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Examination of Students' Metacognitive Awareness and Their Physical Problem Solving Strategies

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Abstract: Although studies suggest that metacognitive strategy instruction can promote increased problem solving in the classroom, little evidence has been collected that directly probes the role of metacognition in problem solving. This study examined high school students' metacognition and physical problem solving skills and looked for a relationship between the two. A correlational research design was carried out for this research. Participants of the study were eleventh graders studying in an urban all-boys school. The Metacognition Awareness Inventory was administered to determine the students' metacognition. Physical Problem Solving Assessment Inventory was used to assess the participants' problem solving strategies. Results showed that the students' metacognitive awareness level was close to high. Their knowledge about cognition was higher than their regulation of cognition. Additionally, the students' physical problem solving strategies were little. Results also presented that the more metacognitive awareness the students had the more knowledge of reading they had. Pearson correlation coefficient analyses indicated a significant medium level positive relationship between the students' metacognitive awareness and their physical problem solving strategies.

Keywords: Metacognitive awareness, Physical problem solving, High school students

Introduction

Since metacognition refers to higher-order mental process involved in using appropriate skills and strategies to solve a problem (Coutinho, 2007), learners' metacognitive ability allows them solving of problems successfully (Eric & Mansoor, 2007). Several cognitive processes and metacognitive strategies are integral to problem representation and problem execution and underlie successful problem solving (Mayer, 1998).

Metacognitive training programs were found effective for problem-solving strategies regardless of learning aptitude or achievement (Delclos & Harrington, 1991). Swanson (1990) indicated that metacognitive skills helped children of lower aptitude compensate on problem-solving tasks. In addition, Sperling, Howard, Miller and Murphy (2002) showed significant correlations between children's metacognitive awareness and problem solving strategies. However, more research is needed to examine the possible relationship between students' metacognition and their physical problem solving strategies. Therefore, the following research questions put a light on this research:

1. What is students' metacognitive awareness level?
2. What are students' physical problem solving strategies?
3. Is there a statistically significant relationship between physics students' metacognitive awareness and their physical problem solving strategies?

Methodology

A correlational research design (Creswell, 2008) was carried out for this research to examine the relationship between participants' metacognition and their problem solving strategies. Both qualitative and quantitative methods were used to collect and analyze the data in order to understand the possible relationship.

Participants and Settings

Participants in the study were eleventh graders studying in an urban all-boys school. Their ages were between 17 and 18 years old. The participants were taught geometrical optics and the related concepts such as light intensity and illumination in the eleventh grade. The students took physics for 4 h/week.

Role of the Researchers

Two researchers planned the research together but the first researcher collected the data. The first author was the teacher of the students. Hence, she had two roles. One was as a teacher and the other one was as a researcher. This situation enabled her to establish good communication with the students and to create an environment where the students felt comfortable about stating their thoughts. The students were ensured that their participation to the research and their responses would not affect their physics grades.

Data Collection and Analysis

Metacognitive Awareness Inventory

The Metacognition Awareness Inventory (MAI) developed by Schraw and Dennison (1994) was used in this study to determine the participants' metacognition. This inventory was selected among the similar instruments because it is valid, reliable and suitable for high school students. The MAI was a self-report instrument and consists of 52 items based on five-point Likert scale. There were 17 items related to knowledge about cognition and 35 items related to regulation of cognition. Items related to knowledge about cognition were distributed under the following components: declarative knowledge, procedural knowledge, and conditional or strategic knowledge. There were five components of regulation of cognition called: Planning, information management, monitoring, debugging, and evaluation.

