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A COMPARISON OF STUDENTS' PERFORMANCE, SKILL AND CONFIDENCE WITH PEER INSTRUCTION AND FORMAL EDUCATION

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Abstract. *The effects of peer instruction (PI) and formal education (FE) on students' performance, skill, and confidence were investigated. The research was performed in a two-year college classroom with 98 students from two groups enrolled in a physics course. One of the groups was selected as an experimental group, and the other was the control group. The students in the experimental group were instructed by peer instruction with problem solving strategy steps (PSSS), whereas the students in the control group were instructed by formal education including PSSS. The research data were collected with the Physics Achievement Test (PAT) and the Problem Solving Confidence Questionnaire (PSCQ). The problem solving skills of the students in both groups were evaluated using quantitative problems in Newtonian mechanics. The PAT and the PSCQ results related to the performance and confidence of the students indicated that there was a statistically significant difference between the means of the experimental group and the control group in favor of the experimental group. The combination of PI with PSSS was more effective for increasing the problem solving skills of the students than the combination of FE with PSSS.*

Key words: *formal education, peer instruction, problem solving strategy steps.*

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Introduction

Peer Instruction (PI) was developed by Mazur, a physicist at Harvard University, in response to the results of the ConcepTests (Mazur, 1997; Pilzer, 2001). PI is defined as "an interactive teaching technique that promotes classroom interaction to engage students and address difficult aspects of the material" (Watkins & Mazur, 2010).

PI is a student-centered approach (Crouch & Mazur, 2001), and its application has many educational advantages. An effective interaction occurs between the instructor and the students during class. Students can learn concepts, voice their ideas, and resolve misunderstandings by talking with their peers (Watkins & Mazur, 2010). Students can discuss with peers when they do not comprehend concepts. The evaluation of studies has shown that PI increases student learning regardless of their background knowledge, diminishes gender gaps in student learning and reduces the course dropout rate (Lasry, Mazur, & Watkins, 2008; Lorenzo, Crouch, & Mazur, 2006; Watkins & Mazur, 2010).

PI can be implemented in many courses (e.g., chemistry (Brooks & Koretsky, 2011), mathematics (Pilzer, 2001), astronomy (Green, 2003), and genetics (Smith, Wood, Krauter, & Knight, 2011)). Researchers have examined the effects of PI on conceptual learning and found it to be effective (e.g., Crouch & Mazur, 2001; Crouch et al., 2007; Gok, 2011a; Gok, 2012a; Gok, 2012b; Lasry et al., 2008).

Problem of Research

Conceptual learning is fundamental in the educational system (Gok, 2012a; Gok, 2012b). Although most students understand course concepts, they do not typically solve the problems in the textbook. They generally use the solution steps of similar problems

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and focus on the numerical results of the problems. Students do not determine the concepts of the problem, analyze the solution methods of the problem, or evaluate/interpret the solution of the problem. Formal education is simply training to reach correct formal results without any comprehension of the actual complexity of a problem (Gok, 2012a).

Research Focus

Problem solving is accepted as an important activity of teaching and learning in science courses (Bascones, Novak & Novak, 1985; Heller, Keith & Anderson, 1992; Gok, 2010; Harskamp & Ding, 2006; Larkin & Reif, 1979; Reif, Larkin & Brackett, 1976; Reif, 1981). Many studies have been conducted on problem solving, and a number of researchers have examined the differences between expert and novice problem solvers (Chi, Feltovich, & Glaser, 1981; Kohl & Finkelstein, 2008; Larkin, 1979; Reif et al., 1976; Reif & Heller, 1982; Van Heuvelen, 1991) and have developed effective instruction strategies for problem solving (Dufrense, Gerace & Leonard, 1997; Heller et al., 1992; Garrett, 1986; Gok, 2012a; Larkin & Reif, 1979; Walsh, Robert, & Bowe, 2007). Researchers have focused on general and specific problem solving strategies (Bagno & Eylon, 1997; Dewey, 1910; Heller et al., 1992; Heller & Hollabaugh, 1992; Pol, 2005; Polya, 1945; Reif, 1995).

