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Evaluation of 8th-Grade Students' Approaches to Solving New-generation Science Questions Based on Variable Determination from Scientific Process Skills[1]

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Abstract

This study aims to investigate students' approaches to solving questions that examine dependent-independent and control variables from scientific process skills in the new-generation questions related to the science lesson. The research was designed as a holistic single case study, one of the qualitative research methods. The research was carried out with 20 students studying in a public school. A total of 25 questions aiming to determine the identifying variables in the High School Entrance Exams between 2018-2020 were selected and applied as a test. These questions were divided into four categories. These categories are requiring concrete thinking, requiring abstract thinking, conducting an experiment, and inferring from the experimental design. A detailed description of the case was made by interviewing the students. The interviews were conducted with six students. In order to understand the students' strategies for reading new-generation questions, a reading strategies meta-awareness inventory was applied. When the findings were evaluated, it was understood that the students took two approaches as the first encounter with the questions asked to them and when solving the questions, and they benefited from strategies based on deep and surface sub-themes in these approaches. It was understood that students' reading strategies meta-awareness and sub dimensions (global reading, problem-solving, supporting reading strategies) were above the medium level. However, when the inventory items were evaluated, it was noticed that they gave low scores to the items containing the phrases; write summaries to reflect on key ideas, take notes while reading, summarizing, and using typographical aids to identify key information, which are associated with the deep approach.

INTRODUCTION

In recent years, in the education system in Turkey, instead of questions that aim at students' knowing and remembering, the emphasis has been on questions that put forward students' research and reasoning skills. In the 2023 Education Vision of the Ministry of National Education, it is planned to reorganize the exams within the scope of their purpose, content, and structure depending on question types and the benefits they will provide. In addition, it is aimed to test reasoning, critical thinking, interpretation, prediction and similar thinking skills (MEB 2018). In this context, it is seen that "skill-based" questions, which are expressed as "new-generation", have been included in the content of the High School Entrance Exam (LGS) since 2018. In accordance with these questions, it is aimed to measure students' high-level skills such

as reading comprehension, interpretation, deduction, problem-solving, analysis, critical thinking, and scientific process skills (Erden, 2020; Sanca, Artun, Bakırcı and Okur, 2021). Scientific process skills (SPS) are used to obtain scientific knowledge and include thinking skills that scientists use during their studies, such as observing, measuring, classifying, saving data, establishing hypotheses, using data and creating a model, changing and controlling variables, and conducting an experiment (MEB, 2013; 2017; 2018). SPS are the thinking skills used from the moment the problem situation first arises to the solution (Çepni & Çil, 2013). The skills related to identifying a problem, identifying variables, establishing hypotheses, saving data, and interpreting data are mutually supportive skills (Kocakülah, Turan & Kocakülah, 2020). Identifying and controlling the variables from these skills clearly is essential for planning, implementation and interpretation (Kılıç & Sağlam 2009). Identifying the variables means understanding all the factors that affect the research process (Aslan, Ertaş-Kılıç & Kılıç 2016). In the studies conducted at the primary and secondary school level, it is understood that the students do not acquire the skills related to determining the variables, changing and controlling the variables enough, and it is not easy to gain them (Çakar 2008; Çam & Yalman,2020; Durmaz & Mutlu 2012; Keser & Başak 2013; Ocak & Tümer 2014; Temiz, 2020; Tosun, 2019).

