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INSTRUCTION OF PROBLEM SOLVING STRATEGIES: EFFECTS ON PHYSICS ACHIEVEMENT AND SELF-EFFICACY BELIEFS

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Abstract. *This study has investigated the effects of problem solving instruction on physics achievement, and physics self-efficacy beliefs in an introductory physics course at university level. In this study, pretest-posttest and quasi-experimental design with a non-equivalent control group was used. Two groups of student teachers (n=77) participated in this study. During the study, one group received problem solving strategy instruction while the control group received traditional problem solving strategies. Data was collected using the Physics Achievement Test and Physics Self-Efficacy Scale. Results indicate that strategy instruction has positive effects on physics achievement, and physics self-efficacy beliefs. On the basis of the findings, it is strongly recommended that physics instructors use explicit problem solving strategy instruction in their lessons to develop students' problem solving skills and related outcomes such as course achievement.*

Key words: *problem solving, strategy instruction, physics, achievement, self-efficacy beliefs.*

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Introduction

Problem solving is usually defined as the formulation of new answers which go beyond the simple application of previously learned rules to create a solution (Woolfolk, 1993). The fundamental problem solving process is a linear and hierarchical process; and each step is the precursor of the next step, and the result of the previous step (Johnson, 1994). Each of these steps is considered as a separate skill which can be categorized into sub skills. These skills can be considered as the analytical parts of the problem solving process which requires the defining, investigating, reviewing and processing of the information regarding the problem.

Problem-solving strategy (heuristic) is a technique that may not guarantee solution, but serves as a guide in the problem solving process (Mayer, 1983). In one sense, a problem solving strategy is defined as the proper set of necessary steps to solve a problem. And these steps can constitute different sets (Wong, 1994). Although each step is a general problem solving strategy, sub-steps can be called special problem solving strategies or problem solving behaviors as they are more specific.

In the field literature review, a lot of problem solving strategies created according to the step model in the areas of mathematics, chemistry, and physics were encountered: STAR strategy (Maccini & Hughes, 2000), RURRR strategy (Sutherland, 2002), GOAL strategy (Beichner, 2002), WISE strategy (Wright & Williams, 1986), and Minnesota problem solving strategy (Heller, Keith, & Anderson, 1992), to mention a few.

These aforementioned step models actually display the processes used by experts. In other words, these steps are those used by expert problem solvers while solving well-structured problems (Johnson, 1994). In this context, the efficient use of the problem solving strategies, which are the most important components of the problem solving process, is an important indicator of being an expert problem solver. Nevertheless, problem solving skills cannot be inherited but can be learned and improved on. Students learn better when opportunities to teach are increased, when they participate in the arranged activities directly, and when they succeed in solving the presented problems (Dale & Balloti, 1997). Hence, education in the sciences must address the crucially important task of teaching students to become more proficient problem-solvers (Larkin & Reif, 1979). In this context, in the field literature, various programs to teach problem solving strategies were identified. Some examples of which are benefiting from individual instruction (for instance in Mathematics, Montague, 1992), thinking aloud pair problem solving (TAPPS) instruction (for instance in chemistry, Jeon, Huffman, & Noh, 2005), using cooperative groups instruction (for instance Heller et al., 1992) and using computer-aided instruction (for instance Schulze, Treacy, Wintersgill, VanLehn, & Gertner, 2000).

Cognitive interventions directed to teach problem solving strategically and systematically are often called "strategy instruction" (Owen & Fuchs, 2002). By means of strategy instruction programs, students are facilitated and are able to follow a series of steps to simplify understanding and solve the problem (Wong, 1994). However, one of the most important instructional methods that have been used to address problem solving performance is explicit problem solving instruction. According to Huffman (1997), "explicit problem solving is instruction that directly teaches students how to use more advanced techniques for solving problems".

The place, aim, and importance of the present research in literature

During a physics lecture taught by the traditional instruction method, the teacher explains which principles and concepts will be applied while solving a problem. Only the related equations and formulas are written down on the board and students are told that drawing diagrams or drawings is helpful and important. Ultimately, the students use poor problem solving skills, and primitive problem solving strategies based on the formulas in such a problem solving environment (Buffler & Allie, 1993). In addition, it has been proven many times that such a traditional instruction method is not effective in helping the students to be good or expert problem solvers (Gerace & Beatty, 2005) and a clear majority of the students remain incapable of solving a problem (Hestenes, 1987).