Gok (2011a) modified general and specific problem solving strategies and developed a problem solving strategy with three major steps. The problem solving (fundamental and applied/technical problems) strategy steps consist of *Identifying the Fundamental Principle(s), Solving, and Checking.*

1st Step- *Identifying the Fundamental Principle(s)*: Students should primarily understand the concepts and comprehend the given phenomena/problem by associating real life phenomena with the concepts. They should restate the problem in their own words. They should construct the problem with the help of an illustration or a figure.

2nd Step- *Solving*: Students should construct a mathematical model (formulas and equations) regarding the problem and solve the problem qualitatively first, then quantitatively. If necessary, they should divide the problem into sub-problems. Finally, they should find the asked variables by using the given variables.

3rd Step- *Checking*: Students should check the solution method of the problem, determine the units of variables and evaluate/interpret the result of the problem.

The studies performed on PI reported that the peer instruction method was effective in conceptual learning (Crouch & Mazur, 2001; Crouch et al., 2007; Gok, 2011a; Gok, 2012a; Gok, 2012b; Lasry et al., 2008; Lorenzo et al., 2006; Mazur, 1997; Watkins & Mazur, 2010). No research studies on students' problem solving skills, performance, and confidence related to PI have appeared in the open literature as of 2013. The major purpose of this study was to examine the effects of peer instruction and formal education on students' performance, skills, and confidence. The researcher investigated the following research questions:

1. Are there any differences between the experimental group and the control group students' performances?
2. Are there any differences between the experimental group and the control group students' problem solving skills?
3. Are there any differences between the experimental group and the control group students' problem solving confidence?

Methodology of the Research

Sample of the Research

This study was performed in a two-year college classroom. The sample of this study consisted of 98 students from two different groups enrolled in a physics course. The experimental group consisted of 42 students, and the control group included 56 students. The researcher examined the academic background of the students included in both groups (by their GPA "Grade-Point Average" and university entrance scores), and the difference in these scores was not statistically significant.

Instrument and Procedures

The data used in this study and the answers regarding the research questions were collected and analyzed by the following statistical tools: the Physics Achievement Test (*PAT)* developed by the researcher and the Problem Solving Confidence Questionnaire *(PSCQ)* (Gok, 2012c).

PAT was developed to assess the students' knowledge about Newtonian mechanics. It consists of 20 multiple choice questions (quantitative problems) related to applications of Newton's laws. It was used as a pre-and post-test. The evaluation of PAT was based on 100 points, and the internal reliabilities (Kuder-Richardson 21) for the pre-and post-tests were calculated as 0.72 and 0.75, respectively.

Problem Solving Confidence Questionnaire (PSCQ): The PSCQ developed by Gok (2012c) was implemented after the English version of the survey was translated into Turkish. The statistical analyses of the survey and content review were conducted by the researcher.

Three factors were extracted by Exploratory Factor Analysis (EFA) from the statistical analysis data. The items with factor loadings below 0.40 were disregarded, which led to the exclusion of four items from the three dimensions. The first factor of PSCQ is "*interested",* which rates the students' interest in solving the problem. The second factor of PSCQ is "*endeavored*", which rates the students' attempt to solve the problem. The last factor of PSCQ is "*confident",* which rates the students confidence level about solving the problem. Some statistical values of the survey were given in Table 1.

Table 1. Dimensions, item numbers, and Cronbach's-α values of PSCQ.

Dimensions		Item Numbers	Cronbach's-α
Factor I	Interested	4	α=0.91
Factor II	Endeavored	6	α=0.87
Factor III	Confident	6	α=0.90
Total	PSCQ	16	α=0.88

During the implementation, the problem solving skills of the students in the experimental group and the control group was determined with 20 multiple choice questions (MCQs) that were divided into three subsections according to PSSS. Each step was organized by the MCQs. The students were asked about the fundamental principles and concepts of the problem in the first step of problem solving. The students were asked about methods of solving the problem in the second step and about checking the problem in the final step of problem solving. The content of the problems covers the applications of Newton's Laws.

