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Abstract

In order to effectively learn physics, students need to be actively involved in problem solving. The purpose of this study was to evaluate the relationship between students' metacognitive awareness and their problem solving strategies in physics. Conceptual framework was based on Polya's problem solving strategies and Shraw and Dennison's metacognitive awareness theory. Correlational design including both quantitative and qualitative data collection methods was carried out for this research. The participants of the research consisted of 30 high school students. Data were collected by using Metacognitive Awareness Inventory and Physics Problem Solving Assessment. The first conclusion drawn from this research is that high school students have high metacognitive awareness. Second, students are not very good at in physics problem solving strategies. Third, metacognitive awareness can have impact on problem solving strategies in physics. Fourth, looking back-reflection stage is the problem solving strategy that is affected by the dimensions of metacognitive awareness most. Finally, procedural knowledge and monitoring dimensions of metacognitive awareness have critical roles in physics problem solving strategies. Reflection of metacognitive awareness to problem solving strategies and especially using procedural knowledge and monitoring during problem solving are important strategies that need to be emphasized and encouraged in teaching and learning science.

Introduction

Problem solving is part of the 21st century skills and has been an important goal in science education (Zhang & Shen, 2015) especially in physics education (Adams & Wieman, 2015; Docktor et al., 2010). Problem solving is a cognitive process (Greiff et al., 2013) of finding ways to solve the problem within the difficulties caused by the problem situation (Polya, 1971). There are two tendencies in the literature regarding the problem solving process. The first trend focuses on the process of the solution (Reif, Larkin & Brackett, 1976; Schoenfeld, 1979) while the second one emphases the knowledge of the problem solving and the organization of knowledge (Chi, Feltovich & Glas, 1981). Many factors, such as metacognitive awareness and content knowledge affect students' problem solving process.

Well-developed metacognitive awareness is not only an important predictor in problem solving but also in learning process (Börnert & Wilbert, 2015). The metacognitive awareness is defined as the operations of realizing, monitoring, controlling and regulating performed by the individual with his or her own cognitive processes (Brown, 1987; Flavell, 1987; Metcalfe & Shimamura, 1994; Obstal & Daubenmire, 2015). Metacognitive awareness involves the individual to realize his/her thoughts, task performances, and the thinking process about thinking (Flavell, 1979). Recently, researchers argue that whether metacognitive awareness is a general skill or a domain-specific skill. Some researchers think that although metacognition is used in different fields, it can be transferred from one field to another (Veenman & Verheij, 2003). Other researchers have found that young students' metacognitive awareness seems domain specific and it may generalize with age (Van der Stel & Veenman, 2014; Veenman & Spaans, 2005). In addition, research evidence suggests that metacognition develops gradually and is dependent on knowledge as well as experience (Koretsky et al., 2018).

Metacognitive awareness refers to individuals’ awareness of where they are in the process of solving a problem and their knowledge about problem solving strategies (Kuzle, 2019). Metacognition is used in the orientation, organization, execution, and verification of problem solving (Pugalee, 2004; Zhao et al., 2019). Many studies have investigated the relationship between students' metacognitive awareness and problem-solving process in different disciplines such as mathematics (Baten, Praet & Desoete, 2017; Desoete & De-Craene, 2019; Hammouri, 2003; Lucangeli, Tressoldi & Cendron, 1998; Rosenzweig et al., 2011; Schoenfeld, 1992; Stillman & Mevarech, 2010; Veenman & Van Cleef, 2019; Yimer & Ellerton, 2006), chemistry (Cooper & Sandi-Urena, 2009; Heidbrink & Weinrich, 2021; Rickey & Stacy, 2000; Sandi-Urena et al., 2012), physics (Morphew, Gladding & Mestre, 2020; Mota et al., 2019; Neto & Valente, 1997; Taasoobshirazi, Bailey & Farley, 2015), physics and history (Meijer, Veenman & Van Hout-Wolters, 2006), STEM (Vestal, Miller & Browning, 2017), geometry (Kuzle, 2013) and science (Akben, 2020; Rozencwajg, 2003). Research showed that cognitive and metacognitive processes involved in problem solving (García et al., 2015). It is known that physics is a difficult field (Ornek, Robinson & Haugan, 2008). Metacognitive awareness is critical in helping students learn physics (Taasoobshirazi et al., 2015). Since metacognitive awareness refers to the high-level mental process of using appropriate strategies to solve a problem (Coutinho, 2007), learners' metacognitive abilities enable them to solve problems successfully (Eric & Mansoor, 2007). That is, metacognitive strategies are integral parts of problem representation and problem solving (Mayer, 1998). Therefore, this research focused on the examination of the relationship between students' metacognitive awareness and their problem solving strategies in physics.

