Journal of Posthumanism
2025
Volume: 5, No: 3, pp. 1581–1606
ISSN: 2634-3576 (Print) | ISSN 2634-3584 (Online)
posthumanism.co.uk

DOI: https://doi.org/10.63332/joph.v5i3.948

The Patterns Between 9th Grade Students' Level of Subject Matter Knowledge and the Cognitive and Metacognitive Strategies They Use While Solving Multiple Choice Questions in Science

Emine Hatun DİKEN[1], Nejla YÜRÜK[2]

Abstract

This research aimed to explore the strategies employed by 9th-grade students from Science High Schools, Anatolian High Schools, and Vocational High Schools when solving multiple-choice science questions, examining how these strategies differed based on the students' subject matter knowledge and the difficulty of the questions. These participating students solved multiple-choice science questions from the units of "Force and Motion, Structure and Properties of Substance, and Living Creatures and Energy Relations". The students were observed by the researcher in the process of solving the questions, and students were asked to think aloud to determine the cognitive and metacognitive strategies used by the students. A qualitative case study approach was adopted, involving 15 students from these three school types in Ankara. Data were gathered through observation records of students' question-solving processes and semi-structured interviews conducted after solving the questions. To determine students' levels of content knowledge related to the multiple-choice questions, they were asked open-ended questions about each multiple-choice question. The results revealed that the subject matter knowledge of Science and Anatolian High School students played a crucial role in answering questions correctly, and the cognitive and metacognitive strategies they employed were essential for reaching accurate answers. Additionally, it was found that some students from these schools, despite using a variety of cognitive and metacognitive strategies, failed to answer correctly due to underlying misconceptions. In addition, it was found out that some students from the Science High School and Anatolian High Schools answering the questions wrongly had misconceptions despite using a large number and variety of cognitive and metacognitive strategies.

Keywords: *Cognitive Strategies, Metacognitive Strategies, Multiple Choice Questions, Problem-Solving.*

Introduction

One of the most important goals of education in Turkey is to improve students' problem-solving skills (Gursel & Karacam, 2020, p.416). Problem-solving is also one of the most important elements of the knowledge and skills that students need to have to attend the educational institutions they want to study in the central exams in Turkey (Baki, Karatas & Guven, 2002). A problem is a case where an individual is faced with a problem that he/she does not know at that moment what steps he/she needs to take for a goal he/she wants to realize (Newell & Simon, 1972). According to Resnick & Glaser (1976), a problem is a situation that the individual has not encountered before and does not have any information about how to solve it. Problem-solving refers to efforts that require achieving a goal or finding a solution when an automated solution is not possible (Schunk, 2000). Problem-solving makes it easier for individuals to

[1] Kafkas University, Dede Korkut Faculty of Education, Department of Science Education, KARS/TURKEY, Email: hatundiken06@gmail.com, ORCID ID: 0000-0003-3922-2535
[2] Gazi University, Gazi Faculty of Education, Department of Science Education, ANKARA/TURKEY, Email: nejlayuruk@gazi.edu.tr, ORCID ID: 0000-0001-9240-750X

discover and develop their talents and meet their needs. Individuals do not wait for others to decide on the difficulties they face, they seek solutions to these difficulties themselves. In this way, they increase their sense of confidence by using their previously acquired knowledge and skills. Some researchers who study problem-solving (Dewey, 1910; Ray, 1955; Newell & Simon, 1972; Mayer, 1998) agree that the problem arises only when an individual is confronted with a challenge to which he or she does not already know the direct answer. The degree of difficulty of the problem is not an intrinsic feature of the problem. The degree of difficulty of the problem depends on the knowledge and experience of the individual solving the problem (Elshout, 1987; Gil-Perez, et. al., 1990). The first of the three factors affecting students' problem-solving processes is students' problem-solving skills and subject matter knowledge about problem-solving. The second is the strategies used by students on how to use their subject matter knowledge while solving problems with their higher abilities. The third is students' willpower, problem-solving skills, and their feelings and beliefs about problem-solving (Mayer 1998). Students' subject matter knowledge is the most significant determinant of their problem-solving success (Alugar, 2025; Friege & Lind, 2006). When interpreting a problem, the conceptual network in memory for the problem should be activated. This conceptual network encompasses information about the content, purpose, and solution of the problem (Gick & Holyoak, 1983). Briefly, when solving a problem, individuals use task-subject matter knowledge, strategies, and monitoring of problem-solving processes (Van Gog, et. al., 2005). Problem-solving involves identifying strategies for solving different types of problems, training the chosen strategies, planning explanations, and measuring the results of interventions (Taconis, Hessler, & Broekkamp, 2001). Problem-solving strategies have a significant role in helping individuals perform a multitude of tasks in their professional (academic) and daily lives. Problem-solving strategies are a crucial component of problem-solving (Abdullah 2006). When students are solving problems, their subject matter knowledge and awareness of strategies should be monitored by the teacher (Santrock 2011). Problem-solving strategies are discussed from two perspectives: cognitive and metacognitive strategies. According to Flavell (1979), a strategy is classified as a cognitive strategy if it is used to maintain the solution of some of the mental operations in problem-solving, and as a metacognitive strategy if it is used to control, monitor, or evaluate the operations performed in the solution processes of the problem. Individuals with high cognitive and metacognitive skills perform more successfully when solving problems, are more controlled throughout the problem-solving process, try to solve complex problems by breaking them down into simpler components, and ask themselves questions to clarify their thoughts (Ozsoy, 2007). In the literature, individuals who have superior qualities in the problem-solving process are defined as experts, while those who do not are defined as novices. Some studies address the differences between the behaviors of experts and novices in the problem-solving process (Anderson, Greeno, Kline & Neves, 1981; Prest & Lindsay, 1992; Finegold & Mass, 1985; Gick, 1986; Clement, 1991; Savelsbergh, de Jong & Ferguson-Hessler, 1996; Dhillon, 1998; Malone, 2006; Tuminaro & Redish, 2007). Individuals who are experts in problem-solving have more subject matter knowledge related to problem-solving, while novices have insufficient subject matter knowledge (Chi, Feltovich & Glaser, 1981; Tuminaro & Redish, 2007). Experts better organize their subject matter knowledge about the problem and can more easily use and apply this existing subject matter knowledge. Novices, on the other hand, have little or no organization of their subject matter knowledge about the problem. Experts' subject matter knowledge about the problem is highly interconnected, whereas novices' subject matter knowledge about the problem is either weakly interconnected or not connected at all (Chi, Feltovich & Glaser, 1981; Tuminaro & Redish, 2007). Previous studies reveal that one of the

most significant determinants of students' problem-solving success is their subject matter knowledge of the problem. In addition, the strategies that students use to solve problems also affect their subject matter knowledge (Lehrer & Littlefield, 1993; Friege & Lind, 2006). This study examined how the cognitive and metacognitive strategies employed by high school students in Turkey, with varying achievement levels, differ based on their subject matter knowledge and the difficulty levels of multiple-choice science questions, identifying distinct patterns. The findings from this research are expected to inform future studies by providing insights into how the problem-solving behaviors of high-achieving and expert students can be effectively taught to low-achieving students and novices in problem-solving.*Method*

Research Design

The study employed a case study design, a widely used qualitative research method. Given that each case was analyzed holistically and compared with others, the research was structured as a holistic multiple-case study (Yin, 2003; Yildirim & Simsek, 2006).