The interaction between the student and the learning task expected from the student is defined as the approaches to learning. Learning emerges as a form of processing information influenced by various factors that reveal the way of perceiving, interacting with, and reacting to the environment (Biggs, 1987; Entwistle, 1986; Entwistle, 2005, Entwistle & Ramsden, 1982; Marton & Säljö, 2005). Biggs (1999) states that each student, concerning the attitude they show and the path they choose, applies different approaches to learning toward the task presented to them. Some students strive to learn and understand, while others are only interested in passing the course. How students approaches to learning is related to the strategies, and the surface approaches is defined as not trying to make sense of what they have learned, relying on rote learning, not establishing a relationship between what has been learned, lack of a specific purpose or target, following their lessons due to fear of failure, and displaying a negative attitude towards the lessons. In addition, a deep approach is defined as trying to relate what has been learned to the facts and events in their life, producing new ideas and reasoning, and aiming for meaningful learning (Biggs, 1987; Entwistle, 1986; Entwistle & Ramsden, 1982; Marton & Säljö, 2005). In this context, asking students to solve the questions posed to them can be considered a demanding task, as well as the expectation of students to perform learning. Therefore, it is crucial to understand how they solve the questions presented as a task and whether an approach is developed towards the questions.

Since many questions about scientific process skills in LGS exams require designing experiments and abstract thinking, it is considered essential to make an arrangement that overlaps students' learning environments and skills (Çepni & Çil, 2013). Başar's (2021) study of evaluating 2018 science curriculum outcomes in terms of SPS showed that the curriculum had very few outcomes related to experimental skills such as "designing experiments" and "changing and controlling variables". In addition, that study revealed four outcomes for the skill of "identifying the variables", but not any outcomes for the skill of "designing an experiment" at the 8^{th}-grade level. The use of new-generation questions in some exams, such as LGS, has affected their in-class practices. In his study, Erden (2020) explains the difficulties that affect the ability to solve and understand new-generation (skill-based) questions by students, such as having difficulty in solving the questions in time, having difficulty in how to approach the questions, the fact that these questions are not included in the lessons since they are time-consuming in school lessons, and that teachers cannot provide guidance to students regarding

the solution of these problems. This study is essential in guiding teachers and education programmers in understanding their students' approaches to solving the questions, identifying variables in new-generation science questions, and designing learning activities considering their approaches to solving the questions in the classroom or laboratory environments. This study aims to explain the students' approaches to solving the questions about identifying variables from scientific process skills in the new-generation questions about the science lesson. For this purpose, answers to the following questions were sought.

How do the 8th-grade students solve the questions about identifying the variables in the new-generation science questions in LGS?

What are the 8th-grade students' approaches to solving the questions about identifying the variables in the new-generation science questions in LGS?

What is the metacognitive awareness of reading strategies of 8th-grade science students?

METHOD

Study Design

The research was designed as a holistic single case study, one of the qualitative research methods. In this design, it is aimed to understand a real-life phenomenon in depth. Explaining the phenomenon means establishing a conjectured set of causal relationships about it, or how or why something happened (Yin, 2009). In this study, secondary school students whose approaches to solving the questions were explained were considered as the unit of analysis.

Study Group

The research was carried out with 20 students (12 girls and 8 boys) studying in a public school located in the center of Bursa in Turkey. While determining the research sample, the convenience sampling method was followed (Creswell, 2016; Miles and Huberman, 2015). Accordingly, 20 volunteer students from the first researcher’s school were included in the research.

Data Collection Tools

New-generation identifying variables test (NIT): In the research, a "new-generation identify variable multiple-choice test was prepared to determine students' success in solving new-generation identifying variables questions. For this purpose, firstly, document analysis was performed. The document analysis was carried out in order to select the questions to be asked to the students about identifying the variable in the new-generation science questions. In this context, LGS science questions published between 2018-2020 constituted the source of the documents. Content analysis was conducted to determine the questions to be selected in this scope. While selecting the questions, two researchers evaluated the questions separately, then the independently-selected questions were compared, and the question themes were determined together by the researchers. The questions that did not reach agreement according to the themes were eliminated, and the final version of the questions was formed. Four categories were determined according to the way of questioning the variables.

According to the way of thinking in the question, the ones with written dependent independent variables are divided as "requiring concrete thinking", and the ones that the student should find the variables are "requiring abstract thinking". According to the experimental design in the question, the ones aiming to establish an experimental design from the variables are divided as; "Conducting an experiment", and the questions that the students deducted and reach a conclusion from the variables in the designed experiment are "inferring from the experimental design".