Conceptual Framework

Flavell (1976) describes metacognition as one’s knowledge concerning one’s own cognitive process and regulating one’s own cognitive process with to help of this knowledge. There are different models in order to better understand and improve metacognitive awareness because it has a complex structure and includes many cognitive processes (Brown et al., 1983). Schraw & Dennison (1994)’s model based on Brown’s (1980) work framed this study. Metacognition is comprised of two components: knowledge about cognition (metacognitive knowledge) and regulation of cognition (metacognitive regulation) (Schraw & Dennison, 1994). Knowledge about cognition is both the individual's knowledge of his/her own cognitive processes and is an awareness of the strategies that should be used in the problem solving strategies (Wilson & Clark, 2004). Regulation of cognition, on the other hand, refers to activities that control one's thinking and learning and provides to use and control of this awareness in the problem solving process (Kallio, Virta & Kallio, 2018). It also gives information on when and why strategies should be chosen to accomplish a task (Brown, 1987; Flavell, 1987; Metcalfe & Shimmura, 1994; Schraw & Moshman, 1995). Metacognitive awareness includes individuals' contextual information and personal learning or problem-solving strategies. It is also about what individuals should do in the learning or problem solving process (Wilson & Clarke, 2004).

Problem solving is one of the most significant factors in the cognitive process. Various researchers refer the crucial of metacognitive awareness for the problem solving strategies (Carifio, 2015; Ifenthaler, 2012). Problem-solving refers to the mental process that people go through to discover, analyze, and solve problems (Sarathy, 2018) and problem solving strategies are defined as planned sequences of activities leading to a goal, the solution of the problem (Taconis et al, 2001). Polya (1971) argues that problem-solving is a process starting from the instant a student is faced with the problem until the end of the process when the problem is solved. Problem-solving strategies developed by Polya (1971) contain the following four steps: description, planning, implementation, and checking. These steps were taken into account for this study's conceptual framework.

Relationship between Metacognitive Awareness and Problem Solving Strategies

Rosenzweig et al., (2011) investigated the metacognitive skills of students with learning disabilities during mathematical problem solving and revealed the differences between the problem solving processes of these students and their peers with low and average achievement. The participants were 73 8th grade students. The researchers found that the participants performed different metacognitive activity models depending on the difficulties of the math problems. In particular, they showed that different patterns of metacognitive activity were evident for different ability groups and productive metacognitive verbalizations directed and helped the problem solver move toward a problem solution by using strategies such as self-instruction, self-questioning, and self-monitoring. Carifio (2015) aimed to update, modernize and test Polya's mathematical problem solving theory in terms of cognitive, affective and information processing theories, learning, emotions and complex performances. 152 technical university students participated in the study. The participants solved two math problems and answered a questionnaire measuring self-report emotional and physiological feelings. The solutions of the mathematical problems were analyzed according to Polya's four-key cognitive process steps. The results of the study revealed that there were significant metacognitive and emotional differences between expert and novice problem solvers. It was also found that the students who solved the problem correctly had more positive emotions and lower physiological reactions than the other students. In another study conducted by Kuzle (2019), 36 2nd and 4th grade students' mathematical problem solving processes were examined by using Wilson and Clarke's (2004) metacognition model and multi-method interview approach. It was seen that the problem-solving process of primary grade students was a non-linear, dynamic interplay between cognitive, and metacognitive actions. As a result, it was emphasized that metacognitive awareness was one of the important competencies required for the problem solving process. Lindfors et al., (2020) examined the relationship between students' scientific epistemic beliefs, epistemic practices and epistemic cognitions during the physics problem solving process. They worked with three upper secondary students and the students' self-evaluation demonstrated their metacognitive reflection while processing feedback from the simulation environment. Findings of the study indicated that the students demonstrated problem solving strategies, conceptual understanding and metacognitive reflections at the same time. Akben (2020) looked for the effects of problem posing approach on students' problem solving skills and metacognitive awareness. 101 undergraduate students participated in the study. According to the results of this quasi-experimental study, structured, semi-structured and free problem posing activities improved students' problem solving skills and metacognitive awareness. Reviewing of the literature exposed a need for more studies exploring how students' metacognitive awareness are related to their problem solving process in different science disciplines by using both quantitative and qualitative research methods to understand the level and status of the relationship.