When field literature is reviewed, it is seen that most of the research in the area of physics which relate to problem solving strategies is research where the differences between experts and novices is determined (Champagne, Gunstone, & Klopfer, 1982; Chi, Feltovich, & Glaser, 1981; Dhillon, 1998; Hardiman, Dufresne, & Mestre, 1989; Larkin, McDermott, Simon, & Simon, 1980; Larkin & Reif, 1979; Priest & Lindsay, 1992). Whereas only a small amount of the reviewed research is concerned with the comparison of the problem solving behaviours of successful and unsuccessful novice problem solvers (de Jong & Ferguson-Hessler, 1986; Zajchowski & Martin, 1993). It was also determined that although there is a lot of research concluding that problem solving strategies instruction has positive effects on the solving of physics problems (Dufresne, Gerace, Hardiman, & Mestre, 1992; Heller & Reif, 1984; Larkin & Reif, 1979; Mestre, Dufresne, Gerace, Hardiman, & Touger, 1993; Numan & Sobolewski, 1998; Reif, Larkin, & Brackett, 1976; Van Heuvelen, 1991; Wright & Williams, 1986), there is a limited amount of research displaying the effect of direct strategy instruction on academic achievement in physics courses (Foster, 2000; Ghavami, 2003; van Weeren, de Mul, Peters, Kramers-Pals, & Roossink, 1982). The scope of this study includes the problem solving instruction and the effects on physics course achievement. Furthermore, we have expanded our study that deal with student self-efficacy beliefs about physics.

In literature review, it is seen that there is no research where the correlation of problem solving strategies instruction in the area of physics with self-efficacy is investigated. In addition to this, certain number of researches determining the self-efficacy beliefs on physics (Selçuk, Çalışkan, & Erol, 2008) and investigating the correlation of them with the variables such as achievement, gender and instructional methods was encountered (Cavallo, Potter, & Rozman, 2004; Fencl & Scheel, 2004; Juuti, Lavonen, &

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Meisalo, 2005; Neber, He, Liu, & Schofield, 2008; Shaw, 2004; Warren, 2006; Zhu, 2007).

From the research results where the correlation of problem solving in different areas with self-efficacy is investigated, it is seen that self-efficacy has an important effects on problem solving. According to Jonassen (2000), although the students who have high self-efficacies believe that they can solve a problem, they put more effort into the problem. This result was shown in the research done by Collins (1982). The students who were ranked according to their low, middle, and high mathematical skills were first defined by their standard test scores. In each skill group, the students with high self-efficacies solved the problems more correctly than the students with low self-efficacies, and they selected to re-study more problems. And from this, it was concluded that self-efficacy is determinative on behaviour and performance achievement over the skill levels in all three groups. According to Zimmerman, high self-efficiency results in a voluntary and patient approach to work, a decrease in fear and anxiety, a focus on problem solving strategies, and positive cognitive experiences which affect achievement expectations (Stipek, 1998). Pintrich and DeGroot (1990) showed the value of high self-efficacy in their research concluding that self-efficacy has a strong correlation with constructional cognitive strategies and self regulatory learning (the students' ability to establish a correlation between the course book and the instruction in the classroom, rereading the material, and making plans, etc.). Bouffard-Bouchard (1990) concluded in their research that experimentally positive or negative feedback affects self-efficacy perception at college level. In addition, there is a correlation between the accuracy of the number of completed problems, the usage of efficient problem solving strategies and the self-evaluation activities which they performed and self-efficacy perception. Also, there is a strong correlation between high self-efficacy and self regulatory strategies and successful performance. Schunk and Gunn (1986) expressed that explaining the importance of the strategy to the students while instructing the problem solving strategies, developed the students' motivation, self-efficacy, and mathematical skills. It is possible for the teacher to show the importance of strategy usage in the problem solving process by means of verbal feedback. For example, the teacher may encourage a student by uttering "You are doing very well, because you are following the steps in the correct order".

Unfortunately, the instruction of problem solving strategies is neglected in Turkey. It can be seen that there are very few studies in the field of physics (Gök, 2006). Furthermore, this subject has not been given sufficient importance in our training system. Teachers neglect it due to the fact that the period of training is limited, course programs are loaded or they themselves have sufficient knowledge in the field. For all of the afore mentioned reasons regarding the necessity of investigating the effects of strategy instruction on achievement in a physics course, especially on self-efficacy towards the course in the field literature, this research aims to evaluate the correlations between present research and these variables. Furthermore, this research hopes to make new contributions in the field of physics education literature.