The questions evaluated according to these categories were rearranged as combined categories since there were questions that contained two ways of thinking together. The questions selected according to the combined categories are presented in Table 1.

Table 1. Categories of questions measuring the ability to identify variables

		YEARS	
CATEGORIES	**2018**	**2019**	**2020**
Requiring concrete thinking - conducting an experiment	Q17	Q3, Q10, Q14, Q18	Q11, Q13
Requiring abstract thinking - conducting an experiment	Q3, Q5	-	-
Requiring concrete thinking- inferring from the experimental design	Q4, Q6, Q8, Q18	Q13, Q11	Q2, Q14, Q15, Q16, Q17
Requiring abstract thinking- inferring from the experimental design	Q11	Q9, Q12, Q20	Q4

Based on these categories, 8 questions in 2020, 9 questions in 2019, and 8 questions in 2018, and a total of 25 questions were selected. Sample questions about requiring concrete thinking- inferring from the experimental design, and requiring abstract thinking- conducting an experiment are presented in Figure 1.

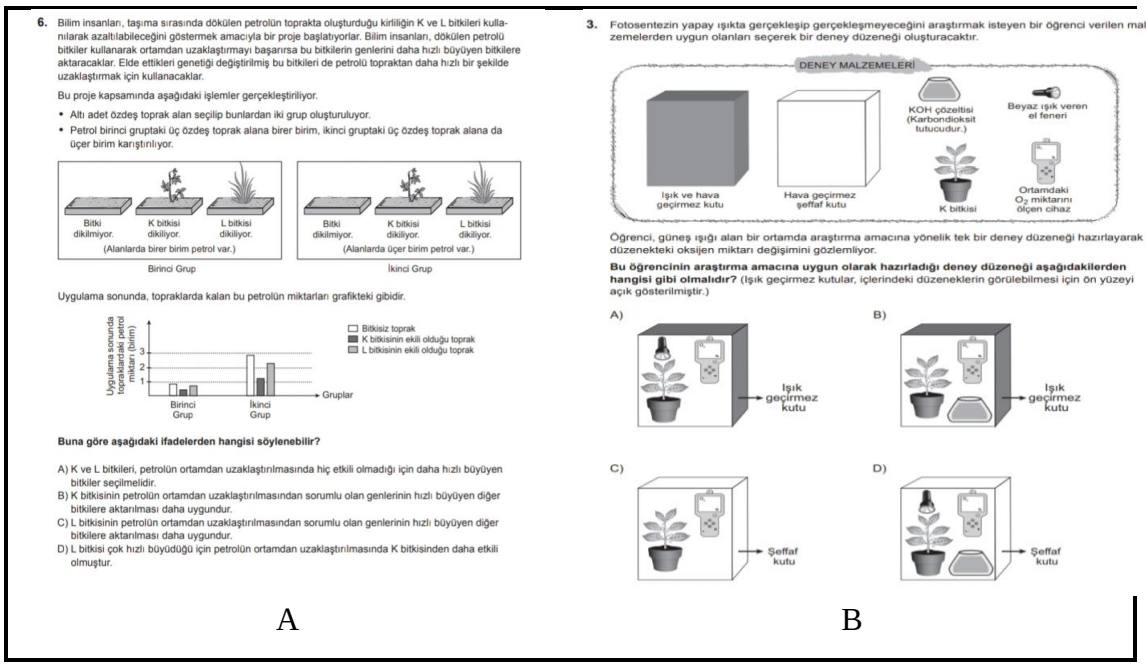

Figure 1. Categories of questions measure the ability to identify variables.

Note: Samples of question categories: Figure A, the sample of requiring concrete thinking- inferring from the experimental design category, 2018; Figure B, the sample of requiring abstract thinking - conducting an experiment category, 2019.