A quasi-experimental design was used in this study (Campbell & Stanley, 1963; Cook & Campbell, 1979). The study was conducted with an experimental group (EG) and a control group (CG). The students included in the EG were instructed by Peer Instruction (PI) with PSSS, whereas the students included in the CG were instructed by Formal Education (FE) with PSSS.

Both groups were taught by the same instructor in a physics course on Newtonian mechanics for five weeks. The primary objective of the course was to encourage the students to describe and explain the principles of kinematics; the first law, second law, and third law; the superposition principle; and the types of force. Before and after the implementation of instruction to both groups, the PAT and PSCQ were administered as pre-and post-tests.

After the instructor gave the recitation section of the course, identical multiple choice questions (MCQs) were presented to both groups. All of the MCQs were quantitative problems designed by the instructor to engage students in thinking about meaningful conceptual issues. Three or four MCQs were solved in a 75-min class. The problem solving procedure was changed according to the implemented methods. The MCQs were divided into three subsections consisting of the following questions: How

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do you *identify* the fundamental principle(s) of the problem? How do you *solve* the problem? How do you *check* the problem?

The students in the experimental group were monitored with the following classroom procedures during the application:

a) The problems were divided into three steps.
b) The instructor posed the first step of the problem to the students (1 min).
c) The students were allowed time to think about the problem (1-2 min).
d) The students recorded/reported their individual answers. During the voting process, the students used a set of five or more flashcards labeled A-F instead of a showing of hands to present their answers during the lectures (1 min).
e) The students discussed their answers with peers/classroom neighbors (3-4 min). The PI discussion process was shown on a chart in Figure 1. The number of correct answers helped the instructor to decide whether to start a discussion. Lasry et al. (2008) noted that when the correct answers were between 30% and 70% of all the answers, discussion could be started by the instructor in an active class environment. Below the 30% threshold of correct answers, the problem was reexamined.
f) The students recorded/reported their revised answers (1 min).
g) The instructor provided feedback on their answers to the students (2-3 min).
h) The instructor explained the correct answer to the problem to the students (2-3 min).
i) The instructor moved to the second and third step of the problem. The entire process took approximately 10-15 min.

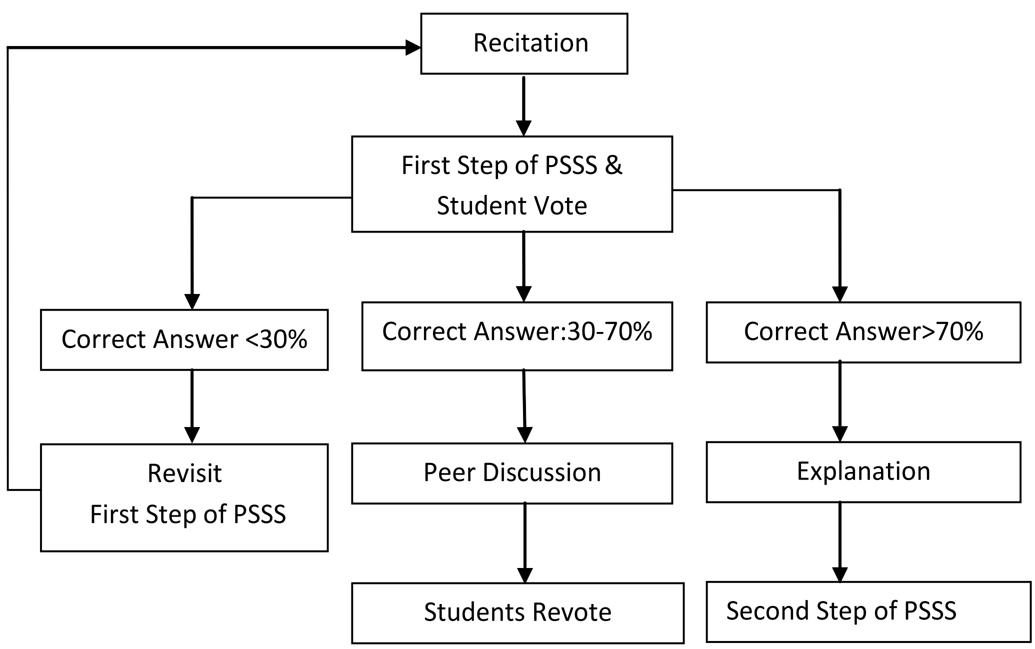

Figure 1: PI and PSSS Application Process (Lasry et al., 2008).