Participants

A total of 15 students—5 from Science High Schools, 5 from Anatolian High Schools, and 5 from Vocational High Schools—were selected for the study based on their scores in a central examination conducted in Turkiye. The students participated in the study voluntarily. The students were given pseudonyms, and the real names of the students were not used. The types of high schools that the students participating in the study studied as a result of the high school placement exam held during the transition from secondary school to high schools in Turkey, their high school placement scores, and the pseudonyms given to them are presented in Table 1.

Type of High School	**Students' Pseudonyms**	**High school placement scores**
Ankara Çankaya / Science High School	Aydın	498,808
	Serkan	498,139
	Meltem	498,001
	Zeynep	495,602
	Yavuz	492,236
Ankara Keçiören/Anatolian High School I	Ebru	459,984
	Onur	456,368
Ankara Yenimahalle/ Anatolian High School II	Banu	436,483
Ankara Yenimahalle/ Anatolian High School III	Gonca	435,54
Ankara Yenimahalle/ Anatolian High School III	Nazlı	416,277
Vocational High School	Hazal	390,842
	Teoman	387,747
	Cemre	364,599
	Kardelen	362,912
	Faruk	292,211

Table 1: The Types of High Schools Students Attended, Their High School Placement Scores, and The Pseudonyms Given to Them

Instrument and Procedures Data Collection Tools

a. Think Aloud Sessions with Multiple Choice Questions

The primary data collection tool utilized in the study was think-aloud sessions, during which students were asked to solve three multiple-choice questions from the area of Science. These questions were carefully selected to represent one discipline each—Physics, Chemistry, and Biology. The multiple-choice questions were drawn from units in the Ministry of National Education science curriculum that featured a high number of learning outcomes. These units are Force and Motion from the discipline of Physics with 26 learning outcomes, Structure and Properties of Matter from the discipline of Chemistry with 46 learning outcomes, and Living Beings and Energy Relations from the discipline of Biology with 23 learning outcomes. The questions were checked by six faculty members who are experts in the fields of Physics, Chemistry, and Biology, and the questions were rechecked and revised according to the feedback given by the faculty members. Multiple-choice questions in the science learning area were solved by students with think-aloud sessions. The think-aloud session is a technique that determines the relationship between students' problem-solving performance and other situations that are effective in problem-solving (Van Someren, Barnard & Sandberg, 1994, p. 82). The observations of the students' think-aloud sessions while solving multiple-choice questions enabled to differentiate the strategies they used while solving the questions as cognitive and metacognitive strategies.

b. Think Aloud Sessions with Open Ended Questions

In the study, open-ended questions were prepared for each multiple-choice question to determine the level of students' subject matter knowledge for multiple-choice questions. Eight open-ended questions were prepared for three multiple-choice questions in the field of science. While preparing open-ended questions, science textbooks and teacher workbooks were used. The open-ended questions were checked by four science teachers and academicians who are experts in the related fields, and the necessary controls and corrections were made to the questions.

c. Semi-Structured Interview Form

Semi-structured interviews were conducted with each student after they completed multiple-choice questions to explore the cognitive and metacognitive strategies they employed. The interview form, after being initially drafted, was reviewed and refined by two researchers with expertise in cognitive and metacognitive strategies. Following their feedback and necessary adjustments, the interview form was finalized and made ready for use in the study.

Some of the semi-structured interview questions are as follows.

* You did it while solving the question (such as putting marks on the options, establishing proportions, etc). Why did you do these?

* What is the benefit of you doing while solving the question (such as marking the options, establishing proportions, etc)?

d. Interview Form for Ease-Difficulty Levels of Multiple Choice Questions

After the students solved each multiple-choice question, they were given a form regarding their perceptions of the ease-difficulty levels of these multiple-choice questions. In this form, students marked one of the categories "Very Difficult", "Difficult", "Moderately Difficult", "Easy", or "Very Easy" for each multiple-choice question. Thus, the opinions of each student participating

in the study on the ease-difficulty levels of each multiple-choice question they solved were determined.

Study Process

a) At the beginning of the study, the necessary permissions were secured from the relevant institutions to proceed with the research. Following this, students were selected for participation based on consultations with the administrators and teachers of Science High Schools, Anatolian High Schools, and Vocational High Schools where the study was conducted, with voluntary participation serving as a key criterion.

b) Prior to solving multiple-choice questions, students were briefed on the think-aloud technique. They then applied this technique while answering multiple-choice science questions. To identify the cognitive and metacognitive strategies employed by students during this process, their problem-solving sessions were recorded on camera. Throughout the implementation, the researcher monitored and adjusted the camera's direction and focus to ensure accurate documentation.

c) After the students solved each multiple-choice question, they were given a form consisting of five categories "Very Easy", "Easy", "Moderately Difficult", "Difficult", "Very Difficult", and their opinions on the ease-difficulty levels of each multiple-choice question were taken with camera recording.

d) After solving each multiple-choice question, semi-structured interviews were conducted with the students, and the sessions were recorded on camera. These interviews aimed to verify and refine the classification of the strategies students employed during the problem-solving process into cognitive and metacognitive categories.

e) Following the semi-structured interviews about the process of solving multiple-choice science questions, students were asked to answer open-ended questions related to the units covered by the multiple-choice questions. This was done to assess their level of subject matter knowledge for each question. The process of solving the open-ended questions was also documented through camera recordings.

f) After the students solved the open-ended questions, the researcher checked whether there were any deficiencies in the solutions to the questions.

g) Observations of students' thinking aloud during the process of solving multiple-choice questions and semi-structured interviews after the solution of each question were transcribed and analyzed.

h) To determine the level of students' subject matter knowledge, analytical and holistic rubrics were prepared for each open-ended question. Analytical rubrics were used to score the students' subject matter knowledge, and holistic rubrics were used to determine the level of subject matter knowledge.

Data Analysis

Analysis of the Data Obtained from the Solution Process of Multiple Choice Questions

Firstly, to identify the cognitive and metacognitive strategies used by students while solving multiple-choice science questions, the data obtained from the observation records of their problem-solving processes and the semi-structured interviews conducted to confirm the

distinction between cognitive and metacognitive strategies were transcribed. Then, the transcripts were coded using a software program designed for qualitative research analysis. To ensure the accuracy and consistency of the coding, a faculty member with expertise in the subject reviewed and discussed whether the strategies were correctly classified as cognitive or metacognitive.

After the coding was completed, a data set for the solution processes of one student was also coded by the other encoder, the faculty member. As a result of the coding, the consistency between the encoders was found to be 87%. The encoders reworked the inconsistent data sections. The researcher and the faculty member, who had sufficient knowledge of the subject, reworked the inconsistent data sections and reached a consensus.

In the coding, the opinions of the students about the difficulty levels of the multiple-choice science questions and the levels of subject matter knowledge related to each multiple-choice question were also categorized. After the Science High School, Anatolian High Schools, and Vocational High School students solved the multiple-choice questions, the students were given a form consisting of five categories "Very Easy", "Easy", "Moderately Difficult", "Difficult", and "Very Difficult" for each of the three multiple-choice questions. The students were asked the question "What do you think about the difficulty level of the question?" and they were asked to mark the appropriate category on this form. In the analysis, student opinions on the ease-difficulty levels of the questions were coded by classifying the feedback on the forms.

Analysis of the Data Obtained from the Solution Process of Open-Ended Questions

While evaluating the students' answers to the open-ended questions, rubrics were used to determine their success status. The holistic rubric, which defines the level of students' subject matter knowledge qualitatively with the steps of “unacceptable or incomplete result or solution”, “inadequate result or solution”, “acceptable result or solution”, and “very good result or solution”, and the analytical rubric, which defines students' subject matter knowledge quantitatively, were used (Luft, 1999).