Inventory: The Metacognitive Awareness of Reading Strategies Inventory (MARSI), developed by Mokhari and Reichard (2002) and adapted into Turkish by Öztürk (2012), was applied in order to understand the students' strategies for reading new-generation science questions." The Metacognitive Awareness of Reading Strategies Inventory" consists of 30 questions of 5-point Likert type (p=0.93). The inventory has three sub-dimensions that can be applied to 6th to 12th-grade students. The first sub-dimension, "Global Reading Strategy", consisted of 13 items (p=0.85), the second sub-dimension ", Problem Solving Strategy", consisted of 8 items (p=0.76), and the third sub-dimension ", Supporting Reading Strategies", consisted of 9 items (p=0.81). The highest scores that can be obtained from the test are 150 for general metacognitive awareness of reading strategies, 65 for global reading strategy, 40 for problem-solving strategy, and 45 for supporting reading strategies.

Interview questions: Interview questions were applied using the Google Docs due to the pandemic. In the interview questions, questions such as “When you first encountered new-generation questions in science class, what did you think about the questions?” “Write your positive or negative thoughts about the effect of new-generation science questions on learning in science questions.” were asked. The three questions that students answered most incorrectly were added to the interview form, and depending on whether or not identifying the variables while answering these questions, "Did you determine the variables (dependent-independent-control) variables in the above question, explain why? If your answer is yes, how did you go about determining the variables while answering this question?" were questioned. The interview was conducted with 6 (3 girls, 3 boys) students.

Data Collection Process and Data Analysis

In the first stage of the study, NIT was applied to measure students' success in new-generation science questions. In the second stage, the MARSI was applied. Finally, semi-structured interviews were conducted with six volunteer students in order to describe the research situation in detail.

The descriptive approach and thematic analysis were used in the analysis of the data. In the analysis of the NIC test, the response frequencies of the questions and question categories are described. Thematic analysis was used in the analysis of the interview data. All the answers were analyzed together to reveal the interviewed students’ general approaches to solving the questions. The students' success in solving the most incorrect questions asked during the interview was not considered, and their correct or incorrect answers were not taken into account. All the answers of the students were evaluated together. The interview questions formed the source of the themes. The common features in the phrases of the students were separated into codes created together by the researchers under these themes, and their frequencies were determined. The data were supported by direct quotations from the students. In addition, the fact that the first researcher spent more time with the students provided more detailed and reliable data from the participants. The students’ names were coded as S1, S2, …, S18 in the forms in which the written opinions of the students were stated.

FINDINGS

At the first stage of the research, the answers given to 25 science questions in LGS, which were selected as a result of document analysis, were evaluated. The frequencies of the answers given by the students to the determined question categories are shown in Table 2.

Table 2. NIT correct answer frequencies by question categories

Year	2018		2019		2010	
	Questions	**Frequency**	**Questions**	**Frequency**	**Questions**	**Frequency**
RCT/CE	Q17	16	Q3	15	Q11	17
			Q10	17	Q13	19
			Q14	13		
			Q18	18		
RAT/CE	Q3	19				
	Q5	15				
RCT/IET	Q4	16	Q13	16	Q2	15
	Q6	13	Q11	18	Q14	10
	Q8	16			Q15	16
	Q18	13			Q16	18
					Q17	13
RAT/IET	Q11	17	Q9	13	Q4	18
			Q12	15		
			Q20	18		

RCT: Requiring Concrete Thinking, RAT: Requiring Abstract Thinking
CE: Conducting an experiment IED: Inferring from the experimental design

When the NIT was applied to the 20 students, it was found that the frequency of correctly solving the questions was in the range of 10-19. It is understood that the frequency of answering the questions correctly is above the average ($\bar{x}f$=10). The average correct answer frequency of the questions in the category of requiring concrete thinking-conducting an experiment was 13-19. The average correct answer frequency of the questions in the category of requiring concrete thinking- inferring from the experimental design was 10-18, the average correct answer frequency of the questions in the category of requiring abstract thinking-conducting an experiment was 15-19, and the average answer frequency of the questions in the category of requiring abstract thinking-inferring from the experimental design was 13-18, and so all the frequencies were found to be close to each other. Students' frequencies of answering questions show that the questions were successfully answered above average by them. As a result of the students' tests in 2018, the 18th question in the category of requiring concrete thinking- inferring from the experimental design was the most wrongly answered question (N=13). The most frequently wrongly answered question in 2019 was the 14th question, which required abstract thinking- inferring from the experimental design category (N=13). In 2020, the 14th question, which required abstract thinking-inferring from the experimental design category, was the most wrongly answered question.