The present study

Mestre et al. (1993) stated that two important goals of physics instruction were to help students achieve a deep, conceptual understanding of the subject and to help them develop powerful problem solving skills. In light of this statement, we designed our explicit problem solving instruction which is integrated content instruction. The main purpose of this study was to examine the effects of explicit problem solving strategy instruction on student teachers' physics achievement, and physics self-efficacy beliefs. The research questions investigated in this study were as follows:

1. Are there any effects of using problem solving strategy instruction on student teachers' physics achievement scores?
2. Are there any effects of using problem solving strategy instruction on student teachers' physics self-efficacy beliefs?

Methodology of Research

Participants

The participants included 77 second-year student teachers who were enrolled in the Department of Elementary Mathematics Education (EME) in Dokuz Eylül University (Dokuz Eylül University or DEU is a Turkish medium university) in Izmir. Department of EME students were randomly divided into two groups and assigned as section A and B. Physics is compulsory in this department, and it is offered in two successive semesters (fall and spring) as Physics I (4 credits) and Physics II (4 credits). Physics I mainly focused on mechanics concepts and Physics II focused on electricity and magnetism. The distribution of participants according to gender and groups is presented in Table 1.

Table 1. The distribution of participants according to gender and groups.

	Strategy Group		Control Group		
Gender	**n**	**%**	**n**	**%**	**Total**
Male	23	59	12	32	35
Female	16	41	26	68	42
Total	39	51	38	49	77

Note: n: number of participants in groups; *%:* percentage of participants in groups

However, the data taken from the students whose pre-test and post-test could not be determined because of their erratic levels of attendance and who did not attend classes during the experimental process although they were participatants were not taken into consideration. In this context, in some of the data collecting tools, the numbers of students whose data was collected displayed a slight alteration.

Research design

In this study, a pretest-posttest quasi-experimental method with equivalent control group, involving a 2 (group) × 2 (time) factorial design was used. There was one control and one experimental group, namely, the strategy group. Students were assigned randomly to the strategy and control groups. The strategy group received strategy plus traditional instruction; however, the control group received only traditional instruction. Both groups were tested before and after the intervention to measure their physics achievement, and physics self-efficacy beliefs. Control variables were prior physics achievement, and physics self-efficacy beliefs. The independent variable was the intervention (the strategy and/or the traditional instruction). The dependent variables were posttest physics achievement, and physics self-efficacy beliefs.

Materials

The data of this study was collected by a Physics Achievement Test (PAT), and a Physics Self-Efficacy Scale (PSES).

Physics Achievement Test (PAT): In the study, in order to determine the students' physics achievement, a test developed by the researchers was used. The PAT contained 37 five-option, multiple-choice questions. Test items were designed by the first researcher insuring their content validities and using various physics course books used at university level. Major topics included in the test were as follows: Motion in One Dimension, Vectors, Motion in Two Dimensions, The Laws of Motion, Circular Motion and Other Applications of Newton Laws, and Energy and Energy Transfer. The test was intended to determine the knowledge of the students relating to these fundamental concepts, and their skills on recalling the

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relationships between the concepts, and applying them to the problems. The Kuder-Richardson reliability of the test was found to be .77.

Physics Self-Efficacy Scale (PSES): The PSES was developed by the researchers in order to determine the physics self-efficacy beliefs of the students. This scale containing 5-choice Likert type items having choices of "Strongly Agree", "Agree", "Undecided", "Disagree", and "Strongly Disagree" consists of a total of 24 items. Items in the scale are grouped in 4 dimensions and can explain 56.68% of total variability. The names of the dimensions are as follows: Problem solving self-efficacy belief (PSSEB), self-efficacy belief towards achievement (SEBTA), self-efficacy belief in applying physics knowledge (SEBAPK), and self-efficacy belief in recalling physics knowledge (SEBRPK). Descriptions and sample items concerning sub-scales of PSES are given in Table 2.

Table 2. Descriptions and sample items concerning sub-scales of physics self-efficacy scale.

Sub-scales	Descriptions	Sample Items
PSSEB	Individual prejudices towards how much he/she could achieve in physics problem solving.	"I strongly believe that I could ultimately reach the solution even if it is a difficult physics problem." "I am sure that I can formulate the necessary formulas to solve a physics problem."
SEBTA	Individual prejudices towards how much he/she could achieve in physics course.	"I believe that I could get 70 or higher scores from the physics exams." "I believe that I cannot succeed in the physics course."
SEBAPK	Individual prejudices towards how much he/she could achieve in applying physics knowledge to various situations.	"I am sure that I could write a simple question related to a physics subject that I learned." "I believe that I could explain a physics subject that I learned in the physics course to my friend rather well."
SEBRPK	Individual prejudices towards how much he/she could achieve in recalling physics knowledge when necessary.	"I believe that I could recall certain formulas that I learned in the physics course when necessary." "I believe that I could recall the fundamental knowledge that I learned at physics course when necessary."

