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# A General Overview Of Research Solutions In Problem Solving Studies In Physics Education

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**Abstract:**

Today's education policy aims to raise individuals with 21st century skills, which are considered to have universal importance and the solution of intelligence and mental problems as a common skill. Teaching problem solving is one of the most important issues in physics education and is also, the area where students encounter the most problems. When students try to solve a physics problem, they usually say that they understand the problem, know the laws of physics on which the problem is based and have solved many similar problems, but the new problem is different from the previous problem and therefore the new problem is different. They cannot solve the problem. The purpose of this study is to present problem-solving research methods in physics education according to the level of students, methods and the development of problem-solving strategies.

**Keywords:** Physics Education, Problem Solving, Physics Problem Solving, Physics Problem Solving Studies.

## 1.INTRODUCTION

We encounter many problems at every stage of life and sometimes these problems can be difficult and we make a lot of effort to solve them. When trying to solve these problems, we use techniques that have solved similar problems before or used different methods. Many studies define problems as "situations that people suddenly encounter and do not know what to do at that moment" (Reys et al., 1998), "anything that can lead people to believe" and uncertainty (Korsunsky, 2003). "Any situation that creates confusion, curiosity, and doubt" (Charles and Lester, 1982) a situation that creates a feeling of solving problems in people, but people are not ready to solve problems, but when they encounter problems, they can first use them. knowledge or abstract information (Blum and Niss, 1991). When all these points are analyzed, it can be said that the problem is a problem that needs to be eliminated but is not ready for solution.

Therefore, a problem is a situation that requires effort, requires the use of existing knowledge and experience. Problems can be classified according to different processes; It is also defined as "the way to overcome the gap between the desired situation and the current situation, whether or not it was affected by past changes" (Huitt, 1992). In addition, problem solving requires people to develop knowledge to solve problems and to use strategies to eliminate negative situations. The problem-solving process, which is also defined as the process of developing knowledge and good behavior towards specific goals, is close to creativity. Questions, daily and intellectual problems, good and bad questions, difficult questions, questions with a single correct answer and more than one question, questions that require little prior knowledge, questions that require a lot of experience, questions that require additional knowledge, problems, problems with many uncertainties, problems encountered first and problems that can be solved in one step. Problems can be classified according to different patterns; but some lines cannot be distinguished from lines; 2000). An activity that requires knowledge and practical skills and is aware of the need for problem solving methods. Many methods have been developed for this. This model is designed to use the same product and can solve the problem. Some of these solutions are; divergent thinking, integrative thinking, feedback, external thinking, broadening or narrowing thinking, integration, comparison, comparison combining and product and content use. Such as the person who knows and understands the known or stated problem, gathers the information needed to solve the problem, finds a solution, tests the suitability of these solutions, selects the most appropriate solution and evaluates the solution.

## 2. Studies on Problem Solving in Physics Education

The aim of this study is to present an overview problem solving studies in Physics Education. For this purpose, the results of the extensive research dating back to 1980's have been presented chronologically. In addition, student level, methodology used for the studies were also presented. Studies of the same authors involving similar results or studies with small sample groups have not been reported in this section. Most of the studies involved are experimental studies with pre-posttest control groups, which is quite important to observe the effectiveness of problem-solving strategies when used as a method.

In the study published by Jong and Hessler in 1986, students with high and low success in solving physics problems investigated ways to organize knowledge for problem solving. The study argued that the students with high problem-solving achievement in physics are more successful in organizing knowledge than those who have fewer problems solving achievement, that they used more and various methods. In addition, the study suggested that computational error, affective and motivational factors are influential in problem solving achievement in physics (Jong and Hessler, 1986).

In 1988, Hardiman et al., studied the problem-solving processes of expert and novice problem solvers. The study was conducted with 45 university physics students and 8 physics doctoral students. The study results revealed that expert problem solvers have an in-depth analysis, decision-making mechanism, and they act based on analysis according to principles whereas novice problem solvers generally have a superficial approach (Hardiman et al., 1988).

In a study published by Jong and Hessler in 1991, university students' problem-solving abilities in physics were examined in terms of their problem-solving success in physics. For this purpose, they identified 12 students with low success and 11 with high success and examined students' problem-solving processes in terms of their ability to reconfigure the problem and to establish operational and conceptual information links. This study demonstrated that the students that are successful in problem solving are better in reconfiguring the problem than those who are less successful in problem solving and that the students with low achievement in problem solving have a superficial approach towards the problem while the ones with high achievement establish operational and conceptual information links correctly (Jong and Hessler, 1991).