When the findings obtained from the interviews of the students were evaluated, the themes of "The strategy of first encountering a question" and "The strategy of solving a question" were constituted. These themes are divided into two sub-learning approaches as deep and surface. Related categories and codes are shown in Table 3.

Table 3. Themes of students' responses

Theme	Subtheme	Category	Code	F	Theme
The strategy of the first encountering a question	Surface approaches	Emotional reaction	Feeling fear	1	S5
			Feeling anxious	3	S1, S3, S6
		Not questioning	Finding it difficult	3	S2, S3, S6
			Finding it time-consuming	1	S2
			Finding it confused	2	S3, S4
	Deep approaches	Cognitive understanding	Searching logic	1	S4
			Seeking meaning	2	S1, S4

		Meaningful-interpretation of visuals	Understanding the visual message	2	S3, S5
The strategy of solving a question	Surface approaches	Copying	Repeating similar question-solving	2	S3, S4
			Incomprehensible repetition	1	S4
		Rote learning	Using codes	1	S4
	Deep approaches	Comprehension of knowledge	Listening to lesson and note-taking	3	S2, S3, S5
		Association	Using comparison	3	S1, S3, S6
			Making logical connection	3	S3, S5,S6
		Inquiring knowledge	Fnding instructive information	3	S1, S3, S4
			Finding experimental and testable information	2	S1, S4

According to Table 3, it is understood that students' approaches to solving the questions of determining new-generation science variables have two themes: "the strategy of the first encountering a question" and "the strategy of solving a question". Moreover, it is noticed that when students first encounter a new-generation science question, they display emotional reaction and non-questioning processes as the surface approaches and cognitive understanding, and meaningful interpretation of visuals processes as the deep approaches. Some of the responses given by the students are presented below.

"I was scared the first time I saw it…" (S5) (emotional reactions)

"When I first saw it, I was anxious because the questions were long and I had never encountered it before, I thought it was challenging, difficult and complicated.". (S3) (emotional reactions, not questioning)

"I thought it was a logic based on meaning because it was long and it would be confusing" (S4) (not questioning)

"I thought that it would be difficult and I could not do it" (S6) (not questioning)

"My negative thinking is that it takes a lot of time" (S2) (not questioning)

"Since science questions were supported with more visuals, they were better understood..." (S3) (Meaningful-interpretation of visuals)

It is understood that when students use the strategy of solving a question, they tend to prefer the surface approaches such as repeating similar questions-solving, incomprehensible repetition called copying, and coding called rote-learning. In addition, they prefer the deep approaches such as listening to the lesson and note-taking in the lesson, using comparison, making logical connections and inquiring about knowledge in order to solve the questions. Some of the responses given by the students are presented below.

"Our teacher repeated and distributed new-generation questions to reinforce them. I kept it in my mind by coding". (S5) (Rote-learning)

"I studied using logic. (S6) (Comprehension of knowledge)

"*First, I listened carefully to the lectures, then I took notes and pasted them on my desk so that I could look at them when I was solving the questions, and as I solved more questions, I reinforced them..." (S3) (Comprehension of knowledge)*

"We can learn things in paragraphs that we do not know. Experimental questions also make it easier to understand." (S1) (Association, inquiring knowledge)

"Since science is a lesson that requires logic based on experimentation and thinking, new-generation questions are according to the content of the lesson and provide learning through experimentation" (S5) (Association, inquiring knowledge).

