Investigating 8th Grade Students' Strategies for Solving Multiple-Choice Physics, Chemistry, and Biology Questions

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Abstract

This study aimed to identify the strategies used by 8th-grade students when solving multiple-choice questions in Physics, Chemistry, and Biology, and to explore any differences or similarities in these strategies. Five 8th-grade students from a private secondary school in Kars participated in the study. They were asked to solve multiple-choice questions in each subject using the Think Aloud strategy, followed by semi-structured interviews to understand their problem-solving approaches. The data from the recordings and interviews were transcribed and analyzed using qualitative research software. The findings indicated that students employed distinct cognitive strategies for each subject. In Physics, strategies focused on numerical operations, including using formulas, setting up equations, and simplifying expressions. Chemistry problem-solving involved strategies such as self-questioning, trial and error, and the use of inequalities. For Biology questions, students relied on strategies that facilitated comprehension, such as careful reading, underlining, and identifying key parts of the question. In addition to cognitive strategies, students also utilized meta-cognitive strategies, such as reviewing and marking graphs or figures in Physics and Chemistry, and increasing reading speed and paraphrasing in Biology. The characteristics of the questions, such as the inclusion of visuals or explanations, appeared to influence the types and number of strategies employed.

Keywords: Multiple-choice questions, Physics, Chemistry, Biology, cognitive strategies, meta-cognitive strategies, 8th-grade students, High School Entrance Exam (LGS)

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INTRODUCTION

Individuals encounter various problems throughout their lives and they need to solve these problems in order to get their lives in order. As 21st century is now known as a problem-solving era, individuals should attain the ability to solve their own problems. Individuals can progress in industry, science and technology by solving the problems they encounter in their academic, professional and private lives (Unsal & Ergin, 2011). When there is a distance/gap between where the individual is and where s/he wants to be, the problem is actually referred to as the issues regarding how to get to where the individual wants to be (Hayes, 1981). Problem solving is the ability of an individual to find useful solutions in the face of a newly introduced situation (Gail, 1996). Problem solving is further defined as the cognitive processes in which an individual can achieve his goal in the face of a problem for which the solution is yet unknown (Mayer & Wittrock). Problem-solving strategies employed in the problem-solving process is very important (Diken, 2020a). Problem-solving strategy is a technique that guides the individual's problem-solving process, though it does not certainly assure achieving the correct result (Mayer, 2003). Problem solving strategies are categorized as cognitive strategies and meta-cognitive strategies. A cognitive strategy employs only a part of the mental processes to derive the solution during the problem solving process. Strategies employed to monitor, control or evaluate an action are defined as meta-cognitive strategies (Flavell, 1979). The multiple-choice question format is used in the central exams administered in Türkiye, hence problem solving and problem-solving strategies have a significant and key role in this regard (Diken, 2014). One of these central exams is the High School Entrance Exam. High School Entrance Exam (LGS) is a central exam administered simultaneously to 8th grade students enrolled in secondary schools affiliated with the Ministry of National Education in the city centers of Türkiye's 81 provinces as well as the districts of these provinces. LGS is administered every year by the Ministry of National Education to ensure the placement of the eighth grade students of private-public secondary schools in science high schools, Anatolian high schools, social sciences high schools and project schools (MoNE, 2023). Students who will take the High School Entrance Exam with multiple-choice questions are required to improve themselves in different learning areas and disciplines. Students are further expected to attain the proficiency and complete their development processes in problem-solving skills for these learning areas until the exam (Berberoglu & Kalender, 2005). Employing the cognitive/meta-cognitive strategies while solving questions is very important for students to improve their success in central exams (Diken, 2020a). In this study, the differences and similarities between the cognitive/meta-cognitive strategies employed by 8th grade students, who achieved well in the pilot tests administered for preparing for the High School Entrance Exam, while solving multiple choice questions from the Physics, Chemistry and Biology learning areas were determined. The results obtained from this research will guide further studies by revealing which cognitive/meta-cognitive strategies should be taught to students preparing for the High School Entrance Exam in line with the learning areas and characteristics of the questions.

METHOD

Purpose

This study serves to determine the differences and similarities between the cognitive/meta-cognitive strategies employed by 8th grade students while solving multiple choice Physics, Chemistry and Biology questions.

Participants

Five 8th grade students enrolled in a private secondary school in the city center of Kars were included in the study. Participants were nominated as the high-achieving students who ranked in the top five in the pilot tests administered for preparing for the High School Entrance Exam.