The MAI was administered to all 95 eleven graders during their physics classes. The students completed the inventory in about 20 minutes. Participation was volunteered. Cronbach alpha value was found as .91 showing that the instrument used in this study had high internal consistency. Descriptive statistics were performed to determine the participants' metacognitive awareness. The students' mean values were ranged between 2.86 and 4.40. Therefore, their performances were assessed based on their mean scores where 2.86 – 3.37 was evaluated as low metacognitive awareness and labeled as Group 1, 3.38 – 3.89 was evaluated as medium metacognitive awareness and labeled as Group 2, and 3.90 – 4.40 was evaluated as high metacognitive awareness and labeled as Group 3. There were 24 participants in the Group 1, 45 participants in the Group 2, and 26 participants in the Group 3. Total of 30 students from each group (eight students from the Group 1, 14 students from the Group 2, and eight students from the Group 3) with a 30% sampling ratio were selected randomly to examine the relationship between metacognition and problem solving.

Physics Problem Solving Assessment

In order to determine the participants' physical problem solving skills, Physical Problem Solving Assessment (PPSA) inventory was prepared by considering the short form of the Mathematical Problem Solving Assessment (MPSA) inventory developed by Montague (1992). Items about perception and attitude were taken out from the Mathematical Problem Solving inventory. The PPSA had two parts. The first part included 10 open-ended questions assessing physical problem solving strategies. The second part consisted of five authentic physics problems. The questions in the first part were distributed under four components of physical problem solving strategies. There were three questions related to the knowledge of problem solving strategies component, three questions related to the knowledge of reading component, two questions related to the use of reading component, and two questions related to the control of reading component. The subject of the physics problems was photo electric.

The selected 30 students were requested to complete the PPSA in the teacher's office. In order to analyze students' problem solving strategies assessed in 10 questions, the researchers prepared a rubric and calculate the score of each participants. The minimum score one can be obtained from this rubric corresponds to 10 whereas the maximum score is 50. Cronbach alpha value was found as .79 for the PPSA showing that the inventory was reliable. The physics problems in the PPSA was not used in this research. Pearson correlation coefficient analysis was performed to find an answer for the third research question.

Results and Discussion

Table 1 shows the students' mean values gathered from the MAI and its components. According to the table, the students' metacognitive awareness level was close to high (M = 3.69). Their knowledge about cognition (M = 3.76) was higher than their regulation of cognition (M = 3.62). This means that the students' knowledge of their own cognitive process was better than their control over their own cognitive process. Moreover, the students' conditional knowledge was high (M = 3.96). That is, they had awareness of the conditions that influenced their learning such as why strategies were appropriate (Deseote et al., 2001). The participants could also debug well (M = 3.87). In other words, they could fix strategies to correct comprehension and performance errors (Schraw & Dennison, 1994).

Table 1. The students' mean values based on the MAI and its components

	Metacognitive awareness	Knowledge about cognition	Regulation of cognition	Declarative knowledge	Procedural knowledge	Conditional knowledge	Planning	Monitoring	Evaluation	Debugging strategies	Information management
M	3.69	3.76	3.62	3.77	3.56	3.96	3.66	3.44	3.56	3.87	3.58

The overall mean value for the students' physical problem solving strategies was 16.52, which was low regarding that the highest value was 50. This finding indicates that the students did not much read physics problems, could not define what were given in the problem and what was asking, did not make a plan or a specific activity to solve the problem, and could not analyze and check the solution every time they solved the problem. Table 2 presents the groups' mean values obtained from 10 questions of the PPSA. As the groups were determined based on their metacognitive awareness, the third group had the highest metacognitive level. According to the table, there was not a statistical significant difference among the groups' physical problem solving strategies (p = 0.17 > 0,05). Although the students' problem solving strategies increased as their metacognitive level increased, this connection was not significant.