According to students' responses, we might say that they can prefer the surface or the deep approaches or both depending on the questions. MARSI, which was applied to understand the students' strategies for reading new-generation questions, was answered by 18 students. When the averages of the answers given by the students to the MARSI were evaluated, their general average was found to be $\bar{x}$=103. The averages of the sub-dimension of the inventory were calculated as global reading strategy $\bar{x}$=43.44, problem-solving strategy $\bar{x}$=34.11, and supporting reading strategies $\bar{x}$=25.11. It was understood that the scores of the students were above the average, and the highest score average was in the problem-solving dimension. When the response frequencies of the statements they gave the lowest score in the inventory were examined in order to be able to interpret them with the students' approacheses to solving the questions, from the global reading strategy sub-dimension items; the 2nd item "I take notes while reading to help me understand what I'm reading." ($\bar{x}$f=47.8), the 22nd item "I use typographical aids like boldface type and italics to identify key information." ($\bar{x}$f=34.4), sub-dimension of supporting reading strategies; the 5th item "When text becomes difficult, I read aloud to help me understand what I'm reading." ($\bar{x}$f=57.8), the 6th item; "I write summaries to reflect on key ideas in the text." ($\bar{x}$f=50.0), the 9th item "I discuss my reading with others to check my understanding" ($\bar{x}$f=55.6), the 15th item "I use reference materials such as dictionaries to help me to understand what I'm reading." ($\bar{x}$f=51.1) were lower than the other items. The highest items are; In the problem-solving strategy sub-dimension items, item 16 "When text becomes difficult, I begin to pay close attention to what I'm reading." ($\bar{x}$f=86.7), item 27 "When text becomes difficult, I reread to increase my understanding." ($\bar{x}$f=81.1) item 30 "I try to guess the meaning of unknown words or phrases." ($\bar{x}$f=82.2), and item 25 in the global reading strategy subscale, "I check my understanding when I come across conflicting information." ($\bar{x}$f=84.4).

DISCUSSION AND CONCLUSION

When the research findings were evaluated, it was determined that students' correct answer frequencies of the new-generation science question categories were close to each other, and the average was above the response frequency. When their approaches to solving these questions were evaluated, it was understood that they had two strategic approaches to solving the identifying variables questions "The strategy of first encountering a question" and "The strategy of solving a question", containing deep and surface sub-approaches. When students' approaches to solving new-generation questions were evaluated in terms of MARSI, it was noticed that the general averages and sub-dimensions of their answers (global reading strategy, problem-solving strategy and supporting reading strategy) were above the average. However, the statements that scored lowest were noticed in the global reading strategy and supporting reading strategies sub-dimensions.

It is understood that in the first encounter with the questions, the students might approach to solving a question with emotions such as fear, and anxiety, which include emotional reactions and lead to the surface approaches. Öztürk (2012) explained the problem-solving strategy in MARSI as the strategy used when having difficulty reading a text. According to the research findings, it is noticed that the students gave the highest scores in the problem-solving sub-dimensions in their answers to MARSI. Entwistle (1986:14) stated that when students focus on meeting a task that is expected of them, they reveal a sense of fear and failure concerning external motivation, which are surface approaches. Marton and Saljö (2005) stated that extrinsic motivation was related to the tasks expected from the student and led to a surface approaches.

Therefore, a sense of failure might arise in students expected to succeed only because of external motivation. For this reason, it should be ensured that students' preliminary ideas about why they solve the questions are improved, and they are aware of the strategies to approaches to solving the question. In addition, according to the research findings, it was understood that students might show emotional reactions such as confusion and time-consuming before questioning with understanding in their first encounter with the questions. However, Güneş (2016) emphasized that questioning is the basis of mental skills, affects and activates complex mental processes of the individual, and is essential for developing high-level learning and comprehension skills. For this reason, it is essential for students to realize by questioning their deep approaches, such as searching for logic, trying to make sense of the information, evaluating the knowledge of the question, which they represent in their first encounter with the questions, and it is thought that it might contribute to the reinforcement of their mental skills such as the determination of the variables that a question aims to measure.

