The Effects of Problem Solving Strategies on Students' Achievement, Attitude and Motivation

Gök, T.[1,2] & Sılay, İ[3]
[1]*Colorado School of Mines, Department of Physics, Colorado School of Mines, 1523 Illinois Street Golden, CO, 80401, USA.*
[2]*Dokuz Eylul University, Izmir, Turkey.*
[3]*Science and Mathematics Education Department, University of Dokuz Eylul, Izmir, Turkey.*

E-mail: tgok@mines.edu; tolga.gok@deu.edu.tr

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Abstract

The aim of this study was to examine the effects of teaching of the problem solving strategies on the students' physics achievement, strategy level, attitude, and achievement motivation. Experimental procedures were conducted on the tenth grade students in Turkey. Research data were collected with Physics Achievement Test, Surveys of Problem Solving Strategies, Problem Solving Attitude, and Achievement Motivation, and problem solving worksheets. During this study, problem solving strategies were applied to the experimental group by the cooperative learning method and to the control group by conventional teaching. The averages of the experimental group's achievement, motivation, strategy level, and attitude were found to be higher than control group's. According to the experimental data, gender didn't effect the physics achievement of students. It was concluded that problem solving strategies was more effective in cooperative learning than conventional teaching.

Keywords: Achievement Motivation; Attitude; Cooperative Learning; Problem Solving.

Resumen

El objetivo de este estudio fue examinar los efectos de la enseñanza de estrategias para la resolución de problemas en los logros de los estudiantes de física, sus niveles de estrategia, actitud y motivación al logro. Los procedimientos experimentales fueron conducidos en estudiantes de décimo grado en Turquía. La datos fueron recolectados a través de exámenes para medir el éxito de los estudiantes en Física, estudios de estrategias de resolución de problemas, actitud para la resolución de problemas, motivación al logro y hojas de cálculo para resolver problemas. Durante este estudio, las estrategias para la resolución de problemas fueron aplicadas al grupo experimental usando el método de aprendizaje cooperativo y al grupo de control usando enseñanza convencional. Los promedios de logro, motivación, nivel de estrategia y actitud en el grupo experimental fueron mayores que los del grupo de control. De acuerdo a los datos experimentales, se encontró que el género no afecta los logros de los estudiantes de Física. Se concluyó que las técnicas de solución de problemas fueron más efectivas en aprendizaje cooperativo que en aprendizaje convencional.

Palabras clave: Motivación al logro, actitud, aprendizaje cooperativo, resolución de problemas.

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I. INTRODUCTION

Most researchers working on problem solving [1, 2, 3] agree that a problem occurs only when someone is confronted with a difficulty for which an immediate answer is not available. However, difficulty is not an intrinsic characteristic of a problem because it depends on the solver's knowledge and experience [4, 5, 6]. So, a problem might be a genuine problem for one individual but might not be for another. In short, problem solving refers to the effort needed in achieving a goal or finding a solution when no automatic solution is available [7].

One of the fundamental achievements of education is to enable students to use their knowledge in problem solving [8, 9, 10, 11]. Therefore, many researchers find that their students do not solve problems at the wanted level of proficiency [12, 13, 14]. To help improve the teaching and learning of physics problem solving, studies were started in the 1970's [15].

Research on developing an effective general instruction for physics problem solving started at least 50 years ago [5] and changed after the late 1970s with the works of researchers [16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26]. Most of the research during this period aimed to identify the differences between experienced and inexperienced physics problem-solvers.

These studies show that the experienced problem solvers were individuals with important knowledge, experience and training in physics, and so the process of reaching a solution was both easy and automatic for them. In contrast, the inexperienced problem solvers had less knowledge, experience and training in physics which mean that they were facing real problem.

In physics problem, inexperienced problem solvers tend to spend little time representing the problem and quickly jump into quantitative expressions [27]. Instructors have found that inexperienced problem solvers carry out problem solving techniques that include haphazard formula-seeking and solution pattern matching [10, 14, 28]. By contrast, experienced problem solvers solve problems by interjecting an another step of a qualitative analysis or a low-detail review of the problem before writing down equations [27]. This qualitative analysis used by experienced problem solvers, such as a verbal description or a picture, serves as a decision guide for planning and evaluating the solution [17]. Although this step takes extra time to complete, it facilitates the efficient completion of further solution steps and usually the experienced problem solver is able to successfully complete the problem in less time than an inexperienced problem solver.

Reif and Heller [29] discussed this view of problem solvers by comparing and contrasting the problem solving abilities of inexperienced and experienced problem solvers. Their findings showed that the principal difference between the two was in how they organize and use their knowledge about solving a problem. Experienced problem solvers rapidly redescribe the problem and often use qualitative arguments to plan solutions before elaborating on them in greater mathematical detail. Inexperienced problem solvers rush into the solution by stinging together miscellaneous mathematical equations and quickly encounter difficulties. Inexperienced problem solvers do not necessarily have this knowledge structure, as their understanding consists of random facts and equations that have little conceptual meaning. This gap between experienced and inexperienced problem solvers has been well studied with an emphasis on classifying the differences between students and experienced problem solvers in an effort to discover how students can become more expert like in their approach to problem solving [18, 29, 30].

As well as differences in procedures, experienced and inexperienced problem solvers differ in their organization of knowledge about physics concepts. Larkin [20, 27] suggested that experienced problem solvers store physics principles in memory as chunks of information that are connected and can be usefully applied together, whereas inexperienced problem solvers must inefficiently access each principle or equation individually from memory. Because of this chunking of information, the cognitive load on an experienced problem solver's short-term memory is lower and they can devote more memory to the process of solving the problem [31]. For inexperienced problem solvers, accessing information in pieces places a higher cognitive load on short-term memory and can interfere with the problem solving process.

Chi *et al*. [19] found that experienced problem solvers classify physics problems based on underlying structure or physics principles involved, whereas inexperienced problem solvers look at the surface features of the problem such as the objects mentioned in the problem description. They further hypothesized that these classifications point out that the problem schemata of experienced and inexperienced problem solvers contain different knowledge which influence representations and the approaches used by those experienced and inexperienced problem solvers.

Mestre [32] concluded that experienced problem solvers have extensive knowledge that is organized and used efficiently in problem solving. The experienced problem solvers also approach problem solving differently from the inexperienced problem solvers. The experienced problem solvers classify problems qualitatively and according to major principles whereas the inexperienced problem solvers classify problems quantitatively and according to superficial attributes of the problems.