The analytical and holistic rubrics were evaluated by six science teachers, including the researcher. After the analytical rubric for the open-ended questions was created, the students' answers to the open-ended questions according to the analytical rubric were evaluated in the following categories: "very good result or solution", "acceptable result or solution", "insufficient result or solution", "unacceptable or incomplete result or solution". In the analytical rubric, 0 points were given to the category "unacceptable or incomplete result or solution", 1 point to the category "inadequate result or solution", 2 points to the category "acceptable result or solution", and 3 points to the category "very good result or solution". The fit index between the analytical scores of the students for solving open-ended questions and the evaluations of the researchers and science teachers about these analytical scores was found to be 86%. The researcher and teachers worked together on the inconsistent scores until they reached a consensus.

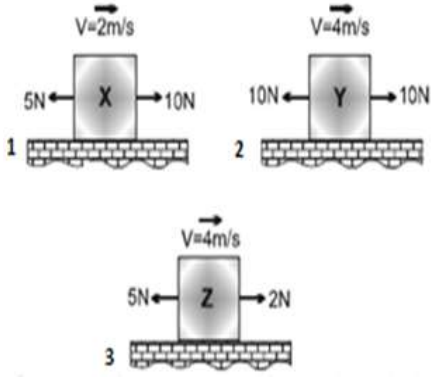
After the analytical rating criteria for the open-ended questions were determined, the rating scores for each open-ended question were summed and divided by the number of open-ended questions prepared for each multiple-choice question. If the score obtained is between 2.26 and 3, it is rated as a "very good result or solution [VG]"; if the score obtained is between 1.6 and 2.25, it is rated as an "acceptable result or solution [A]"; if the score obtained is between 0.76 and 1.5, it is rated as "inadequate result or solution [I]"; and if the score obtained is between 0

and 0.75, it is rated as an "unacceptable or incomplete result or solution [U]". By taking these four categories of criteria, the level of students' subject matter knowledge was determined.

Research Results

This section presents and explains, with the help of tables, how the cognitive and metacognitive strategies employed by 9th-grade students from Science High Schools, Anatolian High Schools, and Vocational High Schools in solving multiple-choice Physics, Chemistry, and Biology questions in the field of Science differ based on the students' level of subject matter knowledge required for solving the questions, their ability to answer the questions correctly, and their perceptions of the questions' ease or difficulty levels. It is abbreviated as Science High School [S], Anatolian High School [A], and Vocational High School [V]. Students studying at Anatolian High Schools are abbreviated as Aydın [A], Serkan [S], Meltem [M], Zeynep [Z], and Yavuz [Y]. Students studying at Anatolian High Schools are abbreviated as Ebru[E], Onur[A], Banu[B], Gonca[G], and Nazlı[N]. Students studying at Vocational High School are abbreviated as Hazal [H], Teoman [T], Cemre [C], Kardelen [K], and Faruk [F]. The correct answer is abbreviated as [C], the wrong answer [W], and the blank [B]. The ease-difficulty levels of the questions are abbreviated as very easy question [VE], easy question [E], moderately difficult question [MD], difficult question [D], and very difficult question [VD]. The subject matter knowledge levels are abbreviated as “very good result or solution [VG], acceptable result or solution [A], inadequate result or solution [I]”, and “unacceptable-incomplete result or solution [U]”.

The multiple-choice Science question from the Physics discipline is as follows



The forces in the figure act on the X, Y and Z objects that move in the frictionless environment.

According to this, which of these objects continue their constant speed movement?

A) Only Y B) X and Y

C) X and Z D) Y and Z

The findings on how the cognitive strategies used by Science High School, Anatolian High Schools, and Vocational High School students while solving the Physics question vary according to their level of subject matter knowledge, whether they answered the question correctly or not, and their perceptions of the ease-difficulty level of the question are presented in Table 2.

MULTIPLE-CHOICE PHYSICS QUESTION						
HIGH SCHOOLS	S	A	V	S	A	V

STUDENTS	A	S	M	O	E	G	N	C	T	F	H	Y	Z	B	K
ANSWERS	C	C	C	C	C	C	C	C	C	C	C	W	W	W	B
CONTENT KNOWLEDGE	VG	VG	VG	VG	VG	VG	I	U	U	U	U	VG	A	VG	U
DIFFICULTY LEVEL	M	M	M	E	E	E	M	M	M	M	M	E	M	D	VD
COGNITIVE STRATEGIES															
Envisioning	√			√								√			
Reading the whole question starting from the question sentence			√	√	√		√				√				
Reflecting the problem to the behaviors	√	√		√			√					√	√	√	
Taking notes			√				√					√	√	√	
Expressing by one's own words	√	√													
Reading by underlining the words		√						√		√	√	√			
Reading by following the words with a pen	√		√	√		√	√		√	√			√	√	
COMPARING															
Comparing the figures											√				
EXAMINING															
Examining figures	√	√		√	√	√	√	√	√	√	√	√	√	√	

Table 2: Patterns Between the Cognitive Strategies Used for the Physics Question, Subject matter knowledge, and the Level of Difficulty of the Question

As can be seen in Table 2, Aydın (A), Serkan (S), and Meltem (M), who had very good (VG) subject matter knowledge, answered the question correctly (C) and rated the question as moderately difficult (MD), used a large number and variety of cognitive strategies while solving the question. Yavuz (Y), whose level of subject matter knowledge about the question was very good (VG) and who rated the question as easy (E), and Zeynep (Z), whose level of subject matter knowledge for the question was acceptable (A) and rated the question as moderately difficulty (MD), answered the question incorrectly despite using a large number and variety of cognitive strategies.

Onur (O), Ebru (E), and Gonca (G), who were among the Anatolian High School students who had very good subject matter knowledge (VG), rated the question as easy (E) and answered the question correctly (C), used cognitive strategies while solving the question. Nazlı (N), an Anatolian High School student who answered the question correctly (C) even though her level of subject matter knowledge was insufficient (I) and rated the question as moderately difficult (MD), used a large number and variety of cognitive strategies while solving the question. It was determined that Nazlı (N) answered the question correctly using only the information that "an object under the influence of balanced forces does not move".

Banu (B), one of the Anatolian High School students whose level of subject matter knowledge was insufficient (I) and who rated the question as difficult (D), answered the question incorrectly due to her insufficient level of subject matter knowledge, although she used a large number and variety of cognitive strategies while solving the question.

It was determined that Yavuz (Y), a student of Science High School, and Banu (B), a student of Anatolian High School, answered the question incorrectly (W) even though their level of subject matter knowledge was very good (VG). Yavuz (Y) and Banu (B) have reached the correct information that "the object Y is moving at a constant speed". However, in object X, they subtracted the small force (5 N) directed to the left from the large force (10 N) directed to the right and found the net force (5 N). It was determined that they chose the wrong option because they had the misconception that “object X will move with constant speed towards the right side with a net force of 5 Newtons” because the directions of net force (5 N) and velocity (v = 2 m/s) are to the right, that is, “if a constant force acts on the object in the direction of motion, the object will continue its path with constant speed”.

Among the Vocational High School students, Cemre (C), Teoman (T), Faruk (F), and Hazal (H), whose level of subject matter knowledge was unacceptable (U) and who rated the question as moderately difficult (MD), answered the question correctly (C) and used some of the cognitive strategies while solving the question. These students stated that they had solved a similar question in the past and that they answered the question correctly because they remembered the process of solving the problem in the past rather than using their subject matter knowledge. Kardelen (K), a Vocational High School student whose level of subject matter knowledge was unacceptable (U) and who rated the question as very difficult (VD), did not use any cognitive strategy because she gave up as soon as she saw the question, that is, she did not solve the question and left it blank.

