Determining students' attitude towards physics through problem-solving strategy

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Contents

Abstract

In this study, the effects of teacher-directed and self-directed problem-solving strategies on students' attitudes toward physics were explored. Problem-solving strategies were used with the experimental group, while the control group was instructed using traditional teaching methods. The study was conducted with 270 students at various high schools in Turkey. Data obtained from the sample was analyzed using a one-way ANOVA analysis. The findings indicated that students in the experimental group made more positive improvement in attitude towards physics than the control group. Thus, teachers may integrate problem based strategies in their teaching practice and let their students increase their positive attitude toward physics. As a result of this increase, students could have better success in physics.

Keywords: Physics Education, Problem Solving Strategies, Learning, Attitude

Introduction

Physics is considered as the most problematic area within the realm of science, and it traditionally attracts fewer pupils than chemistry and biology. Physics is perceived as a difficult course for students from secondary school to university and also for adults in graduate education. In developed countries, it has been determined that goals of science are never fully realised, that student success in physics is lower than chemistry and biology, that students do not like science lectures and that most have no preference for science, particularly physics (Boylan, 1996; Dieck, 1997; Mattern and Schau, 2002; Neathery, 1991; Rivard and Straw, 2000). It is well known that both high school and college students find physics difficult, and as a scientific discipline it is avoided because of its negative reputation. In a general analysis of the physics situation in schools in England, Osborne, et al. (1998) claimed that the subject of physics and physics courses at school are only taken by students who do well and are not taken as incidental or additional subjects. Among students in England, physics is perceived as an elite discipline, which is viewed as conceptually difficult and only suitable for exceptionally talented and gifted pupils (Koballa, 1988; Osborne, et al., 1998; Woolnough, 1994).

Exploratory research has revealed the reason associated with students' attitudes towards physics courses and methods of teaching (Craker, 2006; Normah and Salleh, 2006; Hough and Piper, 1982; Long, 1981; Newble, 1998). They have highlighted that they take pleasure in physics course if the students know how to plan and implement the strategies of solution to the questions through teaching methods. Normah and Salleh (2006) indicated that students' attitude and interests could play a substantial role among pupils studying science. Several studies, such as Ajzen & Fishbein (2000), Wilson, et al. (2000) and Gonen and Basaran (2008), report that students' positive attitudes towards science highly correlate with their achievement in science.

Achievement, motivation and student interest are influenced by positive and negative attitudes (Miller, 1961). Morse and Morse (1995) found that students with positive attitudes towards science had positive attitudes towards their science teacher, science curriculum and science-classroom climate. Students' attitude toward science is more likely to influence the success in science courses than success in influencing attitude.

The measurement of students' attitudes towards physics should take into account their attitudes towards the learning environment (Crawley & Black, 1992). Research has demonstrated that, "the attitudes toward science change with exposure to science, but that the direction of change may be related to the quality of that exposure, the learning environment, and teaching method" (Newble, 1998; Craker, 2006). Armstrong and Impara (1991) determined that fifth and seventh grade students using nature as a curriculum supplement developed more positive attitudes than those who did not. Aiyelaagbe (1998) also reported a more positive attitude of students after exposing them to self-learning strategies. Similar results were obtained in the study conducted by Mattern and Schau (2002) after exposing students to a self-learning device.

If students have negative attitudes towards science, they also do not like physics courses and physics teachers. Based on this premise, numerous studies have been conducted to determine the factors that affect the students' attitudes in science. From these studies, some basic factors can be listed, including: teaching-learning approaches, the use of the presentation graphics, the type of science courses taken, methods of studying, intelligence, gender, motivation, attitudes, science teachers and their attitudes, self-adequacy, previous learning, cognitive styles of pupils, career interest, socioeconomic levels, influence of parents, social implications of science and achievement (Craker, 2006; Dieck, 1997; Halladyna & Shanghnessy, 1982; Mattern & Schau, 2002; Morrell & Lederman, 1998; Normah & Salleh, 2006; Rivard & Straw, 2000). Studies have revealed the influence of methods of instruction on students' attitudes towards science (Adesoji, 2008; Altun, 2002; Gok and Sılay, 2008). These studies on attitudes generally explore how attitudes influence success. Attitudes, whether positive or negative, affect learning in science and physics. However, it is well known that a negative attitude towards a certain subject makes learning or future-learning difficult. Therefore, helping students develop positive attitudes towards physics courses should be considered an important step in science education.