According to these findings, instead of researching the advantages of experienced problem solvers to produce a problem solving instruction, researchers can try to examine students' difficulties in confronting real physics problems and show methods to overcome these difficulties. By researching the characteristics of students' problem solving patterns, a general instruction guideline can be produced to meet the various patterns of physics problem solving found among students. It may be that some inexperienced problem solvers have already had good physics problem solving skills that can be examples for other inexperienced problem solvers.

Over the past 40 years, several physics problem solving methods have been produced by researchers to help students improve their problem solving. Recently, varied physics problem solving models and methods were introduced the logical problem solving model [33]; teaching a simple problem solving strategy [10]; systematic modelling method [34]; didactic approach [35]; collaboration method [36]; computer-assisted instruction [37, 38] and translating context-rich problem [8, 39, 40].

Most of the researchers examined on general and specific problem solving strategies. The most notably general strategies are Polya's [41] and Dewey's [1] problem solving strategy steps. Dewey [1] cited for his four steps (problem's location and definition, suggestion of possible solution, development by reasoning the bearings of the solution, and further observation and experiment leadings to its acceptance or rejection) problem solving strategy.

Polya [41] cited for his four steps problem solving strategy. The first step is *Description,* by identifying the unknown, the data, and the condition, and then drawing a figure and introducing suitable notation. The second step is *Planning,* in which the solver seeks a connection between the data and the unknown. If an immediate connection is not found, the solver considers related problems or problems that have already been solved, and uses this information to devise a plan to reach the unknown. In the third step, *Implementation,* the steps outlined in part two are carried out, and each step is checked for correctness. In the final step *Checking*, the problem solution is examined, and arguments are checked.

Reif, Larkin, and Brackett [10] tried to teach students a simple problem solving strategy consisting of the following four major steps: *Description,* which lists clearly the given and wanted information. Draw a diagram of the situation. The next step, *Planning*, selects the basic relations suitable for solving the problem and outline how they are to be used. The step *Implementation* performs the preceding plan by doing all necessary calculations. The final step is *Checking,* which checks that each of the preceding steps was valid and that the final answer makes sense.

Problem solving strategy steps have been developed by Reif [13] in his textbook "Understanding Basic Mechanics". According to Reif's problem solving strategy steps, his steps include *Analyze the Problem*, in which a basic description of the situation and goals is generated, and a refined physics description according to time sequences and intervals is developed. The second step is *Construction of a solution,* in which basic useful relations are identified and performed until unwanted quantities are eliminated. The final step is called *Checks,* and asks the solver if the goal has been attained, the answer is with known quantities, and there is consistency within the solution with units, signs, and sensibility of values.

The steps of the University of Minnesota problem solving strategy include *Focus the Problem*, which involves determining the question and sketching a picture, and selecting a qualitative approach. The next step, *Describe the Physics*, includes drawing a diagram, defining symbols, and stating quantitative relationships. The *Plan a Solution* entails choosing a relationship that includes the target quantity, undergoing a cycle of choosing another relationship to eliminate unknowns and substituting to solve for the target. The step *Execute the Plan* involves simplifying an expression, and putting in numerical values for quantities if requested. The final step is *Evaluate the Answer,* which means evaluating the solution for reasonableness, and to check that it is properly stated [33].

Bagno & Eylon's [35] didactic approach constructed through active problem solving by students. According to them, the learning sequence consists of several stages. The first stage is *Solve.* The student solves a problem in which the relevant relationship between A and B plays a central role. These problems can be selected from standard problems that are used in regular instruction. The second stage is *Reflect.* The student identifies the relationship, compares it to other relevant relationships recognizes differences and likenesses and finally formulated the relationship verbally, symbolically, and visually. The third stage is *Conceptualize.* The student develops and elaborates the concepts. This is the stage in which common misconceptions are explained and important differences between concepts. The fourth is *Apply.* At this stage the following means are used to help students apply their knowledge and create an improved knowledge structure; a) concrete examples including non-routine situations show the relationship, b) students are asked to apply the already relationships in non-familiar problem solving, c) students are asked to use the concept map to describe various physical processes. Special attention is given to misconceptions. Non-routine problems which create conflicts are used in each chapter to highlight inconsistencies. The final stage is *Link*, which the written materials provide compact tables to facilitate retention and retrieval. The student links the new part of the concept map including A and B and the relevant relationship to the previously existing concept map.

Savage and Williams [34] suggested a method of physics problem solving using real-world problem modelling. This method is purposely designed to solve algebraic mechanics (kinematics and dynamics) problems at university level. The main processes in this method are preparing the model, analysing the problem, interpreting and confirming the mathematical answer to produce a solution.

Recently, Loucks [42] introduced a method for solving university physics problems, particularly when algebra is involved, which is similar to Savage and Williams' problem solving. For Loucks, the most important factor is to set up the problem, so that the solver can determine which equations are suitable. Once it is set up, the problem becomes simply a mathematical problem. Loucks recommended five steps to effectively solve physics problems with algebra; a) identify the type of problem (for example, concept, keyword, feature), b) sort by interval and/or object (e.g., list everything, draw diagram), c) find the equation and unknowns, try to relate the intervals, d) outline solution or make a chain of reaction, e) do the mathematics.

II. COOPERATIVE LEARNING

Many teaching methods can be used for the problem solving strategies. One of them is cooperative learning. Cooperative learning is the instructional use of small groups in which pupils/students work together to increase and gain from each other [43]. In cooperative learning, students are expected to help, discuss and argue with each other; assess each other's current knowledge; and fill any gaps in each other's understanding [44].

There are many different cooperative learning techniques; however, all of them have certain elements in common as established by Johnson et al [45]. These elements are the ingredients necessary to ensure that when students do work in groups, they work in groups, they work cooperatively: firstly, the members of a group must notice that they are part of a team and that they all have a common goal; secondly, group members must realize that the problem they are going to solve is a group problem and the success or failure of the group will be shared by all members of the group; also, to carry out the group's goal, all students must talk with one another to engage in discussion of all problems, finally, it must be clear to all that each member's individual work has a direction effect on the group's success. Individual study or coming up with an idea is not important in the cooperative learning groups. It is thought that the use of problem solving strategies is more useful for cooperative learning than conventional teaching because of having more outputs, improving abilities of leadership, sharing, criticizing, without needing any other organization or having expenses, and individualizing of teaching [46].