The findings on how the metacognitive strategies used by Science High School, Anatolian High Schools, and Vocational High School students while solving the Physics question vary according to their level of subject matter knowledge, whether they answered the question correctly or not, and their perceptions of the ease-difficulty level of the question are presented in Table 3.

MULTIPLE-CHOICE PHYSICS QUESTION															
HIGH SCHOOLS	S			A				V				S		A	V
STUDENTS	A	S	M	O	E	G	N	C	T	F	H	Z	Y	B	K
ANSWER	C	C	C	C	C	C	C	C	C	C	C	W	W	W	B
CONTENT KNOWLEDGE	VG	VG	VG	VG	VG	VG	I	U	U	U	U	VG	A	VG	U
DIFFICULTY LEVEL	MD	MD	MD	E	E	E	MD	MD	MD	MD	MD	MD	E	D	VD
METACOGNITIVE STRATEGIES															
Re-reading			√		√		√	√		√	√				
Revising important points	√	√				√	√					√		√	
Reflecting the problem to behaviors							√								
Enhancing reading speed											√				
Asking questions to oneself		√	√									√		√	
Underlining clues						√	√	√					√	√	
Circling clues		√	√			√	√	√		√		√			
Turning back		√	√				√					√			
MARKING															
Marking the figure	√	√	√			√					√	√	√	√	
EXAMINING															
Re-examining the figure	√	√	√	√		√	√		√	√	√	√	√		

Table 3: Question Patterns Between the Metacognitive Strategies Used for The Physics Question, Subject matter knowledge, and The Level of Difficulty of The Question

ELIMINATION															
Eliminating the figure in the question sentence	√	√			√										
Eliminating the options						√						√		√	

As can be seen in Table 3, Aydın (A), Serkan (S), and Meltem (M), who were Science High School students with a very good (VG) level of subject matter knowledge, rated the question as moderately difficult (MD) and answered the question correctly (C), used a large number and variety of metacognitive strategies while solving the question. It was determined that Yavuz (Y), whose level of subject matter knowledge was very good (VG) and rated the question as easy (E), and Zeynep (Z), whose level of subject matter knowledge was acceptable (A) and rated the question as moderately difficult (MD), answered the question incorrectly (W) due to their misconceptions although they used a large number and variety of metacognitive strategies while solving the question. In short, although the level of their subject matter knowledge was "very good (VG)", students with misconceptions answered the question incorrectly (W) no matter how many and various metacognitive strategies they used while solving the Physics question.

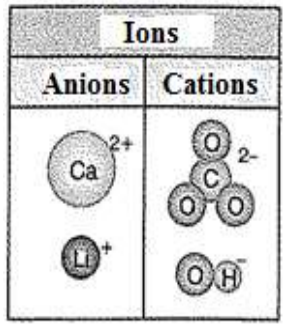
Onur (O), Ebru (E), and Gonca (G), who were among the Anatolian High School students who had very good subject matter knowledge (VG), and rated the question as easy (E), used some metacognitive strategies while solving the question. Nazlı (N), an Anatolian High School student who answered the question correctly even though her level of subject matter knowledge was insufficient (I) and rated the question as moderately difficult (MD), used a large number and variety of metacognitive strategies while solving the question.

It was determined that although Banu (B), whose level of subject matter knowledge was insufficient (I) and who rated the question as difficult (D), used a large number and variety of metacognitive strategies while solving the question, she answered incorrectly because she had misconceptions about the question.

Vocational High School students Cemre (C), Teoman (T), Faruk (F), and Hazal (H) answered the question correctly because they had encountered and solved a similar question before and remembered the solution method, although their level of subject matter knowledge was unacceptable (U) and they rated the question as moderately difficult (MD). In addition, it was determined that these students used some metacognitive strategies while solving the question. Kardelen (K), a Vocational High School student whose level of subject matter knowledge was unacceptable (U) and who rated the question as very difficult (VD), did not use any metacognitive strategy because she gave up as soon as she saw the question, that is, she did not solve the question and left it blank.

The multiple-choice Science question from the chemistry discipline is as follows.

Some models of ions are given on the left.



Some models of ions are given on the left.

Which of the following is <u>wrong</u> with the compounds that may occur with these ions?

A) The number of element atoms in the formula of the compound to be formed between Ca^{2+} and CO_3^{2-} ions is 5.

B) The compound formed between Li^+ and CO_3^{2-} ions has 3 kinds of atoms.

C) 1 Ca^{2+} ion and 2 OH^- ion form a compound.

D) The formula of the compound formed with Li^+ and CO_3^{2-} ions is $Li(CO_3)_2$.

The findings regarding how the cognitive strategies used by Science High School, Anatolian High Schools, and Vocational High School students while solving the Chemistry question vary according to their level of subject matter knowledge, whether they answered the question correctly or not, and their perceptions of the ease-difficulty level of the question are presented in Table 4.

MULTIPLE-CHOICE CHEMISTRY QUESTION															
HIGH SCHOOLS	S					A				A	V				
STUDENTS	A	Z	S	M	Y	G	O	E	B	N	C	T	F	H	K
ANSWER	C	C	C	C	C	C	C	C	C	W	B	B	B	B	B
CONTENT KNOWLEDGE	VG	VG	VG	VG	VG	VG	VG	VG	A	I	I	I	U	U	U
DIFFICULTY LEVEL	VE	VE	VE	VE	VE	MD	MD	MD	E	MD	D	D	D	VD	VD
COGNITIVE STRATEGIES															
Envisioning	√		√		√	√	√								
Reading the question starting from the question sentence				√		√	√	√							
Taking notes	√	√	√	√	√				√						
Expressing by one's own words			√												

Reading by underlining the words		√			√				√						
Reading by following the words with a pen	√	√	√	√		√	√	√	√	√					
EXAMINING															
Examining figures	√	√	√	√	√		√	√	√	√					

Table 4: Patterns Between the Cognitive Strategies Used for The Chemistry Question, Subject matter knowledge, and The Level of Difficulty of The Question

As can be seen in Table 4, all of the Science High School students [Aydın (A), Zeynep (Z), Serkan (S), Meltem (M), and Yavuz (Y)] had a very good (VG) level of subject matter knowledge for the chemistry question, they rated the question as very easy (VE), they answered the question correctly (C), and they used a large number and variety of cognitive strategies while solving the question.

Gonca (G), Onur (O), and Ebru (E), Anatolian High School students, who had a very good (VG) level of subject matter knowledge and rated the question as moderately difficult (MD), answered the question correctly (C) and used a large number and variety of cognitive strategies while solving the question. Banu (B), an Anatolian High School student, whose level of subject matter knowledge was insufficient (I), rated the question as moderately difficult (MD), and answered the question correctly (C), used a large number and variety of cognitive strategies while solving the question. Nazlı (N), an Anatolian High School student, whose level of subject matter knowledge was insufficient (I), who rated the question as moderately difficult (MD), and who answered the question incorrectly (W), used few and varied cognitive strategies while solving the question.

Vocational High School students Cemre (C) and Teoman (T), whose level of subject matter knowledge was Inadequate (I) and who rated the question as difficult (D), and Faruk (F), Hazal (H), and Kardelen (K), whose level of subject matter knowledge was Unacceptable (U) and who rated the question as very difficult (VD), gave up solving the question as soon as they saw it and did not use cognitive strategies.

The findings on how the metacognitive strategies used by Science High School, Anatolian High Schools, and Vocational High School students while solving the Chemistry question vary according to their level of subject matter knowledge, whether they answered the question correctly or not, and their perceptions of the ease-difficulty level of the question are presented in Table 5.