Study Design

The cognitive/meta-cognitive strategies employed by students in solving Physics, Chemistry and Biology questions were first evaluated within their own context and then comparatively. In other words, this is a case study which is one of the qualitative research designs (Yildirim & Simsek, 2020; Yin, 2003).

Data Collection Tools

Multiple Choice Physics, Chemistry, Biology Questions

Three multiple choice questions, one from each of the Physics, Chemistry and Biology disciplines, which were previously asked in the prior years' High School Entrance Exams (LGS) were used for the purpose of the study. Opinions of Physics, Chemistry and Biology teachers were sought while selecting these questions. Though the validity and reliability of the questions asked in the prior years' High School Entrance Exams (LGS) have already been confirmed, they were reviewed by three faculty members who have worked in the Physics, Chemistry and Biology disciplines for many years. The Physics question was related to the "Pressure" unit, Chemistry question was about the "Materials and Industry" unit and the Biology question was about the "DNA and Genetic Codes" unit. The reason why these units are preferred is that questions from these units have definitely been included in the High School Entrance Exams every year and that these units offer a high number of learning outcomes. The questions were paraphrased to be used in the research. Furthermore, the author who has been working on cognitive/meta-cognitive strategies argued that students will be more likely to employ strategies while solving these questions. These were medium to difficult questions, including graphics, figures and explanations, in which reading, reading comprehension and problem solving strategies can be used effectively.

Semi-Structured Interview Questions

Semi-Structured Interview Questions used for the purpose of this study served to confirm students' employment of cognitive/meta-cognitive strategies while solving Physics, Chemistry and Biology questions and to guide the author in categorizing these strategies as either cognitive or meta-cognitive strategies. Following the problem-solving session, students were asked for what purposes and why they employed these strategies while solving these questions. For example, "Why did you use this formula while solving the question?" "Why did you encircle some words with your pen while solving the question?".

Research Process

Relevant permissions were obtained for the author to conduct this research in a private secondary school. Verbal consent was further obtained from the administrator of the private secondary school and the science teachers of the students and they were informed about how the research would be implemented. The author then met the students who scored in the top five ranks in the pilot tests administered for preparing for the High School Entrance Exam and informed them about how the research would be implemented. Students were asked whether they wanted to participate in the study. All five students expressed their consent to participate in the research. The questions were then administered to the students. The author primarily explained to the students how they should use the Think Aloud Strategy while solving the questions. Students successfully completed the problem solving session using the Think Aloud Strategy. Students were then asked to answer the semi-structured questions about the purposes for which they used the strategies while solving the questions. All these processes were recorded with camera footage. Following the implementation process, the author transcribed all of the camera-recorded problem-solving processes and post problem-solving session interviews on a computer. The transcribed data were analyzed on the computer environment using a unique qualitative research program.

Data Analysis

For the purpose of the data analysis, the strategies employed were primarily categorized into two as cognitive strategies and meta-cognitive strategies. The strategies employed were further coded taking into consideration prior studies reviewed by the author during the literature review. In line with the purposes of using the strategies, expressed by the students, these codes were then assigned to one of two relevant categories: cognitive and meta-cognitive. Some codes appeared in both categories (i.e. both cognitive and meta-cognitive strategies). A strategy can be classified as both cognitive and meta-cognitive, depending on the purpose of use (Flavell, 1979). After completing the coding, the author met with a colleague who had also worked on strategies for many years and discussed the codes of the study. Some of the data were further coded by the other researcher. The consistency between cross-codings was found to be 99%. The only disagreement was on whether the note-taking strategy employed by a single student on a question should be considered as a cognitive or meta-cognitive strategy. After watching the problem solving session in which this strategy was employed and the subsequent interview, two researchers adopted a mutual understanding that the strategy should be coded as a meta-cognitive strategy. Analyzed data were then transferred to the table format in order to be presented in the results section of the study.

FINDINGS

The tables and explanations of the results obtained by analyzing the research data are as follows: Real identities of the students were kept confidential and the students were anonymized as A1, A2, A3, A4, A5.

The results with regard to the cognitive strategies employed by 8th grade students while solving Physics, Chemistry and Biology questions are presented in Table 1.