It was understood that the students tend to choose the surface approaches such as repeating similar question-solving and incomprehensible repetition as the strategy of solving a question. In addition, students' comments that form the idea that they are trying to memorize, such as using codes are noticed. According to the results of the Ilkorucu-Gocmencelebi, Ozkan & Bayram (2010), the 6^{th},7^{th}, and 8^{th}-grade students who prefer a deep approach to learning science tend to solve more multiple-choice questions. However, they believe that it should not be thought that the students' success in multiple-choice questions depends on their preference for a deep learning approaches. In addition, the students were asked whether they enjoyed doing the tests, and it was found that they preferred a deep learning approaches to a surface learning approaches in the subjects in which they are interested. Thus, students might prefer the deep approaches but succeed with the surface approaches while solving questions. For this reason, the purpose of solving questions should not be only success-oriented; students should be encouraged to solve questions with deep approaches and should be aimed at meaningful comprehension instead of incomprehensible repetition. Arıkan and Kırıntı (2020) state that one of the criticized points of the education system in our country is the LGS. They mentioned that the high level of the demands in the institutions preferred to move to a higher education institution, and the wishes of families to ensure their children receive a better education created a competitive environment. It is thought that these external processes would affect the students' strategies to answer and solve the questions.

The answers given by the students to MARSI were examined, the sub-dimension of global reading strategies items; "I take notes while reading to help me understand what I'm reading", "I use typographical aids like boldface type and italics to identify key information.", and the sub-dimension of supporting reading strategies items; "When text becomes difficult, I read aloud to help me understand what I'm reading", "I write summaries to reflect on key ideas in the text", "I use reference materials such as dictionaries to help me to understand what I'm reading" were found lower than the others. It is noticed that these phrases were especially related to the effort to understand. Remarkably, these items have been related to the deep approaches, which aims to comprehension of knowledge and the association in the students approaches to the solving questions. Marton & Säljö (2005) found in their study that students who are under the effect of external motivation, that is, what is demanded, tend to memorize, which is related to the surface approaches. In their studies, it was found that the students adopted the surface approaches by not paying attention to what a text given to them was about, and remained indifferent to the text read. Öztürk (2012) states that in the students' process of reading and constructing meaning, comprehending knowledge increases when they know and apply reading strategies. Therefore, if the items that students give low scores have assumed to be

related to the deep approaches, it could be said that improving students' comprehension of these statements might also be effective in using the deep approaches in solving questions. Öztürk (2012) emphasizes the difference between knowing information and using information and states that the essential thing is to use information effectively. In this respect, students could focus on memorizing the questions instead of constructing meaningful relationships due to tasks such as exam success expected of them. Therefore, even if students seem to concentrate on comprehending facts and details while solving questions, their failure to remember them will not be a surprising result.

As a result, it is understood that the students did not only use the strategy of solving a question when solving the questions about the identifying variables in new-generation science questions evaluated within the scope of this study but also showed an approach as the strategy of first encountering the question. These strategies, which appeared in students' approaches to solving the identifying variables questions, can be seen as information processors or interpreters used to select, memorize, and recall the information encountered by the student. In these strategies that emerge in students, they may prefer the deep approaches that they would get efficiency from a question or the surface approach that they might not remember later. While the deep approaches are an effort to focus and understand the question, the surface approaches might appear as feeling emotional reactions such as anxiety and fear about the question, not remembering the information, and not questioning. For these reasons, when behaviour such as taking notes, using comparisons and making logical connections for the deep approaches has been considered instinctive strategies for solving questions, teachers can be expected to direct their students to these strategies while identifying variable questions. This research was limited to six students' approaches to solving questions based on identifying variables. With questions based on different scientific thinking processes, the scope can be expanded, and students' approaches to solving the questions in these thinking processes can be investigated. In this study, the approaches to solving the questions was tried to be comprehended in a general framework with a holistic evaluation because the correct answer frequencies given to the question categories were close to each other. It can be recommended to repeat it in larger groups and investigate whether there is a difference in approaches to solving the question of the students according to the question categories.

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