Several factors are found important in cooperative learning to make this a valuable learning experience. Forming the groups would be the first step. The first groups were formed randomly. Once the first exams were graded, mixed ability groups were formed with three students who had the top, average, and lowest scores. Students were transferred to a different group every three weeks. Groups were adjusted in terms of gender homogeneity. Members have faced each other, so the room with movable seats was preferable. If seating was fixed, two students would need to sit in one row and the third one would sit across from them.

In cooperative learning groups, each student was assigned a role to play. In groups of three, first one was manager, second one was skeptic, and third one was recorder. The roles were switched each week, so each member had each role for once during the three-week period of a group. The goal was trying to prevent a student from being dominant in the group. A small group structure had a potential to increase the active participation of each student and to reduce individual isolation. In organized small groups more students had the opportunity to offer their ideas and to receive immediate feedback. Students needed some first instructions about the roles. One task of the instructor was to ensure the students stayed in their roles.

Cooperative group problem solving was performed for two reasons. The firstly, it was an effective technique to help students to teach a complex skill. Also it was more practical. Recommended teaching techniques were expected to help students to become better problem solvers, and less need for an instructor [8].

Cooperative group problem solving has following advantages as pointed out in literature [39]. (a) The structured-problem solving strategy seems too long and complex to most students. Cooperative group problem solving gives students a chance to practice the strategy until it becomes more practical. (b) Complex problems can be solved easier by groups rather than individuals. (c) Students get practice developing and using the language of physics. (d) In their discussion with each other, students must deal with and resolve their misconceptions. (e) At the brainstorming of the problems, students are less intimidated because they are not answering as an individual, but as a group.

The positive effects of cooperative learning style on problem solving in physics education can't be argued. Also other important parameters, students' attitudes and achievement motivation while solving a problem, the following sections express the importance of these factors in details.

III. ATTITUDE

Most researchers define the attitude as a mental concept that depicts favorable or unfavorable feelings toward an object [47, 48. 49, 50]. Social psychologists have viewed attitudes as having three components: cognitive, affective, and behavioral. The cognitive component is a set of beliefs about the attributes of the attitudes' object and its assessment is performed using paper-and-pencil tests. The affective component includes feelings about the object and its assessment is performed by using psychological indices. Finally, the behavioral component pertains to the way in which people act toward the object and its assessment is performed with directly observed behaviors [51].

Most studies done on physics education focused on the attitude towards course of the students. Especially during the last three decades many researchers have reported decline in attitudes toward science of all ability level during middle or high school [52, 53, 54, 55, 56, 57]. In this research was focused on the attitudes of the students during solving a problem.

IV. ACHIEVEMENT MOTIVATION

Motivation is a theoretical construct used to explain the beginning, direction, intensity, persistence, and quality of behavior, especially goal-directed behavior [58]. Motives are hypothetical constructs used to explain why people are doing what they are doing. In contrary, goals need to be more specific and to be used to explain the direction and quality of action sequences in particular situations.

Motives, goals, and strategies can be difficult to distinguish in situations that call for intentional learning of cognitive content, because ideal forms of motivation to learn and optimal strategies for performing the learning tend to occur together. In the classroom context, the concept of student motivation is used to explain the degree of attention and effort in various pursuits. Individuals' actual achievement behavior depends not only on their motivation to achieve but also on expectation for achievement and fear of failure [59]. The studies done on students' achievement, attitude, motivation, abilities, etc. showed that the achievements of male are higher than females' [60, 61, 62].

The purpose of present study was to examine the effect of problem solving strategies on students' achievement, attitude, and motivation and to enlighten the effect of gender on those parameters. Generally females and males are significantly different in physics lectures: males achieve higher grades in tests and more interested in learning physics than females. On social and linguistic behavior, it is claimed that males and females hold different notions of what it means to understand physics. Briefly, females seem to think that they understand a concept only if they can put it into a broader world-view. Males appear to view physics as valuable in itself and are pleased if there is internal coherence within the physics concepts learned [63].

Problems typically used in traditional physics instruction are mostly goal-directed, narrow, disconnected and simplistic. By goal-directed, it is meant that the student is given problems very specific objective, such as calculating a physical quantity. By narrow it is meant that problems can be solved by the straightforward application of a single principle, definition, or procedure. By disconnected, it is meant that problems are closely related to the topics and worked-out examples recently covered in lecture or assigned readings, and do not integrate previously got knowledge. By simplistic, it is meant that problems ignore most of the complicated, messy physics that is needed to address real-world situations.

When students are faced with those type problems, they tend to engage in a host of undesirable behaviors rather than in cognitive activity that builds and structures knowledge and develops desirable habits of mind. They focus excessively on the goal of determining the answer. They construct an abstract representation of the problem based mainly on superficial features of the situation, with in limited use of concepts. They employ means-ends analysis to determine a solution path, and engage in equation manipulation. And they try to use physics that is familiar, rather than new and unfamiliar solution way.

What students don't do, but should, is: analyze situations in terms of concepts; interpret mathematical formulation; employ multiple representations; seek and weigh alternative solutions; formulate a strategy before solving; compare and contrast with more familiar situations; and monitor and reflect on their own problem solving.

Problem solving as traditionally practiced within physics education isn't particularly effective at helping students to develop true expertise. Students attend introductory physics courses with strong preconceptions which are often misconceptions. They use primitive formula-centered problem solving strategies. Their knowledge consists of a few facts and equations stored randomly in the mind. Problem solving in physics is viewed by students as a try to determine the value of one or more unknown quantities. Students' solutions to these problems are almost entirely formula centered devoid of qualitative sketches and diagrams that contribute to understanding. Therefore, problem solving can and should be the center of the instruction the way, also it is practiced must change, it should be a part of an active learning of the instructional process.

Although the problem solving strategy is quite primitive, it addresses some of the key points for many students. In particular, it provides a systematic approach which encourages students to examine a problem before blindly calculating and to check their answers afterwards. Further, the steps in this simple strategy remain essential steps in a more complex strategy designed to deal with sophisticated problems. When students know all the relevant fact and principles necessary for the solution of a problem, they may be unable to solve it because they lack any systematic strategy for guiding them to apply such facts and principles. So, it was tired to teach students a simple problem solving strategy consisting of the five major steps (comprehend the problem, represent the problem informal terms, plan a solution, execute the plan, interpret and evaluate the solution).