Moreover, research has shown that conventional teaching and traditional teaching methods have negative effects on the ability of learning physics for the majority of the students (Erdemir, 2004; Halloun and Hestenes, 1987; Van Heuvelen, 1991). Conclusions from research show that in order to increase the level of attitude and success in physics education, new teaching methods and technology need to be implemented into physics education (Adesoji, 2008; Gonen and Basaran, 2008; Reid & Skryabina, 2002). In this regard, Gok and Sılay (2008) worked on the effects of directive and non-directive problem-solving on attitudes and achievement of students in a developmental science course; the result was that attitude becomes more positive after instruction. Therefore, it is reasonable to claim that the usage of problem-solving strategies is more useful than conventional methods for physics learning. Learning to solve problems is a primary objective in learning science, as problems are an inevitable fact of life (Patton, et al., 1997). By solving problems, a student needs to think and make decisions using appropriate strategies. Students' success in achieving their goals will encourage them to develop positive attitudes towards physics and other problem-solving activities.

Several teaching methods can be used in physics teaching. Problem solving is one approach. Problem-solving involves knowing what to do in the situation of not knowing what to do. Problem-solving is not only finding the correct answer, but also is an action which covers a wide range of mental abilities. Students should realize what and why they are doing, and know the strengths of these strategies, in order to understand the strategies completely and be able to select appropriate ones (Altun, 2002; Erol, et al., 2006). Numerous teaching methods can be used for problem-solving strategies. Therefore, the investigation of students' attitudes, behaviors, problem solving knowledge and skills becomes important while solving a problem.

An individual should have new experiences and information to change his or her attitude toward an object. Attitude is a tendency for individuals who organize thoughts, emotions and behaviors towards a psychological object. Human beings are not born with attitudes; they learn them afterwards. Some attitudes are based on people's own experiences, knowledge and skills, and some are gained from other sources. However, the attitude does not stay the same, it changes in the course of time (Kagıtcıbası, 2004; Erdemir, & Bakırcı, 2009). After all, these new experiences, knowledge and skills should change the beliefs and attitudes of the individual regarding the difficulty of physics by gaining problem solving skills. Problem-solving also involves a student's willingness to accept challenges. Accepting a challenge in this context means that the student is willing to find appropriate methods to solve a problem. Normah and Salleh (2006) discovered that students who can successfully solve a problem possess good reading skills, have the ability to compare and contrast various cases, can identify important aspects of a problem, can estimate and create analogies and attempt trying various strategies.

The effect of solving problem on a student's attitude toward science is incredibly important, because problem solving requires patience, persistence, perseverance and willingness to accept risks (Charles et al., 1997; Udousoro, 2002). Many researchers believed that if students were allowed to demonstrate higher cognitive abilities through problem solving, either through a teacher-centered approach or a student-centered approach, their attitudes toward physics might be positively affected. The studies reviewed suggest that there is a relationship between attitude and methods of instruction and between attitude and achievement. Therefore, it is possible to predict the level of achievement from attitude scores. Although many researchers argue that teaching methods have a great impact on students' attitude to learn a subject, students' attitudes towards physics have not yet been examined. In this study, the effects of the problem-solving strategy on students' attitudes were investigated.

The objective of this study was to investigate whether attitudes towards physics would change when students were exposed to both problem solving techniques through a teacher-directed, self- directed and a non-directive problem-solving approach.

In this research, it is hypothesized that there is no significant difference in the attitude of students towards physics after exposing them to teacher-directed and self-directed problem solving techniques.

Methodology

Participants

The sample consisted of 270 secondary school students, who were randomly selected from nine schools in the fall semester of the 2007-2008 academic year. 155 of the participants were males and 115 were females (from 16 to 19 years-old). All of these students were studying the same topics in their physics program. Thirty students were randomly recruited from each of the nine schools and for each of the three groups: – teacher-directed and self-directed problem solving techniques (experimental groups), and a control group of ninety students (90). Assigning schools to the experimental and control groups was also a random process. The experimental groups were exposed to problem-solving techniques, one was teacher-directed, whereas the other one was self-directed. The control group was exposed to lecture method (LM).

Treatments

Two treatments and one instrument were developed for the study. The treatments (stimulus instruments) were:

(a) the problem solving technique (PST) aiming to teach dynamics; and

(b) the self-learning material, called programmed text for physics (SLT) (a problem solving packagebased on dynamics), to learn dynamics.