Table 1. Cognitive Strategies employed while solving Physics, Chemistry and Biology questions

HIGH SCHOOL	**PRIVATE SECONDARY SCHOOL**														
GRADE	**8. GRADE**														
LEARNING AREA	**PHYSICS QUESTION**					**CHEMISTRY QUESTION**					**BIOLOGY QUESTION**				
STUDENTS	**A1**	**A2**	**A3**	**A4**	**A5**	**A1**	**A2**	**A3**	**A4**	**A5**	**A1**	**A2**	**A3**	**A4**	**A5**
COGNITIVE STRATEGIES															
Visualization	&	&	&	&	&										
Reading starting from the root of the problem						&		&	&		&	&	&	&	&
Assigning a numerical value	&	&	&	&	&										
Note-taking	&	&	&	&	&	&	&	&	&	&	&	&	&	&	&
Reflecting the problem in the behavior		&	&	&											
Asking oneself questions							&	&	&						
Expressing in one's own words		&	&		&	&	&	&	&		&	&	&		&
Reading with underlining words											&	&	&	&	&
Reading while tracing the words with a pen	&	&	&	&	&	&	&	&	&	&	&	&	&	&	&
Grouping		&		&	&										
Paying attention to the parts of sentences											&	&	&	&	&
Increasing the reading speed											&		&	&	
Using formulas	&	&	&	&	&										
Establishing equations	&	&	&	&	&										
Establishing proportions	&	&	&	&	&										
Simplifying and expanding algebraic expressions	&	&	&	&	&										
Making use of inequalities						&	&	&		&					
Trial and Error	&	&	&	&	&	&	&	&	&	&					
COMPARISON															
Comparing the Figure and the	&	&	&	&	&										

Graphics															
Comparing the inputs of the question	&	&	&	&	&										
Comparing the figures											&	&	&	&	&
Comparing the options	&	&		&	&		&	&	&			&	&		
EXAMINATION															
Examining the Figures	&	&	&	&	&	&	&	&	&	&	&	&	&	&	&
Examining the Graphics	&	&	&	&	&										
DRAWING															
Drawing a Figure/Chart											&	&	&	&	
ELIMINATION															
Eliminating the Options	&		&	&	&	&		&	&		&	&	&	&	&

Table 1 revealed that the students employed the cognitive strategies of Visualization, Assigning a numerical value, Note-taking, Reflecting the problem in the behavior, Expressing in one's own words, Reading while tracing the words with a pen, Grouping, Using formulas, Establishing equations, Establishing proportions, Simplifying and expanding algebraic expressions, Trial and Error, Comparing the Figure and the Graphics, Comparing the inputs of the question, Comparing the Figures, Comparing the options, Reviewing the Figure, Eliminating the Options and Reviewing the Graphics while solving the Physics question. The students were determined to have employed the cognitive strategies of Reading starting from the root of the problem, Note-taking, Asking oneself questions, Expressing in one's own words, Reading while tracing the words with a pen, Making use of inequalities, Trial and Error, Comparing the options, Eliminating the Options and Reviewing the Figure while solving the Chemistry question. The cognitive strategies employed by the students while solving the Biology question were determined as Reading starting from the root of the problem, Note-taking, Expressing in one's own words, Reading with underlining words, Reading while tracing the words with a pen, Paying attention to the parts of sentences, Increasing the reading speed, Reviewing the Figure, Comparing the figures, Comparing the options, Eliminating the Options and Drawing a Figure/Chart. Cognitive strategies employed while solving the Physics question however not used for solving the Chemistry and Biology questions were Visualization, Assigning a numerical value, Reflecting the problem in the behavior, Grouping, Using formulas, Establishing equations, Establishing proportions, Simplifying and expanding algebraic expressions, Comparing the Figure and the Graphics, Comparing the inputs of the question and Reviewing the Graphics. Cognitive strategies employed while solving the Chemistry question however not used for solving the Physics and Biology questions were Asking oneself questions and Making use of inequalities. Cognitive strategies employed while solving the Biology question however not used for solving the Physics and Chemistry questions were Reading with underlining words, Paying attention to the parts of sentences, Increasing the reading speed, Comparing the figures and Drawing a Figure/Chart. Cognitive strategies mutually used while solving Physics, Chemistry and Biology questions were determined as Note-taking, Reading by tracing the words with a pen, Reviewing the Figure and Eliminating the options.

The results with regard to the meta-cognitive strategies employed by 8th grade students while solving Physics, Chemistry and Biology questions are presented in Table 2.