A few studies focused how dimensions of metacognitive awareness affect problem solving. Zepeda and Nokes-Malach (2023), for example, conducted a study with 64 undergraduates to assess metacognitive regulation during the problem solving process. They found positive correlation between the number of evaluation statements measured by verbal protocols and students' responses to the debugging and evaluation of the questionnaire and negative correlation between the number of students' monitoring statements and their responses to the judgments of knowing. The participants of Wang et al. (2023)'s research was 72 medical students'. They indicated that the intensive use of metacognitive scaffolding, i.e. helping students to reflect on their problem-solving processes and solutions, positively predicted students' metacognitive monitoring accuracy. They also showed that strategic scaffolding was negatively related to problem-solving efficiency, whereas metacognitive scaffolding positively influenced problem-solving efficiency. Cashata, Seyoum and Gashaw (2023), in addition, revealed the effect of Jigsaw-IV problem-solving instruction on 136 preservice physics teachers' procedural knowledge. Although the number of studies on this subject has increased in recent years, more research is needed to examine the relationship between dimensions of metacognitive awareness and problem solving strategies in detail.

Purpose of the Study

The purpose of this research was to examine the relationship between physics problem solving strategies and metacognitive awareness. Answers were sought for the following research questions:

1. What is the metacognitive awareness level of the 11th grade students?
2. What are the physics problem solving strategies of the 11th grade students?
3. Is there a relationship between the metacognitive awareness of the 11th grade students and their physics problem solving strategies? How?

Methodology

Correlational research design was used to investigate the relationship between two variables. This relationship indicates whether two variables are related or whether one can predict the other (Creswell, 2012). The participants of the study were 30 11th grade students studying in an urban public high school. Their age ranged from 17 to 18. The researcher was the physics teacher in the school. She collected all the data via survey and interviews. The data of this research were obtained by using the Metacognitive Awareness Inventory (MAI) and the Physics

Problem Solving Assessment (PPSA). The MAI is a valid and reliable instrument and was developed by Schraw and Dennison (1994) to determine metacognitive awareness. It is a self-report tool and consists of 52 items based on a five-point Likert scale. It has two components called knowledge about cognition and regulation of cognition. Declarative knowledge, procedural knowledge, and conditional (strategic) knowledge are the dimensions of the knowledge about cognition component while planning, monitoring, debugging, information management, and evaluation dimensions are under the regulation of cognition component (Schraw & Dennison, 1994). The MAI was administered to the participants at the same time while they were all in one classroom and it took 20-25 minutes for them to complete the survey. In order to examine physics problem solving strategies of the participants, Physics Problem Solving Assessment (PPSA) was adapted from the Mathematical Problem Solving Assessment (MPSA) developed by Montague (1992). During the adaptation process, two questions related to knowledge of reading and the use of reading component were removed because they were not related with the content of the study and the word of "mathematical" was replaced with the word of "physics". The PPSA includes eight open-ended questions evaluating physics problem solving strategies. The PPSA was implemented as a structured interview protocol. The students were interviewed individually in the teacher's room. The participants' responses were voice recorded. Each interview was lasted approximately 20 minutes. Some of the questions in the PPSA were as follows: What do you do to solve physics problems? Are there any special methods you use to solve physics problems? What do you do when you don't understand the problem? What questions do you ask yourself while reading a physics problem?