1st CHEMISTRY QUESTION				
HIGH SCHOOLS	F	A	A	M

STUDENTS	A	Z	S	M	Y	G	O	E	B	N	C	T	F	H	K
ANSWERS	C	C	C	C	C	C	C	C	C	W	B	B	B	B	B
CONTENT KNOWLEDGE	VG	VG	VG	VG	VG	VG	VG	VG	A	I	I	I	U	U	U
DIFFICULTY LEVEL	VE	VE	VE	VE	VE	MD	MD	MD	E	MD	D	D	D	VD	MD
METACOGNITIVE STRATEGIES															
Re-reading	√		√	√	√		√	√	√	√					
Revising the operation performed	√														
Revising important points										√					
Increasing reading speed				√											
Taking notes	√			√	√				√						
Reading by following the lines with a pen	√			√	√										
Underlining clues		√							√						
Circling clues		√	√	√	√	√		√	√	√					
MARKIN															
Marking the options	√	√	√	√	√	√	√	√	√	√					
EXAMINATION															
Re-examining the figure								√	√						

Table 5: Patterns Between the Metacognitive Strategies Used for the Chemistry Question, Subject matter knowledge, and the Level of Difficulty of the Question

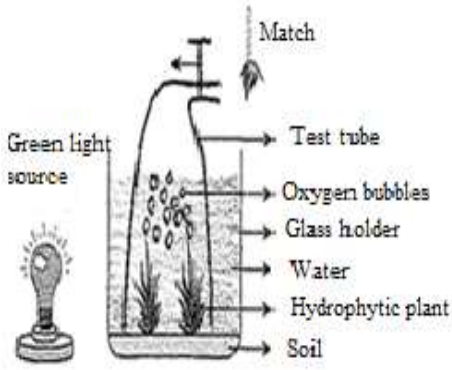
As can be seen in Table 5, all of the Science High School students [Aydın (A), Zeynep (Z), Serkan (S), Meltem (M), and Yavuz (Y)] had a very good (VG) level of subject matter knowledge for the chemistry question, they rated the question as very easy (VE), they answered the question correctly (C), and they used a large number and variety of metacognitive strategies while solving the question. Gonca (G), and Onur (O), Anatolian High School students, who had a very good (VG) level of subject matter knowledge, rated the question as moderately difficult (MD) and answered the question correctly (C), used a large number and variety of metacognitive strategies while solving the question.

It is noteworthy that although Gonca (G) and Onur's use of cognitive strategies while solving the question was high in number and variety (Table 4), their use of metacognitive strategies was low in number and variety (Table 5).

It was determined that Ebru (M), an Anatolian High School student, used more number and variety of metacognitive strategies than Gonca (G) and Onur (O). It was determined that Banu (B), an Anatolian High School student whose level of subject matter knowledge was acceptable (A), rated the question as easy (E), and answered the question correctly (C), used more number and variety of metacognitive strategies than Gonca (G), Onur (O), and Ebru (E). Nazlı (N), an Anatolian High School student whose level of subject matter knowledge was insufficient (I) and who rated the question as moderately difficult (MD), answered the question incorrectly (W) because her subject matter knowledge was insufficient to solve the question, although she used a large number and variety of metacognitive strategies while solving the question.

Vocational High School students Cemre (C) and Teoman (T), whose level of subject matter knowledge was Inadequate (I) and who rated the question as difficult (D), and Faruk (F), Hazal (H), and Kardelen (K), whose level of subject matter knowledge was Unacceptable (U) and who rated the question as very difficult (VD), gave up solving the question as soon as they saw it and did not use metacognitive strategies.

The multiple-choice Science question from the biology discipline is as follows.



When Cemil opened the valve after a certain period of time setting up the mechanism on the left, he found that the match flame had shone.

When Cemil applies which of the following procedures to this mechanism, the brightness of match flame does not increase?

A) Adding carbon dioxide-containing soda to water

B) Changing the green light source with a purple light source

C) Adding carbon dioxide retention agent to plant environment

D) Increasing the number of green light sources

The findings regarding how the cognitive strategies used by Science High School, Anatolian High Schools, and Vocational High School students while solving the biology question vary according to their level of subject matter knowledge, whether they answered the question correctly or not, and their perceptions of the ease-difficulty level of the question are presented in Table 6.

MULTIPLE-CHOICE BIOLOGY QUESTION

Table 6: Patterns Between the Cognitive Strategies Used for the Biology Question, Subject matter knowledge, and The Level of Difficulty of The Question

HIGH SCHOOLS	S					A	A				V		V		
STUDENTS	A	Z	S	M	Y	O	G	B	E	N	H	K	C	T	F
ANSWERS	C	C	C	C	C	C	W	W	W	W	W	W	B	B	B
CONTENT KNOWLEDGE	VG	VG	VG	VG	VG	I	VG	A	A	I	U	U	I	U	U
DIFFICULTY LEVEL	MD	E	MD	D	E	MD	MD	MD	MD	MD	D	D	MD	VD	MD
COGNITIVE STRATEGIES															
Envisioning	√	√	√	√		√	√		√						
Reading the question starting from the question sentence				√		√			√		√	√			
Expressing by one's own words	√		√	√											
Reading by underlining the words		√	√		√					√	√				
Reading by following the words with a pen	√	√	√	√	√	√	√	√	√	√	√	√			
EXAMINING															

Examining figures	√	√	√	√	√	√		√	√	√	√	√			

As can be seen in Table 6, Aydın (A), and Serkan (S), who were Science High School students with a very good (VG) level of subject matter knowledge, rated the question as moderately difficult (MD) and answered the question correctly (C), employed a large number and variety of cognitive strategies while solving the question. Science High School students Zeynep (Z) and Yavuz (Y), whose level of subject matter knowledge was very good (VG), who rated the question as easy (E) and answered it correctly (C), used a large number and variety of cognitive strategies while solving the question. Meltem (M), a Science High School student whose level of subject matter knowledge was very good (VG), who rated the question as difficult (D) and answered it correctly (C), utilized a higher number and variety of cognitive strategies than other Science High School students.

Onur (O), an Anatolian High School student whose level of subject matter knowledge was insufficient (I), who rated the question as moderately difficult (MD) and answered the question correctly (C), used some of the cognitive strategies while solving the question. While solving the question, Onur (O) read the explanation of "adding carbon dioxide scavenger to the environment where the plant is located" in option C and stated that when the carbon dioxide scavenger removes carbon dioxide, oxygen remains in the environment. Onur (O) reached the correct answer by using the clue "carbon dioxide sequestering substance" in option C. In the interview, Onur (O) stated that he solved the question using only the information that carbon dioxide is used and oxygen is released in photosynthesis, he did not know the status of photosynthesis in violet light and green light in options B and D, and therefore he was not sure about the correctness of his answer. Therefore, it was determined that Onur (O) answered the question correctly even though his level of subject matter knowledge for the question was insufficient (I).

As can be seen in Table 6, Gonca (G), an Anatolian High School student, who had a very good level of subject matter knowledge (VG), rated the question as moderately difficult (MD), and answered the question incorrectly (W), used a small number and variety of cognitive strategies while solving the question. Gonca (G) marked option D even though she knew that the photosynthesis rate is low in green light and high in violet light, photosynthesis decreases when a carbon dioxide trap is added to the environment where the plant is located in option C and the brightness of the match flame will not increase. While explaining why she chose option D, Gonca (G) realized that she had chosen the wrong option. Gonca (G) stated that she did not read the sentence in option C carefully. Therefore, Gonca (G) answered the question incorrectly even though her level of subject matter knowledge about the biology question was very good (VG). Gonca stated that the reason she answered this question incorrectly was that she read the options carelessly and very quickly, that she read the options without understanding them, and that she therefore marked the wrong option.