Table 2. Meta-cognitive Strategies employed while solving Physics, Chemistry and Biology questions

HIGH SCHOOL	PRIVATE SECONDARY SCHOOL														
GRADE	8. GRADE														
LEARNING AREA	PHYSICS QUESTION					CHEMISTRY QUESTION					BIOLOGY QUESTION				
STUDENTS	A1	A2	A3	A4	A5	A1	A2	A3	A4	A5	A1	A2	A3	A4	A5
META-COGNITIVE STRATEGIES															
Re-reading		&	&		&	&	&	&		&	&	&	&	&	&
Underlining clues	&	&	&	&	&	&	&	&	&	&	&	&	&	&	&
Encircling clues	&	&	&	&	&	&	&	&	&	&	&	&	&	&	&
Repeating highlights	&	&		&			&	&	&		&	&	&	&	
MARKING															
Marking the Options	&		&	&	&	&	&		&		&			&	&
Reading with underlining words							&			&	&	&	&	&	&
Asking oneself questions			&			&					&				
Backtracking	&	&		&	&	&		&		&					&
Checking whether the answer is correct	&	&	&	&	&	&	&	&	&	&	&	&	&	&	&
REVIEWING															
Reviewing the Figure	&	&	&	&	&	&	&	&	&	&	&	&	&	&	&
Reviewing the Graphics	&	&	&	&	&										
Reviewing the mathematical operation	&	&	&	&	&	&	&	&	&			&	&	&	&
Marking descriptions in the text (with a tick, symbol etc.)											&	&	&	&	&
Marking the figure (with a tick, symbol etc.)						&	&	&	&	&	&	&	&	&	&
Marking the Graphics	&	&	&	&	&										
Increasing the reading speed											&	&	&	&	
Note-taking	&	&	&	&	&	&	&	&	&	&	&	&	&	&	&
Expressing in one's own words												&	&		&
RECOMPARING															
Re-comparing the Options	&	&		&	&		&	&	&			&	&		
Re-comparing the Figure and the Graphics	&	&	&	&	&										
Re-comparing the Figures											&	&	&	&	&
Re-comparing the Options with the descriptions in the text					&	&			&	&	&	&		&	&
Re-comparing the Options with the Figure						&	&	&	&	&	&	&	&	&	&
Re-comparing the Options with the Graphics	&	&	&	&	&										
Re-comparing the descriptions in the text with the Figure							&		&	&	&		&	&	&
Re-comparing the descriptions in the text with the Graphics	&	&	&	&	&										

Table 2 revealed that the students employed the meta-cognitive strategies of Re-reading, Repeating highlights, Underlining clues, Encircling clues, Marking the Options (with a tick, symbol etc.), Reviewing the Figure, Asking oneself questions, Backtracking, Checking whether the answer is correct, Reviewing the Figure, Reviewing the Graphics, Reviewing the mathematical operations, Marking the Graphic, Marking the figure (with a tick, symbol etc.), Marking the Options, Note-taking, Comparing the Options, Comparing the Options with the descriptions in the text, Comparing the Options with the Graphics and Comparing the descriptions in the text with the Graphics while solving the Physics question. The students were determined to have employed the meta-cognitive strategies of Re-reading, Underlining clues, Encircling clues, Reviewing the Figure, Asking oneself questions, Backtracking, Checking whether the answer is correct, Note-taking, Re-comparing the Options, Re-comparing the Options with the Figure, Re-comparing the descriptions in the text with the Figure,

Marking the Options, Repeating highlights, Reading with underlining words while solving the Chemistry question. Meta-cognitive strategies employed by the students while solving the Biology question were determined as Re-reading, Repeating highlights, Underlining clues, Encircling clues, Marking descriptions in the text, Reviewing the Figure, Reading with underlining words, Asking oneself questions, Backtracking, Checking whether the answer is correct, Reviewing the mathematical operations, Marking descriptions in the text (with a tick, symbol etc.), Marking the figure (with a tick, symbol etc.), Marking the Options, Note-taking, Expressing in one's own words, Re-comparing the options, Re-comparing the Figures, Re-comparing the Options with the descriptions in the text, Re-comparing the Options with the Figure, Re-comparing the descriptions in the text with the Figure. Meta-cognitive strategies employed while solving the Physics question however not used for solving the Chemistry and Biology questions were Reviewing the Graphics, Marking the Graphics, Comparing the Figure and the Graphics, Re-comparing the Options with the Graphics, Re-comparing the descriptions in the text with the Graphics. There is no meta-cognitive strategy employed while solving the Chemistry question however not used for solving the Physics and Biology questions. Meta-cognitive strategies employed while solving the Biology question however not used for solving the Physics and Chemistry questions were Marking descriptions in the text and Expressing in one's own words.