This article reports the results of investigations at high school level to answer the following questions:

1. Were there any significant differences in a) achievement, b) problem solving strategies, c) attitude toward problem solving, and d) achievement motivation of the students who use cooperative learning vs. conventional teaching?
2. Were there any significant differences in a) problem-solving strategies and b) achievement of the students who use cooperative learning vs. conventional teaching according to gender?
3. Were there any significant differences in using problem solving strategies with problem solving worksheets between the students who use cooperative learning vs. conventional teaching according to gender?

IV. METHOD

A. Research Design and Participants

The present study is an experimental research in which pre and post test design with control group have been used. Pre and post test comparisons, used in actual experimental design, allow relatively straightforward assessment of a pedagogical or technological development by detecting differences in learning outcomes between two periods of time-before and after it. This assessment strategy is very common in educational research since its implementation is relatively non-intrusive and its analysis does not normally require more advanced statistical procedures.

Two-Groups Control Group Design insures all forms of internal validity. In this design, students are randomly assigned to one of two groups (the experimental or the control group "x" or "y") and are given a pretest, treatment (corresponding to the condition to which they were assigned), and post-test (see Figure 1). (a) Comparison A shows how the treatment group differs from the control group (post-test). (b) Comparisons B & D show how the two groups changed from pretest to post-test in terms of difference or "gain" scores. (c) Comparison C indicates whether the random assignment produced two equivalent groups or not (pretest). (d) Comparison D also points out whether there is any difference overtime for the control group or not. If there is, the researcher should try to determine what is causing the variation and then figure out which effect it might be responsible for this difference for the experimental group's outcomes [64].

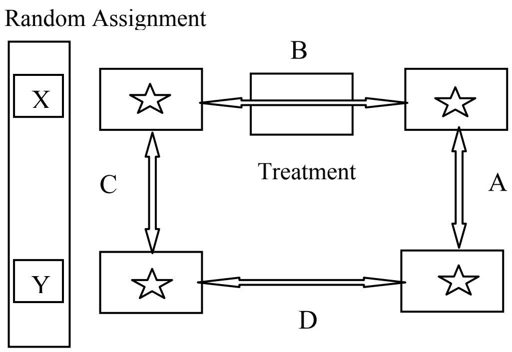

FIGURE 1. Two-groups control group design participants.

The experimental procedures of the research were carried out on high school in Turkey. After according to pretest performed on 10th grade students, two classes, equivalent to one another in terms of knowledge, were chosen. One of them was named as experimental group; the other one as control group. The experimental group consisted of 25 students (12 female and 13 male). The control group consisted of 21 students (8 female and 13 male). High school education is three years in Turkey. After students graduated to high school, for higher education students take National University Entrance Exam done every year. 11th grade students must prepare to take the exam. Because of this, in this research 10th grade students were selected. Besides, the chosen reason of "Kinematics and Dynamics" subjects was connected with concepts.

B. Materials

The data of this research were collected by Physics Achievement Test, Problem Solving Strategies Survey, Problem Solving Attitude Survey, Achievement Motivation Survey, and Problem Solving Worksheets. These measuring instruments were explained in details below.

C. Physics Achievement Test (PAT)

In the study, in order to determine the students' physics achievement, Physics Achievement Test (PAT) developed by the researchers [65] was used. The instrument contained 40 five-option, multiple-choice questions. Physics achievement test contained "Kinematics and Dynamics" subjects. Firstly, the unit analysis was made. Target behaviors were determined based on physics curriculum and then a table of specifications was prepared. To provide the content validity of prepared questions, some instructors' opinions were taken at Dokuz Eylul University. Finally the test completed with total 50 questions. According to Bloom Taxonomy [66], 21 items of the questions included in test were comprehension, 22 items were application, and 7 items were analysis. The test was applied to 335 students who had already learned these subjects and then item analysis was made on the test. ITEMAN (An Item Analysis Program for Test, Questionnaires and Scales) item analysis program was used for the test. The difficulty index and discrimination index of all items were calculated. The items (10 items) less than 0.40 "discrimination index values" were taken out from the test without reducing the content validity. The test was evaluated out of 40 points. Discrimination of the items included in the test changed between 0.40 and 0.68. The Kuder-Richardson (KR-20) reliability of the test was found as 0.92.

D. Problem Solving Strategies Survey (PSSS)

This survey was developed to determine the problem solving strategies used by students while solving a physics problem [65]. Firstly, literature was examined to improve this survey. In order to have a basis for survey items, 320 students who have been educated in the tenth and eleventh grade at high school were asked to write an essay with the topic of "How do you solve a physics problem?" Problem solving strategies surveys which had 60 items with 5 Likert type were prepared with items obtained from essays and literature. The survey was applied to 60 students for taking students' views then it was rearranged. Afterwards survey was applied to 1005 students who were educated at the tenth and eleventh grades at high schools in Turkey for the purpose of calculating the statistical analysis of the survey.

Factor analysis and some statistical analysis (correlation analysis, reliability coefficient, etc.) were applied on the data obtained from the pretest. Exploratory factor analysis was performed on all items. The internal consistency and reliability of each factor in the PSSS were examined with Cronbach's alpha reliability coefficient. The reliable valuable of Cronbach's alpha was assumed as 0.70. The internal factor structure was examined using the principal factor method with varimax rotation. The unrotated solution and the item adequacy were analyzed, using the Kaiser-Meyer-Olkin (KMO) test. One of the preanalyses on the construct validity of the survey was the Bartlett Sphericity test. This test is based on the assumption that factor analysis for the variables would be appropriate if the correlation between variables is different from 1. The result of the Bartlett Sphericity test was obtained as $\chi 2=12343.771$; $p<0.05$. Besides, as a result of principal component analysis, the KMO value point was 0.90 and this showed that the factor analysis was appropriate [68]. The KMO test checks whether partial correlations are small or not and whether distribution is enough for factor analysis.