The items in the scale were numbered as 5, 4, 3, 2, and 1 ranging from Always to Never. Cronbach's alpha reliability coefficient is .93. In Table 3, the number of items for each sub scale calculated using Cronbach's Alpha reliability coefficients are presented. The highest score which can be obtained from this scale is 120, and the lowest score is 24.

Table 3. Results of the reliability calculations concerning the physics self-efficacy scale.

	Sub-scales	Number of items	Cronbach's Alpha Coefficient
Sub-scale 1	PSSEB	10	0.91
Sub-scale 2	SEBTA	5	0.84
Sub-scale 3	SEBAPK	6	0.76
Sub-scale 4	SEBRPK	3	0.70
Whole Scale		24	0.94

Intervention materials: The Turkish translation of the book PHYSICS for Scientists and Engineers by Serway and Beichner (2000) was used as a textbook. Approximately forty multi-step physics problems were selected from the following textbooks, Fundamentals of Physics (Halliday, Resnick, & Walker, 2005) and Physics for Scientists and Engineers (Fishbane, Gasiorowicz, & Thornton, 2003) for use in the strategy and traditional instruction sessions.

Procedure

The experimental processes were performed in the strategy and control groups on the days and during the hours allocated for the Physics I course on the weekly schedule (2 days per week, and during the total lecture hour) in October and November in the Fall Semester. Experimental treatment lasted for 6 weeks. Before the experimental processes, the pre-tests were taken in the first week when the research started, and during the second week, the problem solving strategies training program was applied to the strategy training group during 8 lecture hours (a total of 360 minutes).

In the first part of the lectures done twice per week in both groups, the teacher presented physics concepts, laws and principles using conventional methods. That is, using the textbook. Then, students in the strategy training group were taught how to solve physics problems using problem solving strategy, while those in the control group were taught only by course book/traditional problem solving strategies, namely,: 1-Reading the problem, 2-Determining the given and asked variables, 3-Visualizing, 4-Writing down the formulas related to the problem, and 5-Mathematical Solution.

In the research, the problem solving strategy training, the expert skills gaining approach which is a frequently used approach and one of the main aims of strategy training and similar to the approach in the research of Mestre et al. (1993) was used. In the research, in order to provide the novices with problem solving approaches in order for them to become as good as more expert problem solvers a 5+1 stepped UQAPAC+SE problem solving strategy which presents implicit problem solving strategies used by experts in a stepped structure and which will help the students to reify these strategies was taught using the explicit strategy instruction approach. Each step of the 5+1 stepped UQAPAC+SE problem solving strategy used in this study contains special problem solving strategies (see Table 4).

Table 4. UQAPAC+SE problem solving strategy.

1. ***U**nderstanding the Problem*
    - Reading the problem carefully
    - Restating / writing the problem in his/her own words
    - Listing the given variables in the problem (with their units)
    - Listing the asked variables in the problem (with their units)
    - Visualizing the problem by drawing – drawing diagrams (or establishing correlation between given diagram and the problem)
    - Determining the scaler and vectorial properties of the given and asked variables
2. ***Q**ualitative **A**nalyzing of the Problem*
    - Determining the significant (main) concepts of the problem in physics
    - Determining the general approach of the problem
    - Expressing the fundamental law/rules related to the problem and why/how to use them
3. *Solution **P**lan for the Problem*
    - Planning how to achieve the asked variables from the given variables
    - Writing the formulas related to the problem
    - Considering whether the physics formulas written for the problem were reasonable or not
    - Formulating the final formula before making algebraic operations
    - Checking whether there was an unknown variable or not in the final formula
4. ***A**pplying the Solution Plan*
    - Using the given variables in the problem with their units in the formulas
    - Making the mathematical operations carefully
5. ***C**hecking*
    - *Checking whether all asked variables in the problem were found or not*
    - *Considering whether the found result for the problem was reasonable or not*
    - *Checking the unit of the result*
    - *Reviewing whole solution*

+ ***S**elf **E**valuation:* It is a general strategy containing the activities related to the quality and progress of students' work. The problem solver uses this strategy at the end of the problem solving session, in order to evaluate him/herself.

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In this research, well-structured problems were used. These problems were sourced from textbooks used throughout Turkey in both schools and universities. Special attention was paid to the type of question. Preference was given to problems which were at least two-stepped, and special consideration was paid to whether the strategies could be applied to the question types. Both the control and strategy groups worked on and solved the same problems in parallel during the research period.