CONCLUSION AND DISCUSSION

In line with the results of this study, it is noteworthy that the cognitive strategies employed while solving the Physics question were rather strategies that are significantly important in solving numerical operations such as Visualization, Assigning a numerical value, Note-taking, Reflecting the problem in the behavior, Expressing in one's own words, Using formulas, Establishing equations, Establishing proportions, Simplifying and expanding algebraic expressions and Trial and Error. As the physics learning area includes topics that require numerical operations, making use of these strategies is essential in answering the question correctly. The cognitive strategies commonly employed while solving the Chemistry question were strategies that are partly related to reading comprehension and partly related to solving numerical operations such as Reading starting from the root of the problem, Note-taking, Asking oneself questions, Expressing in one's own words, Making use of inequalities, Trial and Error and Eliminating the Options. It is reasonable to make use of both reading-comprehension and problem-solving strategies in the Chemistry learning area, as it includes topics that require both theory and numerical operations. It was determined that the cognitive strategies employed while solving the Biology question were strategies that are partly related to reading comprehension and partly related to problem solving such as Reading starting from the root of the problem, Note-taking, Expressing in one's own words, Reading with underlining words, Reading while tracing the words with a pen, Paying attention to the parts of sentences, Increasing the reading speed, Reviewing the Figure, Comparing the figures, Eliminating the Options and Drawing a Figure/Chart. The reason for this is that the Biology learning area is conceptual, theoretical and verbal in terms of the topics it covers.

The results of the study indicated that significant meta-cognitive strategies such as re-reading, repeating highlights, underlining clues, encircling clues, marking the options, backtracking, checking whether the answer is correct, reviewing the mathematical operations, marking the graphics, marking the figure (with a tick, symbol etc.), marking the options and note-taking were employed while solving the Physics question that focuses rather on numerical skills. The students were determined to have employed the meta-cognitive strategies of re-reading, underlining clues, encircling clues, reviewing the figure, asking oneself questions, backtracking, checking whether the answer is correct, reviewing the mathematical operations, note-taking, re-comparing the options, re-comparing the options with the figure, marking the options, repeating highlights, reading with underlining words while solving the Chemistry question that focuses partly on verbal skills and partly on numerical skills. It is noteworthy that meta-cognitive strategies related to reading and reading comprehension such as re-reading, repeating highlights, underlining clues, encircling clues, marking descriptions in the text, reading with underlining words, backtracking, checking whether the answer is correct, reviewing the mathematical operations, marking descriptions in the text (with a tick, symbol etc.), marking the figure (with a tick,

symbol etc.), marking the options, note-taking, expressing in one's own words and re-comparing the descriptions in the text with the figure were employed while solving the completely verbal-conceptual Biology question.

There are various studies in the literature that focus on the use of cognitive/meta-cognitive strategies for solving multiple-choice questions (Diken, 2014; Tutar; 2016; Diken & Yuruk, 2019; Diken, 2020a; Diken, 2020b; Karacam & Gursel 2020; Tutar, Demir, & Diken, 2020). There are also studies in the literature aiming to determine the cognitive/meta-cognitive strategies with regard to improving reading comprehension skills (Kumlu, 2012; Diken, 2020c; Diken, 2020d; Yurttas Kumlu & Yuruk, 2020; Yurttaş Kumlu & Yuruk 2023).

It was concluded in this study that the cognitive/meta-cognitive strategies employed while solving Physics, Chemistry and Biology questions vary depending on the characteristics of the questions. In other words, whether the questions include figures, graphics, descriptions, tables or only text without any figures, tables or graphics is a significant factor that affects and triggers the type and number of cognitive/meta-cognitive strategies employed in solving these questions (Diken & Yuruk 2019). Diken (2014) argued that the characteristics of multiple-choice science questions, that is, whether the questions include any figures, tables, graphics or only text or whether it requires only numerical operations affect the frequency, number and types of the strategies employed in the solution processes of these questions.

As the content and learning areas of the questions nominated for the purpose of this study are different, it is possible to conclude that these cognitive/meta-cognitive strategies that students employed while solving the questions are essential tools that allow them to answer the questions correctly. The results of this study will shed a light on further studies as it is revealed that all these strategies employed while solving Physics, Chemistry and Biology questions correctly may assume a critical role when taught to 8th grade secondary school students preparing for the High School Entrance Exam.

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