Exploratory factor analysis was performed for all 60 items on PSSS. The internal factor structure was examined using the principal factor method with varimax rotation. For factors with eigenvalues of 1.32, 1.11, 1.05, and 1.02 were defined. The selective criterion for items was the factor loading which was greater than 0.40 in each case. Fifteen items were cancelled, because factor loading of these items did not reach 0.40. Forty-five items remained at the end of the factor analysis. The cumulative proportion of variance explained was 52.94%. According to Kline [70], the acceptable variance ratio in the survey is 41%. Also, Scherer et al. [72] accept the variance ratio rating from 40% to 60% in social sciences as enough. The internal consistency reliability coefficient (Cronbach's alpha) of the 45 items of the PSSS was high enough (Cronbach's alpha, 0.88) [71].

For the Likert- type survey, the student read a statement and decided on the degree of importance using a 5 point scale. The scores of each item ranged from 1 (never) to 5 (very often). Properties of the factor loads were given in Table I.

In this research was to developed problem solving strategy steps based on according to survey's statistical analysis and the problem solving strategies reported by the researchers mentioned before.

The first factor of the PSSS is "understanding"; In the first and most important step, a student should accurately identify and understand the problem. A student should examine both the qualitative and quantitative aspects of the problem and interpret the problem because of his/her own knowledge and experience. This enables a student to decide whether information is important and what information may be needed. The second one is "planning"; in this step students must: (i) simplify the problem situation by describing it with a diagram or a sketch in terms of simple physical objects and essential physical quantities; (ii) restate what you want to find by naming specific mathematical quantities; (iii) represent the problem with formal concepts and principles. The third one is "solving"; students use qualitative understanding of the problem to prepare a quantitative solution. Dividing the problem into subproblems is an effective strategy for constructing the solution. Thus, the solution process involves repeated applications of the following two steps: (i) choosing some useful subproblems, (ii) carrying out the solution of these subproblems. These steps can then be recursively repeated until the original problem has been solved. The decisions needed to solve a problem arise from choosing subproblems. The two main obstacles can be: (i) lack of needed information; (ii) available numerical relationships which are potentially useful, but contain undesirable features. These choices are promoted if there are only few reasonable options among which a student needs to choose. An effective organization of knowledge has crucial importance in making easy the decisions needed for problem solving. The organization done after applying the particular principle is facilitated by all of a student's previously gained technical knowledge. The final step contains plugging in all the relative quantities into the algebraic solution to determine a numerical value for the wanted unknown quantity (ies). The last one is "checking"; in the final step, a student should check the solution to assess whether it is correct and satisfactory.

Some of the items asked to the students in the survey and related to these factors were: Understanding; "I try to understand the problem before solving it". Planning; "I review the related principles of the problem". Solving; "I put the given variables on the related-equations". Checking; "I examine the solution steps".

E. Problem Solving Attitude Survey (PSAS)

This survey was developed to assess student's attitude toward problem solving [65]. For the statistical analysis procedures, the survey was applied to 1144 students who enrolled to high school. The survey consists of 34 items: 19 items were for attention and 15 items were for fade-phobia. For the Likert- type survey, students read a statement and decided on the degree of importance using a 5 point scale. The scores for each item ranged from 1 (strongly disagree) to 5 (strongly agree). This survey included items about students' problem- solving attitudes. Some rudiments for the survey were given in the following. Exploratory factor analysis was performed for all 51 questions on the PSAS. The internal factor structure was examined using the principal factor method with varimax rotation. Two factors with eigenvalues of 3.02 and 2.95 were defined. The selective criterion for items was the factor loading, which was greater than 0.40 in each case. Seventeen items were taken out, because factor loading of these items did not reach 0.40. Thirty–four items remained at the end of the factor analysis. The cumulative proportion of explained variance was 53.26%. The KMO value point was 0.92. This showed that the factor analysis was appropriate [68]. Properties of the factor loads were given in Table II.

The first factor of the PSAS is "attention" in which students like, enjoy, and are interested in physics problems. The second one is "fade-phobia" in which students still can't solve problems although they work on problems or they look over solved problems. Some of the items asked to the students in the survey and related to these factors were; Attention: "I enjoy thinking about problems". Fade-Phobia: "I can't solve the problem whatever I do".

D. Achievement Motivation Survey (AMS)

This survey was developed to assess students' achievement motivation. The first version of the AMS developed by Açıkgöz and Ellez [67] was performed on university students in 1999 [65]. Adaptation of the survey to high school by researchers was applied on 811 students at some high schools. The survey consists of 32 items: 13 items were for "endeavoring"; 13 items were for "will to work"; 6 items were for "participating". For the Likert- type survey, the student read a statement and decided on the degree of importance using a 5 point scale. This survey includes questions about students' achievement motivation. Some rudiments for the survey were given in Table III.

The first factor of the AMS is "endeavoring" in which students learn and follow their class. The second one is "will to work" in which students show behaviors related to study for class. The last one is "participating" in which students attend activities included in the class. Some of the items asked to the students in the survey and related to these factors were; endeavoring: "I want to take the highest score every time". Will to work: "I study outside homework though teacher doesn't say". Participating: "I follow the class even though attendance is not compulsory".

F. Problem Solving Worksheets

Problem solving worksheets had been prepared to determine the problem solving strategies used by students while solving a physics problem. The problems were arranged at different difficulty level and students included in experimental and control groups were required to solve them. For the response to the problem solving worksheets, firstly problems were to be solved individually then a common solution of the group was to be written in the experimental group. Evaluation of the problems solved by groups was made by researchers. Common strategies of the students were determined while students were solving physics problems according to achievement, behaviors, and gender. How is problem solving performance of the students measured? In most physics and science courses, students' problem solutions on homework, exams or worksheets were given a score based on the correctness of the algebraic or numerical solution [8]. A standard grading practice in physics involved giving students partial credit for particular characteristics of their solution, compared with the ideal solution developed by the instructor. Simply comparing average scores based on this grading scheme, however, did not give a satisfactory description of the student's problem solving performance. At best it only gave a suggestion of whether one solution was better than another in terms of the prescribed grading scheme. A different kind of instrument was required to determine the nature of a student's approach to the problem and assess a solution in terms of characteristics of expertise in solving problems. Problem solving performance of the students was evaluated according to "evidence of conceptual understanding, usefulness of description, match of equations with description, reasonable plan, logical progression, proper mathematics" [8]. The characteristics in this scheme were graded equally and normalized to obtain a score over 100 scores. Problems prepared during this research were based on Bloom's Taxonomy "Knowledge, Comprehension, Application, Analysis, Synthesis, Evaluation" [66].