The group taught by teacher using the lecture method (LM) is the control group, and the PST and SLT groups are experimental groups. The control group (LM) was taught dynamics topics by the teacher using traditional method (direct speech, discussion, etc.). Likewise, the PST group was taught the dynamics topics by a teacher using traditional method; moreover, the teacher instructed the PST group by implementing problem solving strategy techniques; that is, the students in the PST group was directed by a teacher. However, the SLT group was instructed for only in content knowledge of the dynamics by the teacher, and but they were supposed to learn problem solving by themselves; that is, the students in the SLT group were not directed by the teacher about how to learn and put into practice the problem solving strategy techniques.

The problem solving skills tested in this study are based on Mayer's (1992) model for problem solving, which consists of four phases: problem translation, problem integration, solution planning and monitoring and solution execution. During the first phase of problem translation, the problem-solver transforms the statements of the problem into a mental model that represents the problem-solver's interpretation of the problem. In the second phase, problem integration, the different pieces of this interpretation are combined into a coherent structure that will support a problem-solving plan. During the third phase, solution planning and monitoring, the problem-solver formulates a plan in the form of a sequence of steps for solving the problem. Finally, during the solution execution phase, the problem-solver carries out this plan, and solves the problem.

The Instrument

An attitude measuring scale was used for pre and post attitude measure. The PST was in line with the four stages model of solving of physics problems (McGowan, 2008). The SLT was based on the content of the problem solving technique procedure, and prepared in the standard form. The researcher developed both the PST and the SLT. The attitude measuring scale was a twenty items, with five Likert-type options. A five-point scale used was ranged from SD= Strongly Disagree, D= Disagree, QA= Slightly Agree, and A=Agree to SA= Strongly Agree. The total score for each attitude category indicates level of favorable attitude in that category. Six of the thirty items are related to willingness, six are related to perseverance and eight are related to self-confidence. However, they will not be considered in sub-scale. Score for the negative items is recoded so that all the items have a positive value of measurement. The minimum score for an item is 1, and its maximum value is 5. For both the willingness and perseverance scale, the minimum score is 6, and the maximum score is 30. Meanwhile, for self-confidence, the minimum score is 8, and the maximum score is 40. Overall, the minimum score is 20, and the maximum score is 100 for all the items.

A committee of three experts moderated the frames of the SLT. The content of the problem solving technique procedure (PST) was controlled and validated by four physics education lecturers who certified the procedure to be adequate for teaching steps and strategies of problem solving. Experts in Science education helped to examine the 20-item attitude scale. They also helped to identify the positive and negative statements. The reliability determination of the instrument was carried out by using Cronbach's alpha method with the scores acquired from the responses of sixty students. Cronbach's alpha was found to be 0.81. The questionnaire contained personal data, such as name, sex, age, and parent occupation.

Procedure

Prior to teaching the planned topics, both groups were given an attitude measuring scale for pre-test and thus, preliminary data was collected from the both groups, and levels of the groups' attitude were found in equally. The three groups were lectured on the selected topic for three weeks after the completion of the attitude scale. The PST group was taught problem solving technique procedure for another three weeks by the researcher before they completed the attitude scale. Programmed texts, based on the systematic approach to problem solving were distributed to students in the SLT group each time they had physics for their independent studies. They also completed the attitude scale after treatment. The LM group received lectures on the selected topic for three weeks without any trace of problem solving. They also completed the attitude scale thereafter.

After each test, the data collected was loaded into a computer via SPSS for Windows package for the experimental group and the control group. In collaboration with a statistics expert, the researcher analyzed the data collected. In order to make comparison of pretest, final test scores between experimental and control groups, the statistics analysis includes the arithmetic mean, standard deviation and a one-way ANOVA. A one-way analysis of variance (ANOVA) is a statistical method through which the differences between the means of two or more independent groups can be evaluated. ANOVA puts all the data into one number (*F*) and gives us *one P* for the null hypothesis (Buyukozturk, 2002; Cohen, et al., 2003; Ferguson & Takane, 2005).

Results

The problem solving strategies of students in both groups were checked prior to the experimental procedure to assess whether or not there was significant difference in the attitude of students towards physics before exposing them to teacher-directed and self-directed problem solving techniques. ANOVA was applied to check the significant difference between attitude of experimental and control groups.