Heller et al. (1992) investigated how the problem-solving performances of high school students differed after they used problem solving strategy in cooperative groups in physics classes. In this study, which used contextually rich problems, a 5-step problem solving strategy was used. 91 students who had previously practiced problem solving in collaborative groups realized problem solving practice on their own while 118 students implemented this practice in cooperative groups. In this study, which used a 6-step problem solving strategy scoring rubric as a measurement tool, the difficulty ratings of problems were evaluated in 6 stages. This study revealed that the students who were in the experimental group and who used problem solving strategy in cooperative groups showed higher performances of problem solving. In addition to this, it was stated that contextually rich problems improved the conceptual learning of students (Heller et al., 1992).

Heller and Hallabaugh (1992) aimed to invesitagate of students' physics problem-solving strategies in collaborative groups. In this study carried out with 400 university students, they used contextually rich university level physics problems. According to the results of this study, students in collaborative groups used problem solving strategies more effectively and the type of problem is also important in the implementation of problem solving strategies (Heller and Hallabaugh, 1992).

In his study published in 1993 based on literature review, Harmon investigated the best behaviors for an effective problem solving and analyzed researches on expert and novice problem-solving behaviors and studies on problem solving success. He finally reported that the teaching of cognitive awareness strategies is required to be a good problem solver (Harmon, 1993).

In a study published in 1997 by Dufrense et al., a different method was applied to students in the use of problem-solving strategies. In the study carried out with 376 university students, the strategies that were required to be used by the experimental group students in the solution of the physics problems were presented by the teacher and the students were asked to write these strategies. Thus, a common language for problem solving was developed. In the study, the final exam grades were used as the assessment and evaluation. The exams revealed that two-thirds of the students in the experimental group had the ability to write adequate strategies for the solution and they performed more successfully than the control group students in terms of which concepts and principles were required for the problems (Dufrense et al., 1997)

In 1997, Huffman explored the impacts of the explicit problem-solving strategy on the conceptual perceptions of high school students. In the study, which was carried out semi-experimentally with 145 students, the problem-solving strategies were taught to the students in the experimental group while solutions to the problems in the textbooks were presented to the students in the control group. According to this study using force concept test and problem-solving strategy rubric as a measurement tool, the students in the experimental group made progress in the visualization step of problem-solving strategies. However, in the steps of establishing equality, using formulas, mathematical processing skills, there was no difference in the ability of using use problem solving strategies of the experimental and control group students (Huffman, 1997).

The study, published by Netto and Valente in 1997, examined the effect of students' using cognitive awareness strategies in solving physics problems. In this semi-experimental study, problem solving skills of secondary school students were investigated according to the problem-solving steps including cognitive awareness strategies. The study results reported that the students who applied cognitive awareness strategies in problem solving steps were better at problem solving (Netto and Valente, 1997).

Bagno and Eylon (1997) studied the problem solving, conceptual understanding and structuring of knowledge in solving high school physics problems on electromagnetism. In this study, which was conducted experimentally with 180 students, explanations were made to the experiment group students about the correctness of solution and how the students structured concepts were researched using concept maps. According to the results of this study, the students in the experimental group performed better than the students in the control group in problem solving and conceptual understanding. They were also better at transferring new knowledge to different fields (Bagno and Eylon, 1997).

Dhillon (1997) investigated the differences in problem solving behaviors of expert and novice problem solvers. The study included 1 teaching staff at a university's physics department, 2 physics department doctoral students, 4 physics department graduate students, 6 university first grade physics students. 14 of the participants were asked to think aloud while solving physics problems. Written test was used, and the entire process was recorded in the study. All participants were interviewed after the application. "Visualization", one of the steps of problem solving strategy, was the distinguishing feature of expert and novice problem solvers in this study. According to the results of the study, the novice problem solvers focused primarily on solving the problem while the expert problem solvers tried to visualize the problem and use the problem-solving strategies (Dhillon, 1997).

In their work published in 2001, Heller et al. studied the beliefs of teaching staff and students in the physics departments of universities regarding teaching and learning problem solving. The data they gathered through the interviews showed that the teaching staff thought that some of the students believed that problem solving is a linear process but that problem solving requires self-monitoring and evaluation throughout the process (Heller et al., 2001).