Homogeneity, normality and reliability analyses were done for the data gathered from the MAI. Kolmogorov-Smirnov test showed a normal distribution ($p = .20$). Skewness-Kurtosis test values also supported the normal distribution ($\Gamma1 = .11$, $\Gamma2 = -.90$) (Hair et al., 2010). Cronbach Alpha reliability coefficient of the MAI was calculated as .90. Descriptive statistical analysis was performed to determine the participants' metacognitive awareness. Mean values obtained from the MAI scores were divided in to three categories, where 1.00 through 2.33 was named "open to development" level, 2.34 through 3.67 was named "medium" level, and 3.68 through 5.00 was named "high" level. The four-point scoring rubric for problem-solving strategies based upon Polya's stages (1971) was used to analyze the students' physics problem solving strategies. This rubric was appropriate for both the purpose and conceptual framework of the study. The criteria in the rubric based on the problem solving stages are as follows: Define and understand the problem (DUP), devising a plan or strategy to solve the problem (DPSP), carry out or execute the plan (CP), and looking back-reflection (LR). The participants' responses to the eight open-ended questions in the PPSA were evaluated based on the rubric. The total mean score that each student could get from the PPSA by using the rubric was between 4 and 16. Similarly, total mean values obtained from the PPSA scores were divided in to three classifications, where 4.00 through 7.99 was titled "open to development" level, 8.00 through 11.99 was titled "medium" level, and 12.00 through 16.00 was titled "high" level. Values of Kolmogorov-Smirnov test ($p = .20$) and Skewness-Kurtosis test ($\Gamma1 = -.30$; $\Gamma2 = .62$) indicated normal distribution for the data gathered from the PPSA. Cronbach Alpha reliability coefficient of the PPSA was found as .76 indicating that it has good reliability. Pearson (1895) correlation coefficient analysis was performed to look for a relationship between the students' metacognitive awareness and physics problem solving strategies. Moreover, the students' excerpts were analyzed to support the quantitative results.

Results and Discussion

Students' Metacognitive Awareness

Overall mean values of the participants' MAI scores for each dimension were shown in Table 1. The students' metacognitive awareness level was high (M = 3.69). Their highest score was in the conditional knowledge dimension (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 students could also debug well (M = 3.87). In other words, they could fix strategies to correct comprehension and performance errors (Schraw & Dennison, 1994). On the other hand, monitoring was the dimension that the students had the lowest score. In order to demonstrate the students' different scores in different MAI dimensions, mean values of nine students having higher and lower scores relatively were selected and presented in Table 2.

Table 1. Overall Mean Values of the MAI Scores (N = 30)

	Knowledge about Cognition			Regulation of Cognition				
Meta-cognitive Awareness	Declarative Knowledge	Procedural Knowledge	Conditional Knowledge	Planning	Monitoring	Evaluation	Debugging Strategies	Information Management
3.69	3.77	3.56	3.96	3.66	3.44	3.56	3.87	3.58

Table 2. Mean Values of the Dimensions of MAI Scores (N = 9)

S	MA	DK	PK	CK	P	M	E	DS	IM
S4	4.40	4.75	4.50	5.00	4.00	4.38	4.67	3.00	4.22
S5	4.44	4.62	4.50	4.40	4.57	4.00	4.33	4.60	4.33
S8	3.21	2.50	4.25	3.60	2.57	2.50	3.33	3.40	3.11
S12	3.31	3.62	3.25	3.60	3.14	2.50	2.33	4.20	3.33
S13	3.26	3.12	3.00	4.00	3.14	2.88	3.83	3.20	2.67
S19	3.45	3.38	3.00	3.80	3.71	3.00	2.83	4.80	3.22
S20	4.31	4.38	4.00	4.40	4.43	4.38	4.17	5.00	3.78
S21	4.25	4.25	3.25	4.40	4.57	4.50	4.33	4.40	4.89
S30	3.51	3.38	3.75	4.60	2.71	2.75	2.83	3.80	3.44

S: Student, MA: Metacognitive Awareness, DK: Declarative Knowledge, PK: Procedural Knowledge, CK: Conditional Knowledge, P: Planning, M: Monitoring, E: Evaluating, DS: Debugging Strategies, IM: Information management.

S4, S5, S20, and S21 were the students who had higher MAI scores than the others had. However, S4's debugging strategies score (M = 3.00), S20's information management score (M = 3.78), and S21's procedural knowledge scores (M = 3.25) were considerably low. That is S4 used strategies to correct comprehension and performance errors less than other activities, S20 used skills and strategy sequences to process information more efficiently less than other activities, and S21's knowledge level about the execution of procedural skills was lower than their declarative and strategic knowledge. Although S8 had the lowest MAI score (M = 3.21), his score in the procedural knowledge dimension was high (M = 4.25). Similarly, the MAI scores of S12 and S19 (M = 3.31 and M = 3.45) were not high but they received high scores in debugging strategies dimension (M = 4.20 and M = 4.80). These findings indicate that one student could not be good at all the dimensions of metacognitive awareness and might perform differently in terms of knowledge about cognition and regulation of cognition components. Therefore, it is important to determine which dimensions are related more to problem solving strategies.