Treatment in the Strategy Group

In the strategy group, after teaching UQAPAC+SE problem solving strategy, the application of the subjects planned to be taught during experimental process began. The subject of that day was instructed by the researcher by using direct lecturing method during the first 90 minute block of the allotted lecture hours. At the end of the lecture, the researcher acted as a model by solving two sample problems to the topic using UQAPAC+SE problem solving strategy. During the problem solving session hours arranged as the second 90 minute block, the students were given a worksheet and asked to solve 6 selected problems related to the subject of the previous lecture. The worksheets were handed out to the students according to UQAPAC+SE problem solving strategy. Using the techniques learnt in the previous lecture, students solved the problems individually. In order to help them during the problem solving process, students were given a worksheet defining UQAPAC+SE strategy. In the final 15 minutes of the lecture, the problem solving worksheets were collected from the students, and a photocopy of the correct solutions to the problems was handed out to the students for them to review the correct solutions. During the final 5 minutes of the lecture, the students evaluated their problem solving performances on the Self Evaluation Form. The Self Evaluation Forms were collected from the students and reviewed, and the first 10 minutes of the next lecture hour, was allocated to the evaluation of the students work. Deficiencies, and if any, mistakes on the problem solving worksheet were discussed by the researcher and the students.

Treatment in the Control Group

While strategy instruction was applied in the strategy group, no study relating to strategy instruction was carried out in the control group. During this period, conventional teaching methods were used concerning "Thermal Expansion" the same topic covered in the strategy group training program. In the control group, the subject of that day was instructed by the researcher using a direct lecturing method for the first 90 minutes of the time allotted in the course schedule. After the instruction of the lecture was completed, the same two sample problems solved by the strategy group were solved by the researcher on the board for the students in the control group using only traditional problem solving approaches. During the problem solving hours arranged as the second 90 minutes slot of lecture hours, a sample problem related to the subject was solved by the researcher; and then the same 6 problems solved at strategy group were solved by the control group. First, each problem was dictated to the students by the researcher, and then students were given 7-8 minutes to solve the problem. Then a volunteer student who had solved the problem was then asked to show the solution to the problem on the board with guidance from the researcher. If a problem couldn't be solved, then the researcher solved that problem explaining it on the board. During the first 10 minutes of the next lecture hour, the researcher briefly went over the subject and the problems from the previous lecture, and then moved on to the new subject.

Data Analysis

The data from PAT and PSES was analyzed using the SPSS 13.0 statistical analysis program. Frequencies (*n*), percentages (*%*), mean (*M*), and standard deviations (*SD*) were calculated, *t*-test and multivariate analysis of variance (MANOVA) were conducted. To test for changes over time, 2 (group) x 2 (time) repeated measures ANOVA and repeated measures MANOVA were performed with group (strategy vs. control) as the between-subjects factor and time (pretest and posttest) as the within-subjects factor. We used an alpha level of 0.05 for all statistical tests.

Results of Research

The data from the two groups was measured using two dependent variables (physics achievement, and physics self-efficacy belief) and collected two times over two months. Table 5 summarizes the descriptive statistics for PAT, and PSES pre and posttest scores by group. Appropriate parametric tests (independent samples *t*-test and MANOVA) were used to detect any significant differences between the strategy group and the control group on pretest scores. For the MANOVA, preliminary assumption testing was conducted to check for normality, linearity, univariate and multivariate outliers, homogeneity of variance-covariance matrices and multicollinearity. No serious violation was noted. The analyses revealed no statistically significant differences in physics achievement [t(70)=1.304, p=0.197] and physics self-efficacy beliefs [Wilks'Lambda=0.944, F(4,72)=1.077, p=0.374].

Table 5. Means and standard deviations of dependent variables, by group.

	Strategy Group		Control Group	
Measure	M	SD	M	SD
Achievement				
Pretest	12.45	4.34	11.14	4.21
Posttest	23.59	5.12	17.17	5.64
Self-Efficacy				
PSSEB				
Pretest	33.41	5.25	34.02	5.53
Posttest	35.92	4.46	33.92	5.94
SEBTA				
Pretest	17.79	3.33	17.60	2.58
Posttest	18.76	2.85	16.97	3.25
SEBAPK				
Pretest	22.38	3.62	23.47	2.46
Posttest	23.74	2.81	22.92	2.72
SEBRPK				
Pretest	10.48	1.89	10.57	2.07
Posttest	10.71	1.62	10.15	2.09