In a study published by Sherin in 2001, it was investigated how university students perceived equations in physics problems. In the study conducted with a total of 10 students in groups of two, Sherin reported that students produced equations far from the scientific reality and the use of mathematical expressions was incomplete (Sherin, 2001).

In 2001, Zou explored the impact of using graphics in the work-energy subject on problem solving skills of students. In the study conducted with 3 physics problem solutions and interviews, he reported that with the use of graphics, students could better understand the concepts on which the problem was based, set up equations more accurately, and better evaluate the solution of the problem (Zou, 2001).

Hsu et al. examined 109 studies in the literature review on the problem solving published in 2004. These studies were reported that computer-based problem-solving approaches, application of problem-solving steps, use of concept maps in problem solving, cooperative problem-solving method were conducted in previous literature. It was also emphasized that these studies were on the use of problem-solving steps as a method and putting forward a solution method depending on a certain concept in physics (Hsu et al., 2004).

In 2005, Kohl and Finkelstein investigated the effects of mathematical, pictorial, graphical and expressive presentations on problem solving skills of students in physics problems. In this work, which was carried out semi-experimentally with homework including these 4 dimensions which are mathematical, pictorial, graphical and expressive, it was reported that students can more easily solve the problems indicated by pictorial expressions (Kohl and Finkelstein, 2005).

In a study published by De Leone and Gire in 2005, the impact of non-mathematical presentation on students' problem-solving success in physics was investigated. In the study conducted with 39 university students, the students who solved the given physics problems using mathematical expressions and those who solved using only presentations without mathematical expressions were evaluated. This study argued that the students who did not utilize mathematical expressions were successful. It was also stated in the study that the students with inadequate mathematical knowledge need to solve physics problems through this method (De Leone and Gire, 2005).

In 2006, Meijer et al. presented taxonomy of cognitive awareness activities developed for secondary school students to solve physics problems. This taxonomy consists of four main steps as orientation, planning, evaluation, elaboration, and some specific behaviors accompanying these steps (Meijer et al., 2006).

In the study published by Kohl et al. in 2006, students' using multiple representations in solving physics problems was examined. The study was conducted by interviewing 6 students. In the first phase of the study, the first semester physics topics were taught to the students through problem solving practice using free body diagrams, graphs, words and mathematical equations. 2 people with the highest score, 2 people with the lowest score and 2 people with the medium score from this application were selected as samples. Later, when the students were solving the physics problems given to them, they were also interviewed. The study results indicated that all the students had difficulties while applying the methods they had learned during the first semester, and that the performances of the most successful students were different and more appropriate than the other students (Kohl et al., 2006).

Çalışkan et al. (2006) investigated what kind of strategies the students in the department of physics teaching used while solving physics problems and what problem-solving behaviors they showed in this process. The study revealed that the use of problem-solving strategies of pre service teachers at 1st, 2nd and 3rd grades adopted a superficial approach to problem solving whereas those at the 4th grade had a deeper approach and used more problem-solving strategies (Çalışkan et al., 2006).

The study published by Gök in 2006 investigated the effects of cooperative problem-solving strategies teaching method on high school students' physics success, achievement motivation, and problem-solving attitude, strategy use, and gender and achievement levels. In the experimental study, it was reported that teaching cooperative problem-solving strategies had positive effects on students' achievement, attitude and achievement of physics (Gök, 2006).

Malone's research published in 2008; he investigated the effects of cognitive awareness strategies in problem-solving skills of high school students in physics classes. In this semi-experimental study, the students in the experimental group were applied the cognitive awareness skills whereas the students in the control group were applied traditional teaching method. The study results indicated that cognitive awareness skills of the students in the group to which the method of problem-solving skills was applied were high and these students were defined as expert problem solvers. On the other hand, the problem-solving abilities of the students who were applied traditional teaching methods were low and these students showed similar characteristics to novice problem solvers (Malone, 2008).

In his study published in 2008, Çalışkan et al examined the effects of teaching problem solving strategies on the achievement, attitudes, self-efficacy, and strategy using skills, and problem-solving performances of first year university students in physics course. The research results indicated that problem solving strategies teaching had positive effects on physics achievement, attitude toward physics, physics self-efficiency and physics problems solving (Çalışkan et al., 2008).