Students' Physics Problem Solving Strategies

Total mean values of the participant' scores from the PPSA and the mean values of their scores for each stages of problem solving strategies are seen in Table 3. The participants performed developmental level (TotalM = 7.95) physics problem solving strategies. Regarding define and understand the problem stage, the participants showed partially developed understanding of the problem and identified a few specific factors that influence the approach to a problem before solving (M = 2.04). In terms of carry out a plan stage, the students could not demonstrate well developed thought or reasoning in carrying out the plan and sometimes they recognized the need for multiple paths (M = 2.06). When look back to solution stage was taken into account, it was observed that the students sometimes analyzed or synthesized results and applied background or context knowledge of the problem while considering solutions. They also identified partially correct solutions with some reasoning and limited ability for checking their answers (M = 2.11). However, the participants ʹstrategy in devising a plan to solve the problem stage was lower than their problem solving performances in other stages (M = 1.74). That is, they could identify a viable strategy when keywords were provided and the plan was straightforward; however, they did not have the ability to consider new strategies even if theirs were clearly not appropriate.

Table 3. Total Mean Values of the PPSA Scores and the Mean Values of the Stages (N = 30)

Total PPSA Mean Score	Define and Understand the Problem	Devising a Plan or Strategy to Solve the Problem	Carry Out or Execute the Plan	Looking Back - Reflection
7.95	2.04	1.74	2.06	2.11

In order to demonstrate the students' performances in different problem solving stages, mean values of nine students having higher and lower total PPSA scores relatively were selected and presented in Table 4. S4, S5, S7, S11, and S26 had the highest total scores from the PPSA (see Table 4). While S4 was good at in carrying out or executing the plan (M = 3.13), he was in the middle level of defining and understanding the problem (M = 2.38). S4's response to the question i.e., "When you read a physics problem, how do you think to solve the problem?" was as follows: "When I read the question, I first look at the information I have in order to understand what I read comfortably, then I separate the necessary information and determine the formulas. Then I solve the problem". With this answer, it can be said that the student gave importance to recognizing and understanding the physics problem while reading the question and started to make a plan at the reading stage in order to solve the problem. When he was asked “What questions do you ask yourself while reading physics problems?”, he stated that “First of all, I read the question, find a few solutions according to it and ask myself which of those solutions is easier for me, that is, if I can do it in a shorter time, I turn to the answer accordingly”. This answer revealed that the student understood the physics problem and created the solution steps to solve the problem and he directed the problem solving process by giving feedback to himself. Since the student was aware of how to direct the solution of the problem, he also showed metacognitive awareness behaviors to solve the physics problem. S7, on the other hand, performed highest than the other students performed in reflection stage of problem solving (M = 3.00). S13, S16, S18, and S23 had the lowest total scores from the PPSA. S13’s performance in the DUP, DPSP, and CP stages, S16’s performance in the DUP stage, S18’s performance in the CP stage, and S23’s performance in the DPSP and CP stages were very low (M = 1.25). For example, S16 response to the question, i.e. “Are there any special methods you use to solve physics problems?”, was just “formulas”. He revealed superficial understanding about the ways of problem solving and did not give feedback to himself about the solution. Regarding each participant's mean values from the PPSA, there was not much variation in a student's performance at different stages of problem-solving strategies apart from S4’s performance.

Table 4. Mean Values of the Problem Solving Stages and Total PPSA (N = 9)

S	PPSA	DUP	DPSP	CP	LR
S4	11.14	2.38	2.75	3.13	2.88
S5	11.27	2.63	2.88	2.88	2.88
S7	11.01	2.75	2.63	2.63	3.00
S11	10.51	2.50	2.50	2.88	2.63
S13	5.25	1.25	1.25	1.25	1.50
S16	5.51	1.25	1.50	1.38	1.38
S18	5.64	1.63	1.38	1.25	1.38
S23	5.26	1.38	1.25	1.25	1.38
S26	10.76	2.88	2.50	2.50	2.88

S: Student, DUP: Define and Understand the Problem, DPSP: Devising a Plan or Strategy to Solve the Problem, CP: Carry Out or Execute the Plan, LR: Looking Back - Reflection, M: Mean.