Table 1. *Mean and standard deviation of the pretest and post-test scores of the both groups*

Treatments	Groups	N	Pre-test		Post-test	
			$\overline{X}$	SD	$\overline{X}$	SD
PST	Experimental Group	90	3.02	1.241	4.85	.768
SLT		90	3.12	1.180	3.72	.986
LM	Control Group	90	3.01	1.191	3.22	1.10

As can be shown in Table 1, prior to and after the planned topics, mean and standard deviations of both groups' attitude scores were seen. Mean points could be considered to be equal prior to teaching. Mean and standard deviation scores of the experimental group were $\overline{X} = 3.02$, $\overline{X} = 3.12$ and SD = 1.241, SD = 1.180 before teaching, respectively. Mean and standard deviation score of the control group was $\overline{X}$ = 3.01, SD= 1.191 before teaching.

Mean and standard deviation scores of the experimental group were $\overline{X}$ = 4.85, $\overline{X}$ = 3.72 and SD = .768, SD = .986 after teaching, respectively. Mean and standard deviation score of the control group was $\overline{X}$ = 3.22, SD= 1.10 after teaching. Graphical representation of the mean scores was shown as the following:

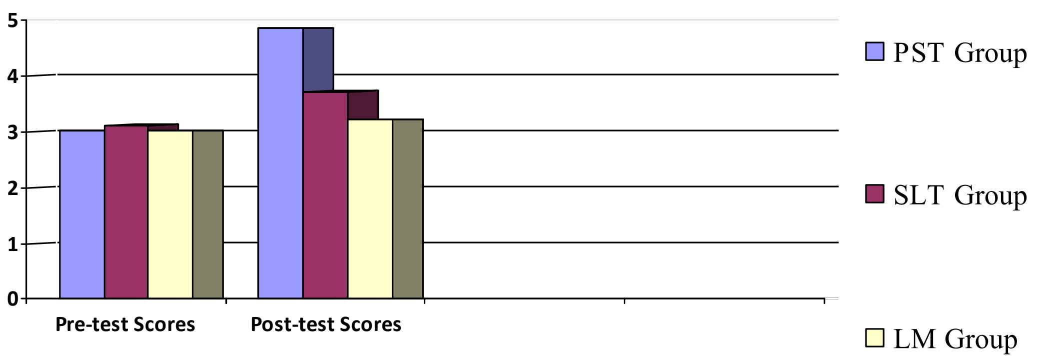

Figure 1. *Mean points of the pretest and posttest of the both groups in the graphical representation*

Table 2. *ANOVA of the scores in attitude scale of experimental and control groups before treatment*

Source of Variation	Sum of Square	df	Mean square	F	Sig.
Between Groups	.783	2	.634	1.965	.141*
Within groups	86.71	268			
Total	87.49	270			

* Significant at level p< 0.05

As can be seen Table 2, the analysis of pre-test data is not a significant difference between groups' scores, because students' readiness attitude score levels towards physics courses are close to each other. In other words, at the end of analysis, no significant difference has been found between attitude scores of the experimental and control groups before treatment (F(2-268) =1.965, p=0.141).

Table 3. *ANOVA of the scores in attitude scale of experimental and control groups after treatment*

Source of Variation	Sum of Square	df	Mean square	F	Sig.
Between Groups	4.16	2	3.353	14.46	0.000*
Within groups	62.32	268			
Total	66.48	270			

* Significant at level p< 0.05

As seen in Table 3, students' attitude scores toward the physics course varies depending on problem-solving strategies practiced in teaching. In other words, problem-solving strategies (independent value) have a positive impact on the students' attitudes scores (dependent value). The analyses shows that there is a significant difference between attitude scores of the experimental and control groups after treatment ($F(2-268) = 14.46$, $p=0.000$).

Table 4. *Scheffe's Post Hoc ANOVA Test for the experimental and control groups in the attitude scores*

(I) Treatment	Mean	(J) Treatment	Mean	N	Mean Difference (I-J)	Sig.
PST	4.85	SLT	3.72	90	1.43*	0.003*
PST	4.83	LM	3.22	90	1.63*	000*
SLT	3.12	LM	3.01	90	0.11	0.52

* Significant at level p< 0.05

As suggested by Scheffe's post hoc test, it was found that there was a significant difference between attitude scores of experimental and control groups after treatment. This significant difference was in favour of experimental group. It could be expressed that the problem solving method had a positive effect on students' attitude towards their physics courses. It might also be concluded that the problem solving method has the effect on student' success in the physics course and science education because of the relationship of attitude with respect to the achievement of students.

Discussion

Determining Students' Attitude towards Physics through Problem Solving

The purpose of the study was to investigate whether or not the problem solving method has an effect on students' attitude towards physics. To test the previously stated hypothesis, the scores of the control group (LM) and experimental groups (PST and SLT) in the attitude scale before treatment were subjected to ANOVA in order to know whether they had a different attitude towards problem solving in physics (dynamics). As can be seen in Table 2, the result drawn from analysis showed that there was no significant difference in the attitude of the three groups towards problem solving related to physics (on dynamics) before the treatment.