In the study published by Selçuk et al in 2008, the effects of problem-solving strategy used in university physics courses on students' physics success, problem solving performances and ability to use problem solving strategies were investigated. In this study, which was conducted semi - experimentally with 74 students, physics achievement test, problem solving performance test and the measurement test of problem - solving strategies prepared according to Polya's problem solving strategies were used. Physics achievements, problem solving performances and problem-solving skills of the students were found to be high at significant levels in this study (Selçuk et al., 2008).

The study published by Gök and Sılay in 2008, they investigated the effects of gender factor in cooperative learning groups on high school students' physics achievement and using problem solving strategies. In this experimental study, physics achievement test, problem solving strategies scale and problem-solving sheets were used as the measurement tools. In the study results, it was reported that the gender variable did not influence the students' physics achievement and problem-solving strategies (Gök and Sılay, 2008).

Çalışkan et al. (2010) investigated the effects of problem-solving strategy teaching on students' ability to solve physics problems and to use physics problem solving strategy. In this semi-experimental study conducted with 77 university students, physics achievement grades and the problem-solving strategy usage rubric developed by the researchers were used as the measurement tools. The study results indicated that problem solving strategy teaching increased both problem solving performances and problem-solving strategy using skills of the students (Çalışkan et al., 2010).

Özcan's research published in 2011 investigated the problem-solving approaches of preservice physics teachers towards solving the problems of special relativity theory. In this study conducted with 34 students at university, 2 problems and semi-structured interview questions were used to determine students' problem-solving approaches. The study results indicated that the problem-solving behaviors of most of the preservice teachers were not scientific or did not include strategic solution approaches (Özcan, 2011).

Yiğit et al.'s study published in 2012 investigated the ability of science students to read the problems in physics classes and accurately convey the desired results on paper. This study, using a screening model, was conducted with 40 students. For this purpose, 5 open-ended questions were used, and the answers were classified according to the students' ability to convert the texts to shapes and define shape-supported texts on a shape. The study results demonstrated that the students were not able to explain what was described and what they were asked in the questions presented in texts and shapes (Yiğit et al., 2012).

In 2012, Abubakar and Danjuma explored the impacts of explicit problem-solving strategy (focusing on the problem, defining the problem, planning for solution, implementation of the plan, and evaluation of solution) on students' academic achievement and remembrance. They used a quartet Solomon model in this study, which they conducted with 80 high school students. As a means of measurement, the physics achievement test developed by the researchers themselves was used. According to the results of the three-dimensional variance analysis, this strategy is the best strategy to improve the academic achievement of the students in high school physics classes and to enable them to remember the past knowledge (Abubakar and Danjuma, 2012).

Taasoobshirazi and Ferley's study published in 2013 investigated the relationships among expert problem solvers' motivations, ability to use metacognition strategies, ability to categorize problems, and ability to use free body diagrams while solving physics problems. In this study conducted with 121 university students, physics motivation test, metacognitive self-regulation test and 5 open-ended well-structured physics problems were used as the measurement tools. According to the results of the study, explained by the structural equation model, the strategy uses of the motivation variable influences metacognitive planning and problem categorization, and the strategy using skill and problem categorization increase the ability of problem solving (Taasoobshirazi and Ferley, 2013).

In a study published by Maries and Singh in 2013, the ability of university students to draw diagrams while solving physics problems was investigated. In this study conducted with 118 university students, 2 problems were asked to the students. The problems were prepared in a structure that can be solved both by drawing a diagram and by using mathematical equations. In this study, it was determined that students did not prefer to draw diagrams while solving problems (Maries and Singh, 2013).

Marlina et al (2014) investigated how students' success in physics problems could be determined. In the study conducted with 21 university students, students were asked to solve 4 physics problems in a written test and to think aloud while solving. This process was recorded, and interviews were held with the students after the implementation. According to the results of this study, students who can use metacognitive problem-solving strategy are successful and at the same time expert problem solvers (Marlina et al., 2014).

Byu and Lee (2014) investigated whether the students' self-confidence, academic achievement and conceptual understanding differed with the increase in the number of physics problems solved. In the study conducted with 49 high school students, force concept test and physics course achievement grades were used as measurement tools and interviews were made with 4 selected students. Students solved an average of 2200 physics problem. The results of this study revealed that the increase in the number of physics problems solved had no impacts on students' academic achievement, self-confidence and understanding of concepts and that students' performance of solving physics problems can be enhanced by the strategies learned and applied (Byu and Lee, 2014).