The Effects of Problem-Solving Strategy Instruction on Physics Achievement

Repeated measures ANOVA technique was used to determine any significant differences between the strategy and control group's mean scores on the pre and post Physics Achievement Test. Results from a 2 × 2 (Time × Group) repeated measures ANOVA confirmed achievement differences between the strategy and control groups. A statistically significant main effect for group was found, F(1,70)=14.232, p=0.000, η_p^2=0.169. A significant main effect for time, F(1,70)=278.601, p=0.000, η_p^2=0.799 suggested that scores for both groups increased from pretest to posttest. The analyses also yielded a statistically significant Time × Group interaction, F(1,70)=24.661, p=0.000, η_p^2=0.261 (see Table 6). Although both groups showed an increase over time, the increase was significantly higher for the strategy group than it was for the control group. Effect sizes were measured via partial Eta squared (η_p^2) effect sizes were considered to be small for $\eta_p^2 \leq 0.01$, medium for $\eta_p^2 = 0.06$, and large for $\eta_p^2 = 0.14$ as suggested by

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Stevens (1992). Accordingly, the proportion of partial population variance explained by the Time × Group interaction can be regarded as large in the present study.

Table 6. ANOVA results of the PAT pretest and posttest scores.

Source of Variation	df	F	P	η^2_p
		Main effects		
Group (Strategy/ Traditional)	1	14.232	0.000	0.169
Time (Pretest-Posttest)	1	278.601	0.000	0.799
Time x Group	1	24.661	0.000	0.261
Error	70	9.509		

Note: Values enclosed in parantheses mean square errors

Pairwise comparisons were performed in order to comment on the Time × Group interaction. According to these results, it is seen that there were statistically significant increases in the average success scores of both the experimental group and control group [$F(1,70)=241.222$, $p=0.000$, $\eta_p^2=0.775$; $F(1,70)=66.884$, $p=0.000$, $\eta_p^2=0.489$ respectively]. When the partial eta squared values were examined, it was determined that both applications had large effect sizes; however, the application done in the experimental group was more effective than the application done in the control group.

The Effects of Problem-Solving Strategy Instruction on Physics Self-Efficacy Beliefs

A 2 x 2 repeated measures MANOVA was conducted to seek out the effects of the treatment on the student teachers' self-efficacy towards the physics course. Neither the group main effect, $F(4,72)=1.535$, $p=0.201$, $\eta_p^2=0.079$ nor the time main effect, $F(4,72)=2.204$, $p=0.077$, $\eta_p^2=0.109$, were statistically significant. On the other hand, time × group interaction was statistically significant, $F(4,72)=3.490$, $p=0.012$, $\eta_p^2= 0.162$ the proportion of partial population variance explained by the Time × Group interaction can be regarded as large in the present study.

Table 7. ANOVA results of the PSES pretest and posttest scores.

Source of Variation	Dependent Variable	df	F	p	η^2_p
Group (Strategy/Traditional)		4	1.535	0.201	0.079
Time (Pretest-Posttest)	PSES	4	2.204	0.077	0.109
TimexGroup		4	3.490	0.012	0.162
Time (Pretest-Posttest)	PSSEB	1	6.469	0.013	0.079
	SEBTA	1	0.308	0.580	0.004
	SEBAPK	1	1.954	0.166	0.025
	SEBRPK	1	0.138	0.711	0.002
Time x Group	PSSEB	1	7.650	0.007	0.093
	SEBTA	1	6.771	0.011	0.083
	SEBAPK	1	10.981	0.001	0.128
	SEBRPK	1	1.622	0.207	0.021
Error	PSSEB	75			
	SEBTA	75			
	SEBAPK	75			
	SEBRPK	75			

Univariate ANOVA indicated a statistically positive mean change for the strategy group then the control group on PSSEB, $F(1,75)=7.650$, $p=0.007$, $\eta_p^2= 0.093$; SEBTA, $F(1,75)=6.771$, $p=0.011$, $\eta_p^2= 0.083$; and SEBAPK $F(1,75)=10.981$, $p=0.001$, $\eta_p^2= 0.128$. SEBRPK did not have a significant interaction, $F(1,75)=1.622$, $p=0.207$. Pairwise comparisons were performed in order to comment on the Time × Group interaction. According to these results, it was determined that there were statistically significant positive increases in the self-efficacy scores of the experimental group in the dimensions of PSSEB, SEBTA and SEBAPK ($p=0.000$, $p=0.028$, $p=0.001$, respectively). Pairwise comparisons revealed no significant change from pretest to posttest for control group in all dimensions ($p=0.876$, $p=0.155$, $p=0.182$, and $p=0.251$, respectively). The increase in the total average scores of the experimental group is statistically significant [$F(4,72)=4.523$; $p=0.003$, $\eta_p^2=0.201$]; however, the decrease in the total average scores of the control group is statistically insignificant [$F(4,72)=1.215$; $p>0.05$, $\eta_p^2=0.063$]. As seen from the partial eta squared value, the experimental application done in the experimental group had a large effect size.