However, at the end of analysis, it was found that there is a significant difference between attitude scores of the experimental and control groups after treatment. As seen in Table 3, this finding was obtained from analysis that showed there was significant difference in the attitude scores of the three groups towards physics dynamics after the treatment. The brief problem solving method learned by students had a positive effect on their attitudes.

The result showed that there is a significant difference in the attitude scores of the control group (LM) and experimental groups (PST and SLT) after treatment. In order to determine which group had more positive attitude, the mean scores of the three groups were contrasted using Scheffe test, as seen in the Table 4. The results in the table showed that the attitude of the PST group towards physics was more positive than those of the LM group after treatment. Thus, the stated hypothesis that there was no significant difference in the attitude of students towards physics after exposing them to teacher-directed and self-directed problem solving techniques was rejected. However, the results from the analysis indicate that there is no significant difference for students' attitude towards problem-solving of physics in experimental groups when evaluated with respect to problem solving method. The PST group had a slightly higher, though insignificant, positive attitude than the SLT group. This finding supports the findings by Mattern and Schau (2002) and Saleh (2004), who found no attitude difference towards physics between PST and SLT groups.

Discussing Students' Attitude towards Physics through Problem Solving

Students in the control group were free to conduct any academic or non-academic activity, as long as they were not under control or within the supervision of their lecturers. Therefore, their attitude towards problem-solving in physics was not influenced by the lecturer method. Based on this method, the findings reveal that students lack knowledge and skills in solving physics problems, compared to problem solving skill of students after treatment. These findings are supported by Morrell & Lederman (1998). For instance, students failed to simplify, as well as to reform expressions; they committed careless mistakes that went against physics laws.

It could be deduced that the problem solving technique was more interesting to the students after they learned the problem solving method. Students are used to being supplied information by the teachers; this is done through lectures and accompanying notes. A positive attitude influences expected achievement and is heavily influenced by attitudes toward science. As would be expected, positive attitudes toward science also lead to better results on achievement measures of science capability (Weinburgh, 1998). A student's attitude toward science is more likely to influence achievement in science than achievement influencing attitude (Craker, 2006). Similar results were stated by O'Connell (2000), who found that students need to have a positive attitude towards problem-solving to be successful, and thus problem-solving requires students' knowledge and problem solving skills to overcome risks.

The results demonstrate that knowledge and skills related to solving physics problems are essential to ensure a positive attitude toward physics. This result agrees with Tooke and Lindstrom's (1998) opinion that students who have a positive attitude towards and beliefs about physics will succeed at a higher level. Charles et al. (1997) are also of the opinion that students' accomplishment in problem-solving depends on their method knowledge, attitude and self-confidence about their problem solving skills.

In order to delve into the realities of both the outer and the inner world of the individual in an educational environment, episodes, new experiences and life narratives that have an adequate conceptuality must be acquired by the individual for an ever-changing and developing attitude from the rudimentary to a sophisticated level. Thus, an individual should have new experience and information to change their attitude toward an object. Individuals are not born with attitudes, they learn them afterwards. Some attitudes are based on one's own experiences, knowledge and skills, and some are gained from other sources (Kagıtcıbası, 2004). After all, the findings showed that these new experiences, knowledge and skills changed the beliefs of the students about the difficulty of physics by gaining problem solving knowledge and skills. Thus, the experimental group developed a more positive attitude toward physics after treatment. The attitude was also significantly more positive than the control groups. Physics lectures generally are teacher-centered and theoretical in terms of students. This makes the lectures monotonous, impractical and memory dependent. Since students cannot solve physics problems correctly, the physics course is considered to be the most challenging course. The first reason for this problem is that the method teaching of physics does not match with the nature of physics and the students. The ineffective application of planned techniques is another reason for the problem. The combination effect of these two factors creates a negative attitude toward and failure in physics education. Selecting appropriate, effective methods and putting them into practice helps students develop a more positive attitude toward physics by fixing the mistake outright.

The study indicates that students who are taught by implementing problem solving techniques are willing to try solving problems, and that they enjoy doing physics and are eager to rise to solving challenging problems. The students are willing to spend a great amount of time solving problems and will not stop trying until they find the answers. They develop the resilience to continue, working on a problem until it is done correctly and appropriately. Willingness and enjoyment are commonly referred to as "the language and engine of physics" of success. Research has shown that conventional teaching has a negative effect on most students' learning than compared to teaching problem solving techniques. Physics education goals cannot be achieved by conventional science teaching (Dieck, 1997; Rivard and Straw, 2000).