Problem solving steps which would be used to solve the problem were selected as; understanding (focus on the problem), planning (plan the solution), solving (execute the plan), and checking (evaluate the answer) [8, 41]. Besides, a solution process for such a problem required one or more of the following: (a) a correct physical interpretation of the situation, including the goals, (b) identification of a problem solution approach, including selection of appropriate physics concepts or fundamental principles, (c) correct implementation of the approach and application of the concept or principle to the situation, and (d) checking the solution [43]. Problems included in problem solving worksheets were prepared as standard textbook problems instead of context-rich problems.

G. Analysis of Data

The collected data from the PAT, PSSS, PSAS, and AMS were analyzed by SPSS (Statistical Package for the Social Science) 15.0 program for windows. Mean (M), Standard Deviation (SD), t-test were employed. All statistical tests reported in this paper were conducted with a significance level of $\alpha = 0.05$.

H. Procedure

The study was performed during the spring semester in High School Physics II course covering "Kinematics and Dynamics" concepts. For this research two classes were selected as mentioned method. The same instructional material was used for both classes. Courses were taught by the same instructor using the same schedule with different instructional methods. The details of this research were given as follows.

1. The pre assessments were given on the day before the implementation session during the regular physics course hours.
2. Before teaching of planned chapters, the students included in the experimental group were informed on teaching of problem solving strategy steps and cooperative learning method. Besides, the students included in the control group were told only on teaching of problem solving strategy steps. The information period was completed in 4 weeks.
3. During the experimental procedures, problem solving strategy steps were applied with the cooperative learning method to the experimental group and with the conventional teaching method to the control group. Problems were solved by using the same problem solving strategies on both groups.
4. Class structure of the experimental group was changed in each application according to cooperative groups [39]. Students included in the experimental group were distributed as mixed groups according to achievement, strategy level, attitude, motivation, and gender. Each group consisted of three students. There were eight mixed groups in the experimental group. Students included in the experimental group were given various tasks during research. These tasks were changed in the group and among groups to provide changing dynamics of the groups at certain times.
5. The activities of both groups were performed by the researcher and same problems were solved in the classes.
6. In the experimental process, students in both groups studied on the problem solving worksheets prepared by researcher.
7. During experimental procedures, the students weren't expected to submit practice problems and/or assignments. Besides, the students didn't take routine examinations.

8. The post assessments were given on the same day immediately after the implementation session. The design of the experimental design and database tools were shown briefly in Table IV.

V. RESULTS

The responses of the research questions were examined. The pre and post test' arithmetic means and standard deviations of PAT, PSSS, PSAS, and AMS were calculated, and then t-tests for independent samples were applied to check whether the difference between the averages of the groups is meaningful. Results were shown in Table V.

Table V presented the mean scores and standard deviations of the pre and post assessments for the control and experimental groups. There were no significant differences on the pre assessments; it was assumed that the two groups started out with equivalent means. T-tests for independent samples were carried out to tests whether the experimental and control groups differed significantly on the post assessment on PAT ($t=10.93$, $p<0.05$), PSSS ($t=9.97$, $p<0.05$), PSAS ($t=5.06$, $p<0.05$), and AMS ($t=5.28$, $p<0.05$). The experimental group scored 35.5 % (PAT), 15.08 % (PSSS), 10.86 % (PSAS), and 8.59 % (AMS) higher than the control group. Results in Table V showed that the scores of the experimental group were consistently higher than those of the control group while the standard deviations were consistently lower. Also, Cohen's d values support this outcome by large effect size. Cohen's d value [73] was defined as any value over 0.8 as large effect size, while those between 0.5 and 0.8 are considered medium.

After the main surveys subscales of the PSSS, PSAS, and AMS were examined. The mean scores and standard deviations of the groups were calculated according to subscales to find the meaningful difference between PSSS, PSAS, and AMS averages of the groups. Results were shown in Table VI.

Table VI presented the mean scores and standard deviations of the pre and post assessment for the control and experiment groups according to subscales. There were no significant differences on the pre assessment. T-tests for independent samples were carried out for subscales whether the experimental and control groups differed significantly on the post assessment PSSS, PSAS, and AMS. According to PSSS, significant differences were found for understanding ($t=7.54$, $p<0.05$), planning ($t=7.05$, $p<0.05$), solving ($t=4.91$, $p<0.05$), and checking ($t=8.63$, $p<0.05$). The experimental group scored 14.56 % (understanding), 15.65 % (planning), 12.5 % (solving), and 18.86 % (checking) higher than the control groups. According to PSAS, significant differences were found for the attention ($t=4.41$, $p<0.05$) and fade-phobia ($t=3.82$, $p<0.05$). The experimental group scored 7.23 % (attention) and 15.45 % (fade-phobia) higher than the control groups. According to AMS, significant differences were found for the endeavoring ($t=4.40$, $p<0.05$), will to work ($t=4.89$, $p<0.05$), and participating ($t=4.10$, $p<0.05$). The experimental group scored 6.86 % (endeavoring), 10.03 % (will to work), and 8.9 % (participating) higher than the control groups. Results in Table VI showed that the scores of the experimental group were consistently higher than those of the control group while the standard deviations were consistently lower. Also, Cohen's d values support this outcome by large effect size.

The effect of applied teaching methods and gender on the physics achievement of the students was examined. So, two-way ANOVA test which is to search gender-method interactions was performed. Obtained results were reported in Table VII. According to variance analysis's result revealed a significant main effect on method ($F_{(1-42)}=132.545$, $p<0.05$). However, the main effect for gender was not significant ($F_{(1-42)}=1.075$, $p>0.05$) and the interaction of gender and method was not significant ($F_{(1-42)}=2.047$, $p>0.05$). To find the sources of the interaction, the means of males and females on the post test scores for the control and experimental group were calculated. Table VIII shows that the gender variety did not cause an important effect on the physics achievement of the student.

Further, the variances analysis was applied to check the meaningful difference between strategy averages of the groups. For examining the effects of gender on strategy use, students included in groups were separated into four groups according to gender: "EG-F, EG-M, CG-F, CG-M". The variance analysis related to each subscales was applied to check the meaningful difference between averages of the female and male students. Data related to pre and post assessment were given in Table IX.