Relationship between Metacognitive Awareness and Physics Problem Solving Strategies

Results of the Pearson Correlation Coefficient analysis presented in Table 5 indicated a significant, positive and moderate relationship between students' metacognitive awareness and problem solving strategies in physics ($r = 0.51$, $p = 0.01$). It is likely that if the students' metacognitive awareness level increase, their problem-solving strategies improve or vice a versa. In other words, the more students apply their cognitive resources through metacognitive control, the more successful they can be in organizing and using problem solving strategies. This finding is similar to the result of the study done by Sandi-Urena (2008) who demonstrated that high school students' chemical problem solving skills and metacognitive awareness increased together during the problem-based chemistry laboratory instruction. The finding of the current study is in agreement with what Young & Worell (2018) found. They presented that metacognitive awareness scores did not predict the mathematical problem solving process but there was a significant and moderate relationship between two variables.

Table 5. Correlations between Metacognitive Awareness and Problem Solving Strategies in Physics (N=30)

Pearson Correlation		Metacognitive Awareness	Problem Solving Strategies
Metacognitive	Correlation Coefficient	1	0.51
Awareness	Sig. (2-tailed)		0.01
Problem Solving	Correlation Coefficient	0.51	1
Strategies	Sig. (2-tailed)	0.01	

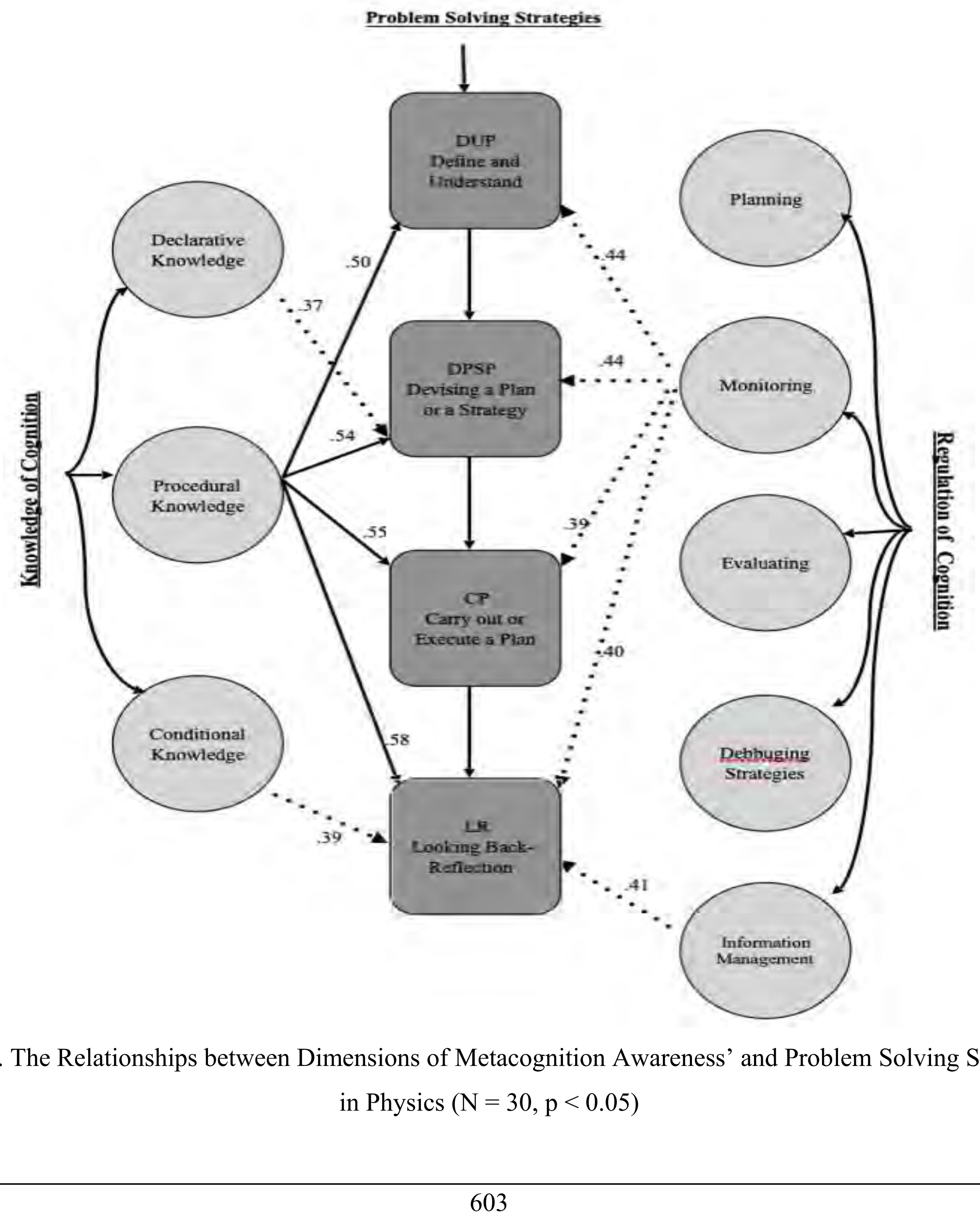

Figure 1. The Relationships between Dimensions of Metacognition Awareness' and Problem Solving Strategies in Physics (N = 30, $p < 0.05$)

The relationships between dimensions of metacognitive awareness and the stages of problem solving strategies in physics are modeled in Figure 1. The first stage of the problem solving process is define and understand the problem. This stage is related to the student's realization of the problem at the beginning and defining what it is. The intersection points between the DUP stage and metacognitive awareness dimensions were procedural knowledge (PK) and monitoring (M). There was a significant positive moderate relationship between PK and DUP ($r = 0.50$; $p= 0.01$). This situation was directly proportional to the student's knowledge of how to think about the solution of the problem and how this process would be realized for the procedural knowledge of the problem identification and understanding dimension (Havenga et al., 2013). In addition, due to the procedural knowledge, students can use different definitions for solving different problems and know how to use appropriate strategies. In order to evaluate students' success at the end of the problem solving process and the efficiency of the process, they should