Banu (B), an Anatolian High School student whose level of subject matter knowledge was acceptable (A), who rated the question as moderately difficult (MD), and who answered the question incorrectly (W), used a small number and variety of cognitive strategies while solving the question. In the process of solving the problem, Banu (B) first marked the wrong option B, thinking that plants can photosynthesize faster in green light. In the interview after the solution of the problem, Banu (B) was asked why she chose option B and it was observed that Banu (B)

remembered the information that the photosynthesis rate of the plant is high in purple light and realized that option B was wrong.

Banu (B) has selected option C, which is the correct option. Banu (B) stated that she had a temporary lack of attention while solving the question and did not think much about the options. In addition, since Banu (B) answered the open-ended question "What are the factors affecting the rate of photosynthesis?" incompletely, her level of subject matter knowledge related to the question was evaluated as acceptable (A).

Among the Anatolian High School students, Ebru (E), whose level of subject matter knowledge was acceptable (A) and who rated the question as moderately difficult (MD), and Nazlı (N), whose level of subject matter knowledge was insufficient (I) and who rated the question as moderately difficult (MD), answered the question incorrectly (W) and used a small number and variety of cognitive strategies while solving the question.

Vocational High School students Hazal (H) and Kardelen (K), whose level of subject matter knowledge was unacceptable (U), who rated the question as difficult (D), and who answered the question incorrectly (W), used a small number and variety of cognitive strategies while solving the question.

Among the Vocational High School students, Teoman (T), whose level of subject matter knowledge was unacceptable (U) and rated the question as very difficult (VD), Faruk (F), who rated the question as moderately difficult (MD), and Cemre (C), whose level of subject matter knowledge was inadequate (I) and rated the question as moderately difficult (MD), gave up when they saw the question and did not use cognitive strategies because they did not solve the question.

The findings regarding how the metacognitive strategies used by Science High School, Anatolian High Schools, and Vocational High School students while solving the biology question vary according to their level of subject matter knowledge, whether they answered the question correctly or not, and their perceptions of the ease-difficulty level of the question are presented in Table 7.

Table 7: Patterns Between the Metacognitive Strategies Used for the Biology Question, Subject matter knowledge, and the Difficulty Level of the Question

As can be seen in Table 7, among Science High School students, Zeynep (Z) and Yavuz (Y), who had very good (VG) subject matter knowledge about the multiple-choice

biology question, rated the question as easy (E) and answered the question correctly (C), and Serkan (S), who rated the question as moderately difficult (MD) and answered the question

	MULTIPLE-CHOICE BIOLOGY QUESTION														
HIGH SCHOOLS	S					A	A				V		V		
STUDENTS	A	Z	S	M	Y	O	G	B	E	N	H	K	C	T	F
ANSWERS	C	C	C	C	C	C	W	W	W	W	W	W	B	B	B
CONTENT KNOWLEDGE	VG	VG	VG	VG	VG	I	VG	A	A	I	U	U	I	U	U
DIFFICULTY LEVEL	MD	E	MD	D	E	MD	MD	MD	MD	MD	D	D	MD	VD	MD
METACOGNITIVE STRATEGIES															
Re-reading			√	√	√	√	√	√	√	√	√	√			
Revising important points							√	√							
Increasing reading speed			√												
Reading other options to check		√													
Underlining clues		√			√					√	√				
Circling clues		√	√	√			√	√	√		√				
MARKING															
Marking the figure		√													
Marking the options	√	√	√	√	√		√	√	√	√	√	√			
EXAMINING															
Re-examining the figure	√	√	√		√	√		√		√	√	√			

correctly (C), used a large number and variety of metacognitive strategies while solving the question. Among the Science High School students, Aydın (A), whose level of subject matter knowledge was very good (VG), who rated the question as moderately difficult (MD), who answered the question correctly (C), and Meltem (M), who rated the question as difficult (D), used a small number and variety of metacognitive strategies while solving the question.

Onur (O), an Anatolian High School student whose level of subject matter knowledge was insufficient (I), who rated the question as moderately difficult (MD), and who answered the

question correctly (C), used very few metacognitive strategies while solving the question. It was determined that the cognitive strategies used by Onur (O) while solving the question (Table 6) were more than the metacognitive strategies he used while solving the question (Table 7) in terms of number and variety. From this, it can be inferred that the cognitive strategies used by Onur, although his level of subject matter knowledge was insufficient (I), contributed more to answering the question correctly than the metacognitive strategies he used.

As can be seen in Table 7, among the Anatolian High School students, Gonca (G), whose subject matter knowledge was very good (VG), rated the question as moderately difficult (MD) and answered the question incorrectly (W), Ebru (E), whose subject matter knowledge was acceptable (A), and Nazlı (N), whose subject matter knowledge was insufficient (I), answered the question incorrectly even though they used metacognitive strategies. However, it was determined that Banu (B), whose level of subject matter knowledge was acceptable (A), rated the question as moderately difficulty (MD), and answered the question incorrectly (W), used more and varied metacognitive strategies. It can be stated that even though these students used metacognitive strategies while solving the question, they answered the question incorrectly (W) because they did not have sufficient subject matter knowledge to solve the question.

It was determined that Hazal (H), one of the Vocational High School students whose level of subject matter knowledge was unacceptable (U), who rated the question as difficult (D), and who answered the question incorrectly (W), used more number and variety of metacognitive strategies while solving the question than Kardelen (K). Among the Vocational High School students, Teoman (T), whose level of subject matter knowledge was unacceptable (U) and rated the question as very difficult (VD), Faruk (F), who rated the question as moderately difficult (MD), and Cemre (C), whose level of subject matter knowledge was inadequate (I) and rated the question as moderately difficult (MD), gave up when they saw the question and did not use cognitive strategies because they did not solve the question.

Discussion

According to Friege and Lind (2006), the most significant determinants of problem-solving success are students' knowledge of the problem and their subject matter knowledge regarding the problem. Lehrer and Littlefield (1993) stated that the strategies used by students in solving problems affect their subject matter knowledge regarding the problem. Simon and Simon (1978) stated that individuals who are experts in problem-solving have more experience with the problem, while individuals who are novices in problem-solving have less experience with the problem. Chi, Feltovich and Glaser (1981) stated that individuals who are experts in problem-solving have more subject matter knowledge regarding problem-solving, but novice individuals have insufficient subject matter knowledge in problem-solving. Tuminaro and Redish (2007) stated that individuals who are experts in problem-solving organize their subject matter knowledge related to the problem better, that is, they apply their existing subject matter knowledge more easily, and that these individuals' subject matter knowledge regarding the problem is highly interconnected. Reif and Allen (1992) examined the differences between novice and expert problem solvers in their use of subject matter knowledge about the problem and found that although both groups had a good level of subject matter knowledge about the problem, novice problem solvers misapplied their subject matter knowledge while solving the problem and solved the problem incorrectly because they could not associate the concepts in the problem with each other. According to Pressley and Gaskins (2006), an individual who is successful in problem-solving constantly monitors the problem-solving process and is aware of

the characteristics of the problem such as the level of compatibility of the problem with the subject matter knowledge and the degree of difficulty and complexity of the problem. While reading and solving the problem, these individuals monitor at which points they have difficulties, which obstacles they encounter, whether their concentration is impaired, and regulate their problem-solving behaviors. While a problem may be an original example for a successful problem solver, it may not be original for another problem solver with an average or low level of success (Gick, 1986). According to some researchers working on problem-solving (Dewey, 1910; Ray, 1955; Newell & Simon, 1972; Mayer, 1991), the degree of difficulty of a problem is not an intrinsic property of the problem but depends on the knowledge and experience of the individual solving the problem (Elshout, 1987; Gil-Perez et al., 1990). According to Karacam (2009), there is an interaction between students' ability to transfer their subject matter knowledge about the questions they solve and the strategies they use while solving the questions. Karacam (2009) emphasized that although there are studies on the relationship between strategies and individuals' levels of expertise, there is a lack of studies examining the relationship between subject matter knowledge and strategy use. This study was conducted to fill this gap in the literature.