Discussion

The purpose of this study was to investigate the effects of problem solving strategy instruction on physics achievement, and self-efficacy beliefs towards physics. From analysis of the data, it was concluded that problem solving strategy instruction increased the performance of the students. The first result of the study is consistent with the findings of problem solving instruction research in different subject matter at different grade levels, from secondary to university. For example, in the research done by Hutchinson (1993) on learning disabled adults in mathematics; Hoek, Eeden and Terwel (1999), in their studies on mathematics course in secondary education level; Mevarech (1999) in his study on secondary school mathematics; and Montague, Applegate and Marquard (1993) in their studies on mathematics at high school level determined that cognitive problem solving strategies instruction given to students with learning disabilities had positive effects on the students' achievements. Moreover, strategy instruction's link to the achievements of students in the physics course supports various research findings which determine that problem solving strategy instruction increased the achievement in different education levels and in different subject matter. For example, Foster (2000), in his study in college level; Ghavami (2003) in his study in freshman college level on physics principles and applications in a physics course; van Weeren, de Mul, Peters, Kramers-Pals and Roossink (1982) in their studies in university level on the electromagnetism course; and Russell and Chiappetta (1981) in their studies of the eighth grade on earth sciences course achievement determined that problem solving strategies instruction had had a positive effect on the students' achievements.

In the research, it was determined that there were significant differences in the progress of both groups from pretest to posttest. Although it was expected that students in the control group would make some progress, in this context, this result can be interpreted as a result of the students willingness to study in order to pass the course or to get higher scores. During the research, it was observed that the students in the control group also actively participated in the traditional lectures and problem solving hours.

During this research, it could clearly be seen that the instruction applied in the strategy group was far more effective than that applied in the control group. This was evident in class observations where it was observed that students in the strategy group reviewed the learning materials, actively participated in the problem solving process and studied by continuously asking questions and asking for help from the teacher. During the problem solving process, students are required to use their prior knowledge and find their deficiencies in learning. In addition, as indicated in Huffman (1997), while traditional problem solving focuses only on quantitative aspects, in explicit problem solving process, a problem is dealt with from both quantitative and qualitative aspects. This qualitative aspect of the explicit problem solving process may have not only improved students' problem solving performance but also enhanced their understanding of physics concepts and principles. In this context, it can be said that direct problem solving instruction was more effective than the traditional problem solving studies on the students' achievements.

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It was determined that problem solving strategies instruction had positive effects on the students' physics self-efficacies. It was determined that there was a statistically significant difference between the pretest and posttest scores of the strategy group in the sub-dimensions of PSSEB, SEBTA, and SEBAPK. These results are consistent with the results of research investigating the correlation between strategy instruction and self-efficacy. Daley (1998) in social sciences; Anderson (1997) in writing *socio-cognitive stories*; Warren (2006) in the evaluation strategies instruction in terms of physics learning; Chularut and DeBacker (2004) in concept mapping as a learning strategy in English; Schunk and Rice (1992) in the instruction of reading comprehension strategies. The research shows that strategy instruction had positive effects on self-efficacy belief. Further research investigating the effects of problem solving strategy instruction on self-efficacy beliefs is consistent with the results. Daniel (2003) and Ahn (1998) determined in their studies that; cognitive strategy instruction on mathematical problem solving for mathematics learning disabled secondary school students had positive effects on the students' self-efficacy beliefs. Research conducted by Metallidou and Vlachou (2007) further supports the results of afore mentioned research. They deduced that the students' self-efficacy beliefs were the most important indicator determining the cognitive and regulatory strategy use in language and mathematics in elementary school level; and Nielsen (2004) deduced that music students who have higher self-efficacies used the cognitive and metacognitive strategies more than the students who have lower self-efficacies. Even though, certain research investigating the correlation between strategy instruction and motivation was encountered in Turkey (Çetingöz, 2006; Gök, 2006; Selçuk, Sahin, & Açıkgöz, 2009); unfortunately, no research directly investigating the correlation between strategy instruction and self-efficacy belief was encountered.