first define and understand the problem. For example, S3 stated that "Isn't it different for each subject, teacher? I think there are different methods for each subject". This statement indicated how he thought for the solution of the problem and how he was trying to understand which subject the problem was related in order to define the problem. Surif, Ibrahim and Mokhtar (2012) also exposed the relationship between students' problem solving process and procedural knowledge in chemistry. There was a significant positive moderate relationship between DUP and M ($r = 0.44$ $p < 0.05$). While defining and understanding the problem, students can monitor themselves. Students can make the necessary corrections by checking the scientific knowledge while they are creating the definition of the problem. For instance, S12 said that "First, I try to comprehend the problem in my head. Then I look it up in my notebooks and books. Then, I solve it". It seemed that he tried to comprehend the problem in his mind in order to define and understand it. He also indicated how he had to do while defining the problem by using the procedural knowledge. Similarly, Guner and Erbay (2021) explored that the metacognitive awareness processes of the secondary school students were good, especially in the step of reading and understanding the problem. According to Mayer (1998), the problem solving process includes the knowledge of how to use, coordinate and monitor metacognitive awareness.

The second step of the problem solving process is devising a plan or strategy to solve the problem. This dimension is related to making a plan or determining the solution strategy before solving the problem. The intersection points between the devising a plan or strategy to solve the problem (DPSP) stage and metacognitive awareness dimensions were declarative knowledge (DK), procedural knowledge (PK) and monitoring (M). There was a significant, positive and medium level relationship between DPSP and PK ($r = 0.54$; $p = 0.00$). Making a plan for the solution of the problem or determining the solution strategy is directly proportional to the student's knowledge of how to think for the solution. For instance, S3 wrote that "I go by skipping. I use shorter routes". That is, metacognitive awareness in this process was immovable for procedural knowledge. S7 stated that "What questions do I ask myself? For example, if I am asked a photoelectricity question, I ask myself how I can do it. Then I ask myself if I give this answer, is it wrong?". S7's answer pointed out that procedural knowledge and monitoring were also used while determining the plan or strategies before solving the problem. Kuzle (2013) declares that metacognitive awareness helps in recognizing and expressing the problem and determining how to reach a solution.