When the students have knowledge about problem solving strategies at the stage of problem translation, it has been proven that students in the experimental groups will have the skill to interpret physics problems sentence by sentence, using knowledge and the problem solving method. Students are able to interpret and understand the terms, facts and physical concepts based on their acquired knowledge. At the stage of problem integration, it has been demonstrated that the students in the experimental groups were able to combine the different pieces of interpreted information into a coherent structure in order to plan a solution.

However, if students are not taught the problem solving method, they cannot fully understand what a given question means or what it requires. They cannot relate it to their existing knowledge. They do not know how to choose methods most suited for solving each problem. This view is supported by researchers (Reid & Skryabina, 2002; Gonen and Basaran, 2008) who show that most students do not always know what to practice for solving of problems because of lack of self-confidence and skill. Therefore, a majority of the students learned knowledge and strategy by conventional teaching try to memorize and apply physical rules and definitions without fully understanding the underlying concepts. These opinions are supported by studies done by Adesoji (2008) and Redish (2005).

Physics education research has demonstrated that knowledge and skill of students taught problem solving techniques or methods can play a powerful role in how they use the knowledge they have learned in their physics courses. Student attitudes towards physics also play a powerful role in how they think about using problem-solving method in their physics (or science) courses (Hammer, 1996). Hopefully, students will become more sensitive and creative in the problem-solving related to physics. Lecturers can also enhance students' problem solving skills by providing appropriate exercises and encouraging positive interaction among students during the learning process. Hence, students will be more skilful in applying their knowledge, and they will find an additional source of knowledge in their learned method. Moreover, according to Snyder (1998), educators must teach an appropriate problem solving method and offer an opportunity for students to explore physics by preparing fun learning activities and by encouraging them to think critically and creatively.

Conclusions

The following results are drawn from the evaluation of problem solving methods conducted on students in both groups and approaches.

Such results have shown that problem solving methods taught by a teacher to students had an important impact on development of positive attitude toward physics. Then, it was deduced that these students correctly used the evaluation of clues, finding better problem solving steps, realizing usage of wrong solution steps, exploration, alternative solutions, stopping when realizing a misunderstanding, explaining the procedures incorrectly, application of the ideas immediately and determining the equation. This is supported by other studies conducted by Hollabaugh (1995), Leonard, Dufrense and Mestre (1996) and McGowan (2008).

The study indicated that teaching the problem solving method to experimental groups was effective on knowledge and skill usage by the students in solving problems. This result is also supported by the studies conducted by Leonard, Dufrense and Mestre (1996) and Tao (2001).

It was concluded that the poor student attitudes toward physics in the control group was due to the lack of information, lack of problem solving skills, lack of self-confidence, using a formula incorrectly and lack of acting like experts while they solve physics problems.

Consequently, some of the advantages of this the method for the experimental group include helping students to build self confidence, meaningful learning, and awareness of how, where and for which problem to use knowledge and skills. Students in the experimental groups showed that they were much more interested in the physics lecture and developed positive attitude toward physics through problem solving knowledge and skill when this technique was taught.

Suggestions

On the basis of these results the following suggestions are offered for program development experts, physics teachers, and all science teachers.

Problem solving strategy can be used to increase students' success in physics courses and science fields in Turkey. Science teachers must adopt this method to help solve the problem of high school students withdrawing from science courses. Moreover, teachers should adopt problem solving techniques in their various institutions. It may be necessary to organize workshops and seminars for practicing teachers through which the importance and appropriateness of the problem solving technique for science teaching and learning could be established.

Teaching problem-solving to students in every field facilitates organization of ideas, development of different thought skills, and building consistent thought models. Physics courses must be taught conceptually to students through problem solving method before physics formulas and equations are taught. Other strategies should be researched, rather than relying on the problem solving method to increase success and for more understanding.

Student teachers in institutions preparing pre-service and in-service teachers should learn problem solving and how to teach this skill.

Studies should be conducted to determine the effect of teacher-directed and self-directed problem-solving strategies on students' academic success in physics or science education, based on a much wider sample and within the context of a multidimensional scale composed of much more items.

Furthermore, prospective studies could be conducted based on a much wider sample and within the context of a multidimensional scale composed of more items, means and modes to provide better understanding of this area of research.

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