In another work published in 2014, Gök explored the effects of using phased problem-solving strategies on students' achievement, problem solving skills, and self-confidence in problem solving. In this semi-experimental study carried out with 70 university students, physics achievement test, problem solving strategy steps scale, problem solving self-confidence test were used as the measurement tools. The study revealed that the use of phased problem-solving strategies increases students' physics achievement, problem solving skills in physics, and problem-solving self-confidence in physics (Gök, 2014).

In another study published by Gök in 2015, the effects of the problem-solving strategy realized through peer tutoring in the university physics courses on the students' physics achievement and problem-solving skills were investigated. In this study which was performed experimentally with 64 students, physics achievement test, problem solving strategies rubric and homework were used as measurement tools and interviews were made with the students after the application. The results of the study showed that the experimental group students' homework performance, achievement scores in physics and visualization, problem solving and solution control skills from problem solving strategies improved highly while there was no difference in the control group students' homework performance, achievement scores in physics and ability to apply problem solving strategies (Gök, 2015).

Körhasan and Özcan (2015) aimed to determine problem solving approaches of students by examining their use of mathematical models. In this study conducted with 92 university students, students were asked to give written answers in detail to the questions and semi-structured interviews were made with 6 students. In this study, it was pointed out that the ability of students to use mathematical model was low and they had difficulties in distinguishing some basic concepts (Körhasan and Özcan, 2015).

Olaniyan and Omosewo (2015) investigated the effects of Target-Task Problem Solving Model on students' problem-solving performances in physics. In this study, which was conducted semi-experimentally with 120 secondary school students, a test consisting of electrical problems was used as a measurement tool. In the study, it was reported that the Target-Task Problem Solving Model improves the performance of even the students with low performance (Olaniyan and Omosewo, 2015).

In a study published by Docktor el al. in 2015, it was investigated how high school physics teachers applied conceptual physics problem solving method. In the conceptual problem solving, teachers explained the concepts on which the problem was based and the relations between the concepts and prepared the techniques and plans that students would use. In this study, the teachers noted that this practice was easy to adapt to the curriculum and added that the students had improved their problem-solving skills and achievement grades through this method (Docktor el al., 2015).

In the study published by Alii et al in 2016, 21 university students were asked to think aloud while solving their physics problems and all data were recorded. Qualitative interviews were held with the students later. It was reported that the fact that the students thought aloud and knew that they were being watched while solving problems increased their success (Alii et al., 2016).

Halim et al. (2016) investigated the ability of students to apply problem solving strategies in physics. In the semi-experimental study carried out with 25 graduate students, routine problems were used, and rubrics were utilized as the measurement tool. Heller's "Troubleshooting Strategy" was used as the problem-solving strategy. According to the results of the study, it was determined that the students had difficulty in identifying the problem (Halim et al., 2016)

Reddy and Panacharoensawad (2017) evaluated the student's problem-solving skills and the factors influences the problem-solving difficulties in physics by 303 students of physics. In this study, it was indicated that poor mathematical skills and lacking understanding the problem are the major obstacles in the domain of problem-solving skills in physics (Reddy and Panacharoensawad, 2017).

## 3. Discussion and Conclusion

The purpose of this study is to provide an overview of research on problem solving in physics education. When we examined research on problem solving in physics education, we came across many studies on the factors affecting problem solving performance. These events are reported according to the type of problem, the characteristics of the solvers, their cognitive abilities, emotional intelligence, whether they can solve similar problems, and their metacognitive characteristics. In certain situations, there is a goal, a method, and a process. If the goal is to solve problems, then problems need to be solved, and there must be problems in daily life. If problem solving is accepted as a method, not only problem solvers, but all problem solvers need to improve their problem solving. If problem solving is defined as a skill, then explicit strategies and specific support should be used to develop problem solving skills. While some of these studies aimed to determine students' problem solving strategies, others showed differences between expert and novice problem solvers. Usually, after determining the type of knowledge and problem-solving skills of students, various problem-solving strategies are designed to improve their problem-solving abilities (Hardiman et al., 1993; Dhillon, 2008; Reddy and Panacharoensawad, 2017).

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