The third stage of the problem solving process is carry out or execute the plan. This step is the process in the plan or strategy prepared for the solution. The intersection points between the CP stage and metacognitive awareness dimensions were PK and M. For example, S24 expressed that "I try to solve the problem. If there is more time left, I look at it again. I search it from internet videos or ask the teachers if I did it right". The statement disclosed a metacognitive awareness in the problem solving process. The student also suggested multiple solutions. In a study done by Scherer & Tiemann (2012), metacognitive awareness was defined together with planning, monitoring, problem-solving strategies, and information- selection strategies. Accordingly, the concept of metacognitive awareness is associated with different stages of the problem-solving process.

The fourth stage of the problem solving process is the looking back-reflection stage. The intersection points between the LR stage and metacognitive awareness dimensions were the procedural knowledge (PK), conditional knowledge (CK), monitoring (M) and information management (IM). There was a significant, positive and moderate relationship between LR and PK ($r = 0.58$, $p = 0.00$). This step is the part where the student gives feedback to himself about the problem solving process and evaluates the process after solving the problem. Doing self-assessment at the end of the solution and giving feedback to himself for the effectiveness of the process is important. Hence, four of the metacognitive dimensions influenced LR stage. For example, the statements, i.e. "I ask myself if I did it right" made by S18 and "I wonder if there is another solution or a shorter solution?" made by S27, after the solution of the problem showed the relationship between LR and PK. Metacognitive awareness is an important part of the looking back-reflection step (Güss & Wiley, 2007). Moreover, S12 responded that "After reading the physics problem, if I have a contradiction or doubt about that question, I start to make a lot of examples about that question. I wonder if I am lacking or where I am lacking. I try to practice and improve myself about that question". Her response illustrated the relationship between feedback and monitoring. Regulation of cognition domain, especially planning, monitoring and evaluation dimensions, plays an important role in the problem-solving process (O'neil & Abedi, 1996).

Conclusions and Suggestions

Metacognitive awareness includes knowledge and regulation of cognition regarding individuals' learning and problem-solving processes. The current study aimed to examine the correlation between metacognitive awareness and problem solving strategies in physics. The first conclusion drawn from this research is that high school students have high metacognitive awareness. Second, students are not very good at in physics problem solving strategies. Third, metacognitive awareness can have impact on problem solving strategies in physics. Fourth, looking back-reflection stage is the problem solving strategy that is affected by the dimensions of metacognitive awareness most. Finally, procedural knowledge and monitoring dimensions of metacognitive awareness have critical roles in physics problem solving strategies. Procedural knowledge is related to knowledge about performing things for achieving specific learning goals, and the awareness of how certain cognitive skills are to be employed in learning (Schraw, 1998). A high level of procedural knowledge can allow learners to do tasks more spontaneously (Pressley, Borkowski & Schneider, 1987). Therefore, procedural knowledge helps student to coordinate several processes into a strategy, demonstrate the ability to invert a process to form a plan, implement plans with several processes or steps, clearly articulate the decision making process, and apply background or context knowledge of the problem when considering appropriateness of the solution. Metacognitive monitoring is a central process during self-regulated learning since it aids students in keeping track of ongoing mental processes and generates metacognitive judgements about learning to guide further regulatory activities (Lajoie, Li & Zheng, 2021; Nelson & Narens, 1994). During the monitoring process, learners do not have direct access to their own cognitive states and can only generate inferences about performance based on the available information (Kauffman et al., 2008; Koriat, 1997). As a result, a student who has metacognitive monitoring can recognize the need for multiple paths to carry out the plan, reflect upon solutions to make adjustments in, and provide insights about their plan.

This research is limited to 30 11th grade high school students but this limitation was tried to eliminate by collecting qualitative data. Further studies can be focused on larger number of participants attending in more divergent grades. Learning through problem solving develops understanding because students' mental webs of ideas grow more complex and more robust when they solve problems that force them to think deeply and to connect, extend, and elaborate on their prior knowledge (Lambdin, 2003). Consequently, reflection of metacognitive awareness to problem solving strategies and especially using procedural knowledge and monitoring during problem solving are important strategies that need to be emphasized and encouraged in teaching and learning science.

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