSICS QUESTION									
SCHOOLS	PRIVATE SECONDARY SCHOOL 1			PRIVATE SECONDARY SCHOOL 2			PUBLIC SECONDARY SCHOOL		
STUDENTS	T1	T2	T3	T4	T5	T6	T7	T8	T9
Level of Grade Point Averages	VG	VG	VG	VG	VG	VG	VG	VG	VG
ANSWER	C	C	C	C	C	C	C	C	C
METACOGNITIVE STRATEGIES									
Re-reading	3		2					1	3
Increasing reading speed	1								
Expressing in one's own words		1							
Asking oneself questions									
Underlining clues	2		3	2		4	2	1	1
ircling clues	5		2	2				3	
Reading with underlining words									1
Checking the solution process			1	1				1	1
MARKING									
Marking the Figure in the Question			6					5	1
Marking the explanations in the Question			6						
NOTE-TAKING									
Taking notes next to the explanations in the question								2	4
Taking notes on the Figure			4						
RE-EXAMINATION									
Reviewing the Figure		4	2	4					4

As can be seen in Table 4, T1, a student at Private Secondary School 1, used the increasing reading speed metacognitive strategy once, the underlying clues metacognitive strategy twice, the re-reading metacognitive strategy three times, and circling the clues metacognitive strategy five times while solving the 2nd open-ended physics question. T2, a student at Private Secondary School 1, used the expressing in own words metacognitive strategy once, and re-examining the figure metacognitive strategy four times while solving the question. T3, a student at Private Secondary School 1, used the checking the solution process metacognitive strategy once, re-reading, circling the clues, and re-examining the figure metacognitive strategies twice each, underlining the clues metacognitive strategy three times, taking notes on the figure metacognitive strategy four times, and marking

the figure in the question and marking the explanations in the question metacognitive strategies six times each while solving the question.

T4, a student at Private Secondary School 2, used the checking the solution process metacognitive strategy once, circling the clues and underlining clues metacognitive strategies twice each, and re-examining the figure metacognitive strategy four times while solving the 2nd open-ended Physics question. It was determined that T5, a student at Private Secondary School 2, did not use any metacognitive strategy while solving the question. T6, a student at Private Secondary School 2, used the underlining the clues metacognitive strategy four times while solving the question.

T7, a student at Public Secondary School, used the underlining the clues metacognitive strategy twice while solving the 2nd open-ended Physics question. T8, a student at Public Secondary School, used the re-reading, checking the solution process, and underlining the clues metacognitive strategies once each, taking notes next to the explanations in the question metacognitive strategy twice, circling the clues metacognitive strategy three times, and marking the figure in the question metacognitive strategy five times while solving the question. T9, a student at Public Secondary School, used the underlining the clues, reading with underlining words, checking the solution process, and marking the figure in the question metacognitive strategies once each, re-reading metacognitive strategy three times, taking notes next to the explanations in the question, and re-examining the figure metacognitive strategies four times while solving the question.

When Tables 3 and 4 are examined, it is seen that students studying at Private Middle School 1 and Private Middle School 2 used a greater number and variety of cognitive and metacognitive strategies than students studying at State Middle Schools. Furthermore, it was determined that students studying at Private Middle School 1, Private Middle School 2, and State Middle School used cognitive strategies more frequently than metacognitive strategies when solving the second open-ended Physics question from the "Pressure" subunit.

CONCLUSION and DISCUSSION

The results obtained from the findings of the study are presented below.

It was determined that students enrolled in Private Secondary School 1, with an average grade of " very good" in science, who correctly solved the first open-ended Physics question in the "Seasons and Climate" sub-unit, used the expressing in their own words, and comparing the explanations in the question with the figure cognitive strategies the most while solving the question.

Students enrolled in Private Secondary School 2, with an average grade of " very good" in science, who correctly solved the first open-ended Physics question in the "Seasons and Climate" sub-unit, used the reading by following the words with a pen and comparing the explanations in the question with the figure cognitive strategies the most while solving the question.

Students enrolled in Public Secondary School, with an average grade of “very good” in science, who correctly solved the first open-ended Physics question in the “Seasons and Climate” sub-unit, used the reading by following the words with a pen and expressing in one’s own words, cognitive strategies the most while solving the question.

Some studies identify the most frequently used cognitive strategies by students attending private and public secondary schools when solving multiple-choice physics questions.

Expressing in one's own words (Çalışkan et al., 2006; Diken & Yürük, 2019; Diken, 2020; Diken, 2024; Karaçam, 2009; Karataş & Güven, 2003), comparing the explanations in the question with the figure (Diken, 2020; Diken, 2024), digitizing visual information (Diken, 2014), reading by tracing words with a pen (Diken & Yürük, 2019; Diken, 2020; Diken, 2024), taking notes next to the explanations in the question (Anastasiou & Griva, 2009; Diken, 2014; Diken & Yürük, 2019; Gelen, 2003; O'Malley & Chamot 1990; Taraban et al., 2004), examining figures, and comparing figures in the question (Diken & Yürük, 2019; Diken, 2020; Diken, 2024; Karaçam 2009) are cognitive strategies identified in studies.