Related to applied statistical analysis, the result of ANOVA test hadn't been shown significant difference, $F_{(1-44)}=0.313$, $p>0.05$ (understanding), $F_{(1-44)}=1.218$, $p>0.05$ (planning), $F_{(1-44)}=2.071$, $p>0.05$ (solving), and $F_{(1-44)}=0.533$, $p>0.05$ (checking). According to obtained from results for PSSS, the strategy average of female students included in the experimental group was higher than the strategy average of male students, and strategy average of females and males included in the control group was almost equal, it can be observed from the results in Table IX. When standard deviations were compared, the standard deviation of the control group was found to be remarkably higher than the standard deviation of the experimental group. This result showed that the experimental group had more homogeneous and the control group had more heterogeneous structure.

VI. CONCLUSIONS

Many researchers had done many investigations while using cooperative learning method by this time. As it was known, cooperative learning method was generally used on social science. The present study, cooperative learning method was applied to physics education and the research was combined with problem solving strategies. Concerned study examined the attitude of problem solving of the students. For evaluation of these variables, the surveys about problem solving strategies and problem solving attitude were developed. Achievement motivation also searched while students were solving problem during research. The difference between this study and other studies was to examine many variables related to achievement. It could be seen that when problem solving achievement of the students increased, the achievement motivation and attitude of the students increased in accordance with statistical data. Besides, the effects of the gender variable on achievement and problem solving strategies couldn't be seen in this present study. The outcomes of the research were given in the below by reporting the answers of the research questions asked.

1. Were there any significant differences in a) achievement, b) problem solving strategies, c) attitude toward problem solving, and d) achievement motivation of the students who use cooperative learning vs. conventional teaching?

Teaching of the problem solving strategy steps in cooperative groups was effective on physics achievements of the students.

According to research data, the reasons for the experimental group's achievement were: effectiveness of the cooperative learning method for the experimental group, explanation in a systematic configuration of problem solving strategies, and applying these strategies in a plan. The reasons for the failure in the control group's problem solving strategies were: solving problems individually, avoiding information exchange with friends during solving, hesitating to ask unknown topics or question to teachers or friends, using solution manual of the problems etc.

The teaching of problem solving strategies was affecting the attitudes of the students toward problem solving. According to the research results, the reasons for the increase in the experimental group's attitude score were: systematic application of the problem solving strategies, information exchange during the teamwork, paying attention to applied methods, excitement, and supporting and helping each other. The reasons for failure in the students' attitude scores in control group were: continuous auditing of students, teacher centered instruction, lack of responsibility, and avoidance of helping and supporting each other.

Besides, the essay written by students obviously showed that the students in the experimental group were more interested in physics lecture and developed a positive attitude toward problem solving.

The problem solving strategies' teaching in cooperative groups also affected achievement motivation of the students in positive ways. The achievement motivation average of the experimental group was higher than the achievement motivation average of control group although both groups were shown the same topics and solved the same problems. Students included in the experimental group were more active in activities, taking responsibility during group study, spending more effort, and continually wanted to succeed.

2. Were there any significant differences in a) problem solving strategies and b) achievement of the students who use cooperative learning vs. conventional teaching according to gender?

The benefit from equality of the female and male students for teaching problem solving strategies in experimental and control groups was determined. Also, students in the experimental group were found to have a more strategic approach to problems than students in the control group. The change in the experimental group was continuously originated from helping each other and solidarity of the students. The results pointed out that the gender variety did not cause an important effect on the physics achievement of the students.

3. Were there any significant differences in using problem solving strategies with problem solving worksheets between the students who use cooperative learning vs. conventional teaching according to gender?

Evaluation of the problem solving worksheets pointed out that females used the strategies of writing data, drawing figures, aimlessly solving, calculating until getting a meaningful result, and noticing wrong solutions. As told above, the behavior and strategy of "noticing wrong solutions" was shown by the solver who answered correctly. The behaviors of "aimlessly solving" and "calculating until getting a meaningful result" were typically shown in unsuccessful problem solving. The behaviors of "writing data", "drawing figure" were not distinguishing characteristics. Assessment of the problem solving worksheets indicated that males used the finding a suitable solution path, noticing wrong solutions, making tables, and getting formulas. As informed above, the behaviors and strategies "finding a suitable solution path", "noticing wrong solutions", and "making tables" were shown for the solvers who answer correctly, while "getting formulas" and "checking the result of the problem" were not distinguishing characteristics.

In this research, female students in proportion to male students used more "writing data" strategy according to this finding. This result showed that female students followed problem solving steps and had routine thought models. "Drawing figures" was a strategy which made the problem easier to solve and more concrete. Females used this strategy more than males did. Male students were more successful than female students in solving the problem, transferring the information, and understanding problems. But because of the fact that male students read problems more than female students did, the generalization of opinion couldn't be made clearly. It could be originated from the lack of the male or tendency of not doing anything without understanding. On the other hand, the females' more reading than males might not mean their quicker opinion. Also, female students could not read problems again since they got bored quickly and return occasionally, etc. As a result of finding, the failure in solving problems could be related to the student's shortage of information, hastiness, or attention.

The strategies and behaviors much more used by the solvers who answer correctly, according to the solvers who answer incorrectly, were: the evaluation of the clues, finding better solution steps, realizing use of wrong solution steps, exploration, another solution, stop when one realizes the misunderstanding, explaining the procedures wrongly, application of the ideas immediately, and determining equations. The strategies and behaviors more used by the solvers who answer mistakenly, according to the solvers who answer correctly, was: tracing solution steps incorrectly, the solving problem by guessing, and misleading calculations. The strategies commonly used and the behaviors shown by the solvers who answer correctly and incorrectly were: writing data, plotting a graph, diagram, table, or schematic suitable for problems, use of each datum, recalling knowledge, guessing the results without calculations, asking questions by oneself, using control strategy by estimating, finding a relationship, using formulas, and implication.

According to worksheets' results, it was determined that the control of the problem results wasn't done by the students. This could be caused by the anxiety of wasting their time, lack of confidence and proof, and/or shortage of information about these strategies.

The results pointed out that teaching of the problem solving strategies is more effective on cooperative learning than traditional teaching.

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Appendix

TABLE I. Results of statistical analysis of the problem solving strategies survey.