Conclusions and Implications

The remarkable results of the study regarding the multiple-choice physics question are as follows.

Science High School students, who have a very good level of subject matter knowledge, rated the question as moderately difficult and answered the physics question correctly, used a large number and variety of cognitive and metacognitive strategies while solving the question. Science High School students, whose level of subject matter knowledge is very good or acceptable, who rated the question as moderately difficult or easy, and who answered the question incorrectly, have misconceptions about the question and therefore answered the physics question incorrectly.

A student from Anatolian High School, whose level of subject matter knowledge was insufficient, who rated the question as moderately difficult, and who answered the question incorrectly, used a large number and variety of cognitive and metacognitive strategies because he continued to solve the question to reach the correct answer without giving up.

Vocational High School students whose level of subject matter knowledge was unacceptable and who rated the question as moderately difficult, answered the question correctly despite their low level of subject matter knowledge because they remembered the solution to the question from similar questions they had solved in the previous year. It was determined that Vocational High School students who answered the question correctly even though their level of subject matter knowledge was unacceptable and they rated the question as moderately difficult used a large number and variety of cognitive and metacognitive strategies because they tried without giving up to solve the question. A student from Vocational High School, whose level of subject matter knowledge was unacceptable and rated the question as very difficult, gave up solving the question and did not use any of the cognitive and metacognitive strategies while solving the question because he gave up.

The remarkable results of the study regarding the multiple-choice chemistry question are as follows.

Science High School students, who have a very good level of subject matter knowledge, rated the question as moderately difficult or very easy, and answered the question correctly, used a

large number and variety of cognitive and metacognitive strategies while solving the question. Anatolian High School students whose level of subject matter knowledge was acceptable, who rated the question as easy, and who answered the question correctly used a large number and variety of cognitive and metacognitive strategies while solving the question.

It was determined that an Anatolian High School student whose level of subject matter knowledge was acceptable, who rated the question as easy, and who answered the question correctly, used a higher number and variety of metacognitive strategies than other Anatolian High School students whose level of subject matter knowledge was very good, who rated the question as moderately difficult, and answered the question correctly. From this, it can be concluded that the use of a large number and variety of metacognitive strategies is an effective tool for a student who has enough subject matter knowledge to solve any multiple-choice question and has no misconceptions about reaching the correct answer to the question.

An Anatolian High School student whose level of subject matter knowledge was insufficient, who rated the question as moderately difficult and answered the question correctly, used fewer number and variety of metacognitive strategies than Anatolian High School students whose level of subject matter knowledge was insufficient, who rated the question as moderately difficult but answered the question incorrectly. The reason for this is that the Anatolian High School students who answered the question incorrectly did not give up and tried to reach the correct answer of the question even if their level of subject matter knowledge was insufficient, and therefore they used more number and variety of metacognitive strategies. Since the level of subject matter knowledge of the students who used a large number and variety of cognitive and metacognitive strategies was insufficient to reach the correct answer, these students answered the question incorrectly. In short, if the subject matter knowledge about the question is insufficient to solve any multiple-choice question, students will answer the question incorrectly no matter how many and variety of cognitive and metacognitive strategies they use.

All of the Vocational High School students, whose level of subject matter knowledge is insufficient and unacceptable, who rated the question as difficult or very difficult, did not use cognitive and metacognitive strategies because they gave up solving the chemistry question, and left the question blank.

Science High School students used a higher number and variety of cognitive and metacognitive strategies than Anatolian High School students while solving the multiple-choice chemistry question.

The remarkable results of the study regarding the multiple-choice biology question are as follows.

Science High School students who had a very good level of subject matter knowledge for the multiple-choice Biology question and rated the question as easy, moderately difficult, or difficult used a large number and variety of cognitive and metacognitive strategies while solving the question.

An Anatolian High School student who had insufficient level of subject matter knowledge about the question, rated the question as moderately difficult, and answered the question correctly used a smaller number and variety of metacognitive strategies than cognitive strategies while solving the question. In the interview with this student after the solution of the problem, it was determined that the student selected the correct option only because he had information about the correct option, and he did not have any information about the other options. In addition, it

was determined that the student could only answer the open-ended question about the correct option and did not respond to the open-ended questions asked to him about the other options. In short, even if the level of subject matter knowledge of the students for a multiple-choice question is insufficient, if they have little subject matter knowledge about the question and if they use a lot of cognitive strategies while solving the question, they may be likely to reach the correct answer.

Some Anatolian High School students whose level of subject matter knowledge was very good or acceptable, who rated the question as moderately difficult, and who answered the question incorrectly used a large number and variety of cognitive and metacognitive strategies while solving the question. In the interviews with these students, the students stated that they answered the question incorrectly, realized the correct answer later, did not read the question carefully and comprehensively, and did not examine the options carefully. When solving a multiple-choice question, students need to use cognitive and metacognitive strategies carefully, and accurately, in accordance with the nature and type of the question to reach the correct answer to the question. It can be stated that, if students use the strategies incompletely or incorrectly while solving a multiple-choice question, they are more likely to answer the question incorrectly.

A student from Anatolian High School, whose level of subject matter knowledge was insufficient and who rated the question as moderately difficulty, answered the question incorrectly because his subject matter knowledge was insufficient, although he used cognitive and metacognitive strategies while solving the question. From this, it can be concluded that if students have little, very little, or no subject matter knowledge required for solving a multiple-choice question, they will not be able to reach the correct answer even if they use cognitive and metacognitive strategies while solving the question.

It was determined that some Vocational High School students who rated the question as difficult and answered the question incorrectly because their level of subject matter knowledge was unacceptable, although they used cognitive and metacognitive strategies.

Some students from Vocational High School who rated the question as moderately difficult or very difficult and whose level of subject matter knowledge was insufficient or unacceptable could not solve it when they saw the question and left it blank; that is, they gave up and, therefore, did not use any cognitive and metacognitive strategies.

The results obtained from this study suggest that if students have adequate subject matter knowledge, do not have misconceptions, and use cognitive and metacognitive strategies appropriate to the types and qualities of the questions, they will definitely be able to answer these multiple-choice questions correctly. In addition, it can be stated that students who rated multiple-choice physics, chemistry, and biology questions as moderately difficult, difficult, or very difficult will be more likely to answer the question correctly when they do not give up and try to solve the question.

The use of cognitive and metacognitive strategies in solving multiple-choice science questions is a significant tool to reach the correct answers to the questions, but it is not sufficient alone. It will be inevitable for students to reach the correct answer when they reflect on their subject subject matter knowledge free from misconceptions, their use of cognitive-metacognitive strategies appropriate to the qualities and types of multiple-choice questions, and their performances according to the ease and difficulty levels of the questions eclectically and holistically in the solution processes of multiple-choice questions.

Acknowledgements

I would like to thank Gazi University Scientific Research Projects Department for their contributions to the current study.

References

Abdullah, F.A.P.B. (2006). The pattern of physics problem- solving from the perspective of metacognition. Unpublished master's dissertation, University of Cambridge.