Students enrolled in Private Secondary School 1, with an average grade of “very good” in science, who correctly solved the first open-ended Physics question in the “Seasons and Climate” sub-unit, used the taking notes next to the explanations in the question and circling the clues metacognitive strategies the most while solving the 1st open-ended Physics question.

The students enrolled in Private Secondary School 2, with an average grade of “very good” in science, who correctly solved the first open-ended Physics question in the “Seasons and Climate” sub-unit, used the re-reading, underlining clues, circling the clues, taking notes next to the explanations in the question, and re-examining the figure metacognitive strategies the most while solving the 1st open-ended Physics question.

The students enrolled in Public Secondary School, with an average grade of “very good” in science, who correctly solved the first open-ended Physics question in the “Seasons and Climate” sub-unit, used the re-reading, underlining clues, circling the clues, taking notes next to the explanations in the question, and re-examining the figure metacognitive strategies the most while solving the 1st open-ended Physics question.

It was determined that students enrolled in Private Secondary School 1, with an average grade of “very good” in science, who correctly solved the second open-ended Physics question in the “Pressure” sub-unit, used the expressing in one’s own words, digitizing visual information, taking notes next to the explanations in the question, examining the figures, and comparing the explanations in the question with the figure cognitive strategies the most while solving the question.

Students enrolled in Private Secondary School 2, with an average grade of “very good” in science, who correctly solved the second open-ended Physics question in the “Pressure” sub-unit, used the expressing in own words, taking notes next to the explanations in the question, examining the figures, comparing the explanations in the

question with the figure, and comparing the figures in the question cognitive strategies the most while solving the question.

Students enrolled in Public Secondary School, with an average grade of “very good” in science, who correctly solved the second open-ended Physics question in the “Pressure” sub-unit, used the taking notes next to the explanations in the question and examining the figures cognitive strategies the most while solving the question.

The students enrolled in Private Secondary School 1, with an average grade of “very good” in science, who correctly solved the second open-ended Physics question in the “Pressure” sub-unit, used the circling the clues, marking the figure in the question, marking the explanations in the question, and re-examining the figure metacognitive strategies while solving the question.

Students enrolled in Private Secondary School 2, with an average grade of “very good” in science, who correctly solved the second open-ended Physics question in the “Pressure” sub-unit, used the underlining clues metacognitive strategies the most while solving the question.

The students enrolled in Public Secondary School, with an average grade of “very good” in science, who correctly solved the second open-ended Physics question in the “Pressure” sub-unit, used the re-reading, marking the figure in the question, taking notes next to the explanations in the question, and re-examining the figure metacognitive strategies the most while solving the question.

Some studies identify the most frequently used metacognitive strategies by students attending Private Secondary School 1, Private Secondary School 2 and Public Secondary School when solving multiple-choice physics questions.

Taking notes next to the explanations in the question (Anastasiou & Griva, 2009; Gelen, 2003; O’Malley & Chamot, 1990; Taraban et al., 2004; Diken, 2020; Diken, 2024), underline the clues, circle the clues (Çalışkan et al., 2006; Goos et al., 2000; Karaçam, 2009; Taraban et al., 2004; Weir, 1999), re-reading (Çalışkan et al., 2006; Diken, 2020; Diken, 2024; Selçuk et al., 2007; Goos et al., 2006; Karaçam, 2009; Weir, 1999), re-examining the figure, marking the figure in the question, and marking the explanations in the question (Diken, 2020; Tutar et al., 2020; Diken, 2024) are the metacognitive strategies identified in the studies.

This study found that students attending Private Secondary School 1, Private Secondary School 2, and Public Secondary School employed cognitive strategies in a greater number and variety than metacognitive strategies when solving open-ended Physics questions. In their studies, Diken and Yürük (2019), Diken (2020), Tutar, Demir and Diken (2020), Diken (2024) determined that students used metacognitive strategies in greater numbers and varieties than cognitive strategies while solving multiple-choice science questions. An important finding of this study is that students use cognitive strategies more frequently and in greater variety than metacognitive

strategies when solving open-ended Physics questions. The main reason for this may be that open-ended Physics questions are the types of questions that require a lot of numerical operations.

SUGGESTIONS

Based on the results of the study, the following recommendations have been made.

1. Cognitive and metacognitive strategies used by 8th-grade students while solving open-ended science questions can be taught to students. In other words, after identifying the strategies students use in solving open-ended questions, studies can be conducted on how to teach these identified strategies.
2. This study identified the cognitive and metacognitive strategies used by 8th-grade students when solving open-ended science questions. The cognitive and metacognitive strategies used by students while solving open-ended questions in different learning areas (Turkish, Social Studies, Mathematics, etc.) can be examined.
3. Studies can be conducted to identify the cognitive and metacognitive strategies used by students in different grade levels (5th, 6th, and 7th grade, etc.) when solving open-ended questions related to different science units and topics.
4. The cognitive and metacognitive strategies used by 8th-grade students when solving open-ended physics questions can be taught. In other words, after identifying the strategies students use in solving open-ended questions, research can be conducted to address the question, "How should these identified strategies be taught?"

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