Table 2. Groups' mean values of physics problem solving strategies

Groups	N	M	SD	Min.	Max.	SE	F	p
First Group	8	14.25	3.62	1100	20.00	1.28	1.92	0.17
Second Group	14	16.43	5.80	10.00	26.00	1.55		
Third Group	8	18.88	3.23	14.00	24.00	1.14		

Table 3 demonstrates the groups' mean values of the components in physical problem solving strategies. It can be seen from the table that the students got the highest score in the knowledge of reading component (M = 5.70) among the other components. The maximum score one can earned from this component was 15; therefore, this result showed that they sometimes read and tried to understand the physics problems. On the other hand, the students got the lowest score in the control of reading component (M = 3.10) out of 10. The students rarely asked themselves questions about understanding the physics problem. There was a significant difference among the groups' problem solving strategies in the knowledge of reading component (p = 0.05). That is, the more metacognitive awareness the students had the more knowledge of reading they had.

Pearson correlation coefficient analyses presented in Table 4 showed a significant medium level positive relationship between the students' metacognitive awareness and their physical problem solving strategies ($r = 0.56$, $p < .05$). In other words, high metacognitive awareness might result in high problem solving strategies in physics. This result was consistent with the result that emerged from the research by Meijer, Veenman and van Hout-Wolters (2006) whose participants were secondary school students. They found substantial correlation between metacognitive activities and studying text and making assignments in physics. This finding supported what Sandi-Urena, Cooper and Stevens (2012) stated that problem-based lab instruction made improvement in college students' metacognitive skills.

Tablo 3. Groups' mean values of the components in problem solving strategies

Component	Groups	N	M	SD	SE	Min.	Max.	F	p
Knowledge of problem solving strategies	First	8	3.88	1.13	0.40	3.00	6.00		
	Second	14	4.50	1.99	0.53	3.00	9.00		
	Third	8	5.13	1.25	0.44	4.00	7.00	1.18	0.32
	Total	30	4.50	1.63	0.30	3.00	9.00		
Knowledge of reading	First	8	4.50	1.07	0.38	3.00	6.00		
	Second	14	5.71	2.30	0.62	3.00	9.00		
	Third	8	6.88	1.46	0.52	5.00	10.00	1.19	0.05
	Total	30	5.70	1.99	0.36	3.00	10.00		
Use of reading	First	8	2.88	0.99	0.35	2.00	5.00		
	Second	14	3.14	1.10	0.29	2.00	5.00		
	Third	8	3.62	1.69	0.60	2.00	7.00	0.24	0.49
	Total	30	3.21	1.24	0.23	2.00	7.00		
Control of reading	First	8	3.00	1.31	0.46	2.00	5.00		
	Second	14	3.07	1.14	0.30	2.00	5.00		
	Third	8	3.25	1.04	0.37	2.00	5.00	0.71	0.91
	Total	30	3.10	1.12	0.21	2.00	5.00		

Table 4. Correlation analyses between metacognitive awareness and physics problem solving strategies (N=30)

Pearson Correlation		Metacognitive Awareness	Physics Problem Solving Strategies
Metacognitive Awareness	Correlation Coefficient Sig. (2-tailed)	1	0.56 0.01
Physics Problem Solving Strategies	Correlation Coefficient Sig. (2-tailed)	0.56 0.01	1

Conclusion and Suggestion

Metacognition plays a critical role in successful learning; hence, it is important to study metacognition and to determine how students can be taught to apply their cognitive resources through metacognitive control (Livingston, 2003). Despite numerous efforts to increase students' problem-solving abilities, many still fail to solving problems even when they are simply required to apply an algorithm in order to obtain the 'correct' solution (Lorenzo, 2005). Although studies suggest that metacognitive strategy instruction can promote increased problem solving in the classroom, little evidence has been collected that directly probes the role of metacognition in problem solving (Sandi-Urena et al., 2012). This research examined high school students' metacognition and physical problem solving skills and looked for a relationship between the two. It can be concluded from the study that although eleventh graders' metacognitive awareness is in reasonable level, they cannot use physical problem solving strategies much. In addition, there is a relationship between students' metacognitive awareness and their physical problem solving strategies. Hence, this research study suggests that enhancing metacognitive awareness can facilitate problem solving.

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