Alugar, R. B.(2025). Elementary practice teachers' technological, pedagogical, content knowledge on reproductive health education: a mixed methods analysis. Internatiinal Journal of Education, Technology and Science, 5(2), 26-46. DOI: https://doi.org/10.5281/zenodo.14905571

Anderson, J., Greeno, J., Kline, P., & Neves, D. (1981). Acquisition of problem solving skill In J.R. Anderson (Ed.), Cognitive skills and their acquisition, (pp. 313-230). Hillsdale, JH: Erlbaum.

Baki, A., Karatas, I., & Guven, B. (2002). Evaluation of problem solving skills using clinical interview method. Paper presented at the V. National Science and Mathematics Education Congress, METU, Ankara.

Chi, M., Feltovich, P., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. Cognitive Sciences, 5, 121-152. https://doi.org/10.1207/s15516709cog0502_2

Clement, J. J. (1991). Constructivism in the classroom: a review of transforming children's mathematics education. Journal for Research in Mathematics Education, 22(5), 422-428. https://doi.org/ 10.1007/BF00579463

Dewey, J. (1910). How we think. London: D. C. Heath and Company.

Dhillon, A. (1998). Individual differences within problem-solving strategies used in physics. Science Education, 82(3), 379-405. https://doi.org/10.1002/(SICI)1098-237X(199806)82:3<379::AID-SCE5>3.0.CO;2-9

Elshout, J. J. (1987). Problem solving and education. In: E. de Corte, H. Lodewijks, R. Parmentier and P. Span (Eds.), Learning and instruction (pp. 259-273). Oxford:: University Press.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive develop mental inquiry. American Psychologist, 34(10), 906-911. https://psycnet.apa.org/doi/10.1037/0003-066X.34.10.906

Finegold, M., & Mass, R. (1985). Differences in the processes of solving physics problems between good physics problem solvers and poor physics problem solvers. Research in Science and Technological Education, 3, 59-67. https://doi.org/10.1080/0263514850030107

Friege, G., & Lind, G. (2006). Types and qualities of knowledge and their relation to problem solving in physics. International Journal of Science and Mathematics Education, 4, 437-465. https://doi.org/10.1007/s10763-005-9013-8

Garner, R. (1990). When children and adults do not use learning strategies: toward a theory of settings. Review of Educational Research, 60(4), 517-529. https://doi.org/10.2307/1170504

Gick, M., L. (1986). Problem solving strategies. Educational Psychologist, 21(1,2), 99-120. https://doi.org/10.1207/s15326985ep2101&2_6

Gick, M. L., & Holyoak, K. J. (1983). Schema induction and analogical transfer. Cognitive Psychology, 15, 1-38. https://doi.org/10.1016/0010-0285(83)90002-6

Gil-Perez, D., Dumas-Carre, A., Caillot, M., & Martinez-Torregrosa, J. (1990). Paper and pencil problem solving in the physical sciences as a research activity. Studies in Science Education, 18, 137-151. https://doi.org/10.1080/03057269008559985

Gursel, U., & Karacam, S. (2020). Examining the cognitive and metacognitive strategies used in question

solving in terms of metacognitive awareness and conceptual understanding. Abant İzzet Baysal University Faculty of Education Journal 20(1), 415-438. http://dx.doi.org/10.17240/aibuefd.2020.20.52925-597115

Hartman, H., & Sternberg, R. J. (1993). A broad BACEIS for improving thinking. Instructional Science, (21)5, 401-425. https://doi.org/10.1007/BF00121204

Karacam, S. (2009). Examining students' conceptual understanding of force and motion and the cognitive and metacognitive strategies they use in solving questions, taking into account question types. Unpublished Doctoral Thesis, Gazi University, Institute of Educational Sciences, Ankara.

Lehrer, R., & Littlefield, J. (1993). Relationships among cognitive components in logo learning and transfer. Journal of Educational Psychology, 85, 317-330. https://doi.org/10.1037/0022-0663.85.2.317

Luft, J. A. (1999). Rubrics: design and use in science teacher education. Journal of Science Teacher Education, 10(2),107-121. https://doi.org/10.1023/A:1009471931127

Malone, L. K. (2006). A comparative study of the cognitive and metacognitive differences between modeling and non-modeling high school physics students. Published doctoral dissertation, University of Carregie Mellon, Pittsbuh, PA.

Mayer, R. E. (1998). Cognitive, metacognitive, and motivational aspects of problem solving. Instructional Science, 26, 49-63. https://doi.org/10.1023/A:1003088013286

Newell, A., & Simon, H. A. (1972). Human problem solving. Englewood Cliffs, NJ: Prentice Hall.

Ozsoy, G. (2007). The effect of teaching metacognitive strategies on problem solving success in the fifth grade of primary school. Unpublished Doctoral Thesis, Gazi University, Institute of Educational Sciences, Ankara.

Pressley, M., & Gaskins, I. W. (2006). Metacognitively competent reading comprehension is constructively responsive reading: How can such reading be developed in students? Metacognition Learning, 1, 99-113. https://doi.org/10.1007/s11409-006-7263-7

Priest, A. G., & Lindsay, R.O. (1992). New light on novice-expert differences in physics problem solving. British Journal of Psychology, 83, 389-405. https://doi.org/10.1111/j.2044-8295.1992.tb02449.x

Ray, W. S. (1955). Complex tasks for use in human problem-solving research. Psychological Bulletin, 52(2), 134-149. https://psycnet.apa.org/doi/10.1037/h0044763

Reif, F., & Allen, S. (1992). Cognition for interpreting scientific concepts: a study of acceleration. Cognition and Instruction, 9(1), 1-44. https://doi.org/10.1207/s1532690xci0901_1

Resnick, L. B., & Glaser, R. (1976). Problem solving and intelligence. In L. B. Resnick, (Ed.), The nature of intelligence (pp. 205-230). New Jersey: Lawrence Erlbaum Associates.

Santrock, J. W. (2011). Educational psychology (5th ed.). Mc Graw-Hill.

Savelsbergh, E. R, de Jong, T., Ferguson-Hessler, M. G. (1996). Forms of problem representation in physics. The Netherlands: University of Twente.

Schunk, D. H. (2000). Learning theories–An educational perspective. New Jersey:Prentice Hall.

Simon, D. P., & Simon. H. A. (1978). Individual differences in solving physics problems. In R. Siegler (ed. 325-348), Children's thinking: What develops? Hillsdale, N.J.: Lawrence Erlbaum Associates.

Taconis, R., Ferguson-Hessler M. G. M., & Broekkamp H. (2001). Teaching science problem solving: An overview of experimental work. Journal of Research in Science Teaching, 38(4), 442-468. https://psycnet.apa.org/doi/10.1002/tea.1013

Tuminaro J., & Redish E. (2007). Elements of a cognitive model of physics problem solving: epistemic games. Physical Review Special Topics-Physics Education Research, 3(2), 101-123. https://doi.org/10.1103/PhysRevSTPER.3.020101

Van Gog, T., Paas, F., van Merriënboer, J. G., & Witte, P. (2005). Uncovering the problem solving process: cued retrospective reporting versus concurrent and retrospective reporting. Journal of Experimental

Psychology, 11(4), 237-244. https://psycnet.apa.org/doi/10.1037/1076-898X.11.4.237
Van Someren, M. W., Barnard, Y. F., & Sandberg, J. A. (1994). The think aloud method: a practical guide to modelling cognitive processes. San Diego: Academic.
Yildirim, A., & Simsek H. (2006). Qualitative research methods in social sciences. Ankara: Seckin Publishing House.
Yin, R. K. (2003). Case study research: design and methods (3rd ed,). Thousand Oaks, CA: Sage.