In this research, instead of overtly attempting to develop the students' self-efficacies, a strategy instruction program providing the students with the opportunity to actively participate in the problem solving sessions, emphasizing the importance of problem solving strategies usage, and which is supported by positive feedback from the teacher during the problem solving process. In addition, a program where *self evaluation* activity (Pintrich & DeGroot 1990; Bouffard-Bouchard 1990) which is one of the self regulatory strategies having a strong correlation with self-efficacy progress was included was applied. Moreover, Bandura (1997) states that the most effective mean for developing a strong sense of efficacy is through mastery experiences. A sense of efficacy starts to develop in the early childhood years as a child faces various experiences, tasks, and situations. Sense of efficacy does not stop to develop in one's youth, instead, it develops throughout a person's whole life as the person gains new experiences, skills, and understanding (Bandura, 1992). Achievements help a person develop a strong sense of efficacy whereas, failures lower one's sense of efficacy. In the light of this information, improvements in students' achievements during problem solving process might have caused their sense of efficacy to change in a positive way.

On the basis of this, it is thought that the self-efficacies of students in the strategy group were increased in general in the sub-dimensions of problem solving self-efficacy belief (PSSEB), self-efficacy belief towards achievement (SEBTA) and self-efficacy belief in applying physics knowledge (SEBAPK).

In this sense, it can be considered that the students' progress in relation to their self-efficacies directed towards problem solving, achievement and ability to use knowledge can be seen as an expected result of problem solving strategies instruction.

There was a tiny decrease in the mean values of the posttest scores in the control group both in general and in all sub-dimensions compared to the pretest scores; however, these differences were not statistically significant. It was observed in the interviews done with the students during the lecture that the reason for this small decrease was the students' having difficulties in solving the problems (problem çözme saatlerinde öğretmenin sunduğu problemler) by means of their pre-learnt skills. This finding of the study is consisted with similar studies (Akay & Boz, 2008; Canakay & Bilen, 2008; Chung & Ro, 2004; Ural, Umay, & Argün, 2008) which have determined that traditional teaching (e.g., mathematics, music, and practical arts) results in declines in students' self-efficacy beliefs. The reason for the regression in self efficacies in the control group can be attributed to the style of instruction which did not include instructional tasks where the students felt successful (Canakay & Bilen, 2008). Moreover such reasons as students' lack of motivation, failure to realize themselves and passiveness may also be considered.

Conclusion

This study provides some evidence of the positive effects of using problem solving instruction (UQAPAC+SE) on student teachers' physics achievement. Explicit problem solving strategy instruction was more effective than traditional instruction in improving physics achievement and self efficacy of the participating students.

In addition to assuring students' active (curiosity and interest) participation in the problem solving activities, explicit problem-solving instruction has helped students by leading them to apply good problem solvers' strategies on the step model while solving physics problems, and thereby helping them to improve their cognitive and metacognitive awareness, features displayed by strategic learners. Moreover, the instruction program provided students with learning activities by which students could feel successful and help their self-efficacy develop. In this context, it can be said that strategy teaching in physics may play a significant role in training strategic, successful, and high self-efficious problem solvers.

In light of the results of the present study, teachers and/or educators who do not include strategy applications in their programs because of time constraints but want to improve the effectiveness of their instructions, may review the potential benefits of strategy instruction.

The fact that the study was carried out within a regular teaching program has limitations on this study. Firstly, prompt feedback related to the problem solving sheets and self evaluation forms collected from the students after the application could not be given. In this context, the feedback related to what the students did could only be given in the following weeks lecture. The provision of prompter feedback would have meant that the students could have understood their mistakes and deficiencies immediately. Secondly, the study has been conducted within a six weeks period. It is thought that long term future studies on the same theme may prove to be useful in producing more positive effects on the results.

On the basis of the findings, it is recommended that physics instructors should use explicit problem solving strategy instruction in their lessons to develop students' problem solving skills and the related outcomes such as course achievement. Research where the effects of instruction of different problem solving strategies in different grade levels on a physics course and different effective characteristics (e.g. learning satisfaction and motivation to learning) are investigated should be done. Problem solving strategies and courses intended to instruct these strategies should be added to the curriculums of the institutions which are educating teachers. In addition to this, many different kinds of research comparing a group where problem solving strategies instruction was implicit with the groups where it was explicit; or comparing the effects of instruction of problem solving strategies and learning strategies; or investigating the effects of instruction of problem solving strategies in computer-aided or cooperative learning groups can be done. Moreover, in further research, by supporting a strategy instruction program combined with a self-efficacy development program which can be applied in addition to a normal instruction program, more effective results could be obtained.

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