Subscales of the Survey	Number of the Item	Cronbach's Alpha	KMO	Factor Loading Range
Understanding	18	0.83	0.91	0.44 - 0.74
Planning	13	0.78	0.82	0.47 - 0.87
Solving	8	0.75	0.81	0.57 - 0.80
Checking	6	0.63	0.70	0.40 - 0.81
Total	45	0.88	0.90	0.40 - 0.87

TABLE II. Results of statistical analysis of the problem solving attitude survey.

Subscales of the Survey	Number of the Item	Cronbach's Alpha	KMO	Factor Loading Range
Attention	19	0.87	0.92	0.41 - 0.80
Fade-Phobia	15	0.87	0.90	0.46 - 0.84
Total	34	0.88	0.92	0.41 - 0.84

TABLE III. Results of statistical analysis of the achievement motivation survey.

Subscales of the Survey	Number of the Item	Cronbach's Alpha	KMO	Factor Loading Range
Endeavoring	13	0.84	0.87	0.45 - 0.76
Will to work	13	0.84	0.89	0.51 - 0.75
Participating	6	0.77	0.76	0.44 - 0.70
Total	32	0.91	0.92	0.44 - 0.75

TABLE IV. Summary of the experimental process.

Groups	Pre Assessment	Experimental Process	Post Assessment
Experimental Group (EG)	PAT, PSSS, PSAS, AMS	Cooperative Learning and Problem Solving Strategies Teaching	PAT, PSSS, PSAS, AMS
Control Group (CG)	PAT, PSSS, PSAS, AMS	Conventional Teaching and Problem Solving Strategies Teaching	PAT, PSSS, PSAS, AMS

TABLE V. Mean scores and standard deviations of pre and post assessment for the PAT.

			Pre Assessment		Post Assessment		t-values*	Cohen's d
Data Tools	Groups	N	M	SD	M	SD		
PAT	EG	25	6.76	2.12	24.64	5.47	11.05	3.33
	CG	21	6.76	2.44	10.42	2.54		
PSSS	EG	25	156.04	20.70	191.40	8.39	9.58	2.88
	CG	21	156.95	20.88	157.47	14.35		
PSAS	EG	25	122.16	13.20	144.36	10.65	4.92	1.48
	CG	21	123.85	17.17	125.90	14.04		
AMS	EG	25	136.84	13.02	150.88	5.36	5.03	1.51
	CG	21	139.47	17.37	137.14	11.62		

*($p<0.05$) The level of significance was taken as 0.05 for surveys; EG "Experimental Group", CG "Control Group"

TABLE VI. Mean scores and standard deviations of pre and post assessment according to subscales.

			Pre Assessment		Post Assessment		t-values*	Cohen's d
Data Tools	Subscales	Groups	M	SD	M	SD		
PSSS	Understanding	EG	61.68	10.15	76.20	4.64	7.28	2.19
		CG	63.19	10.27	63.09	7.05		
	Planning	EG	43.80	6.87	54.64	3.60	6.85	2.06
		CG	45.14	7.40	44.47	6.03		
	Solving	EG	29.84	4.48	35.52	1.82	7.48	2.25
		CG	29.28	4.91	30.52	4.68		
	Checking	EG	20.72	3.82	25.04	1.88	8.38	2.52
		CG	19.33	3.82	19.38	2.55		
PSAS	Attention	EG	77.44	11.70	86.20	4.83	4.31	1.30
		CG	79.52	7.45	79.33	5.70		
	Fade-Phobia	EG	44.72	9.66	58.16	8.24	3.69	1.11
		CG	44.33	13.92	46.57	12.18		
AMS	Endeavoring	EG	58.56	4.80	62.36	2.17	4.21	1.26
		CG	61.42	12.29	57.90	4.47		
	Will to Work	EG	54.52	6.76	61.52	3.21	4.69	1.41
		CG	54.52	8.48	55.00	5.67		
	Participating	EG	23.76	3.88	27.00	1.82	3.98	1.20
		CG	23.52	3.88	24.23	2.71		

TABLE VII. Analysis of variance for gender-method interactions on the PAT.

Source of Variance	Sum of Squares	df	Mean Square	F
Method	2640.776	1	2640.776	132.545
Gender	21.419	1	21.419	1.075
Interaction	40.776	1	40.776	2.047
Error	17804.000	42	19.924	

TABLE VIII. Mean scores and standard deviations for females and males on the PAT.

			Pre Assessment		Post Assessment	
Groups	Gender	N	M	SD	M	SD
EG	Female	12	7.25	2.00	22.91	6.06
	Male	13	6.30	2.21	26.23	4.53
CG	Female	8	8.12	2.79	9.37	3.77
	Male	13	5.92	1.84	8.84	2.67

TABLE IX. Mean scores and standard deviations of females and males on the PSSS.

				Pre Assessment		Post Assessment	
Subscale	Groups	Gender	N	M	SD	M	SD
Understanding	EG	EG-F	12	63.50	11.18	76.75	4.39
		EG-M	13	60.00	9.21	75.69	4.98
	CG	CG-F	8	66.12	6.12	62.50	8.38
		CG-M	13	61.38	12.03	63.46	6.45
Planning	EG	EG-F	12	46.16	7.40	55.66	3.22
		EG-M	13	41.61	5.79	53.69	3.79
	CG	CG-F	8	47.25	4.46	44.75	7.28
		CG-M	13	43.84	8.65	44.30	5.45
Solving	EG	EG-F	12	31.33	5.05	36.08	1.92
		EG-M	13	28.46	3.55	35.00	1.63
	CG	CG-F	8	31.00	3.81	31.50	4.10
		CG-M	13	28.23	5.34	29.92	5.07
Checking	EG	EG-F	12	21.83	3.51	25.50	1.62
		EG-M	13	19.69	3.94	24.61	2.06
	CG	CG-F	8	18.12	2.23	19.00	2.20
		CG-M	13	20.07	4.46	19.61	2.81
Total	EG	EG-F	12	162.83	22.35	194.00	7.42
		EG-M	13	149.76	17.61	189.00	8.79
	CG	CG-F	8	162.50	19.94	157.75	15.83
		CG-M	13	153.53	25.22	157.30	14.03

EG-F; Experimental Group-Female, EG-M; Experimental Group-Male; CG-F; Control Group-Female; CG-M; Control Group- Male.