The students in the control group were monitored with the following classroom procedures during the application: (i) the assigned problems were divided into three steps according to PSSS; (ii) the students were given approximately 3-4 min to formulate their individual answers without a discussion; (iii) the answers for each step were given, and the instructor discussed and analyzed the answers (2 min). The CG students used the flashcards during voting. The total process for solving a problem took approximately 12-15 min.

At the beginning of the study, the researcher gave the EG and CG students a handout on the problem solving strategy steps based on the research by Gok (2011b) and encouraged students to use the steps from the handout explicitly in the solution of the sample problems.

Data Analysis

The PAT and PSCQ were administered to the students enrolled in the physics course as pre-and post-tests. The data collected were analyzed using SPSS 15.0. Fractional gain, analysis of variance (ANOVA), and Bonferroni tests were performed.

$$\text{Fractional Gain (FG)} < g >= \frac{(\text{post}\%-\text{pre}\%)}{(100\%-\text{pre}\%)}$$

This equation was used to calculate the fractional gain, where <g> is the fractional gain, post% is the percentage score on the post-test, and pre% is the percentage score on the pre-test. Hake (1998) defined *high gain* as , *medium gain* as 0, and *low gain* as . The ANOVA test was conducted to test the statistical difference of the means between EG and CG. The Bonferroni test was used to determine the change in the scores of the groups.

The problem solving skills of the students in both groups were evaluated with PSSS during the five weeks of the class, with the students being asked 20 problems concerning Newtonian Mechanics. The students' problem solving skills for each step were evaluated by the arithmetic means of the results.

Results of Research

The Comparisons of the Groups' PAT Results

The results obtained from the research were compared to determine the difference on the performances of the EG and the CG.

Table 2. PAT Results of EG and CG.

		Pre-Test		Post-Test		Fractional Gain
Group	N	M	SD	M	SD	g
EG	42	19.76	14.90	69.07	9.09	0.61
CG	56	17.14	15.27	60.57	9.84	0.51

N the number of the students, M mean, SD standard deviation

Table 2 shows the PAT scores before instruction (pre-test) and after instruction (post-test) as well as the normalized gains (*g*) for the students in the EG and the CG. The difference between the groups was considered significant with *p* values less than 0.05. As presented in Table 2, the descriptive statistics and normalized gains for the students' performances were analyzed on the pre-and-post-test data. The fractional gains of the EG (0.61) and the CG (0.51) were "medium".

The ANOVA test was conducted to test the means of the PAT of the experimental and control groups. As seen in Table 3, the difference in the pre-test scores between the EG and the CG was not statistically significant [$F_{(1-96)}$=0.69; p=0.406]. A comparison of the groups' post-test scores showed a significant difference between the means of the EG and the CG [$F_{(1-96)}$=19.06; p<0.05].

Table 3. ANOVA Test for Performance of the EG and the CG.

Instrument		SS	df	MS	F	p
PAT Pre-Test	Between Groups	164.63	1	164.63	0.69	0.406
	Within Groups	22640.48	96	235.84		
	Total	22805.11	97			
PAT Post-Test	Between Groups	1734.00	1	1734.00	19.06	0.000
	Within Groups	8730.50	96	90.94		
	Total	10464.50	97			

SS sum of squares, df degrees of freedom, MS mean square

The Bonferroni test was used to determine the change in the scores of the groups. According to the obtained results, a significant difference was observed between the EG (M=69.07) and the CG (M=60.57). This difference was found to be in favor of the EG.

The Comparisons of the Groups' Problem Solving Skill Results

The arithmetic means of the students' problem solving skill results were generally evaluated according to PSSS and presented as follows;

a) 1st Step- *Identifying the Fundamental Principle(s)*

First, the students in both groups determined the fundamental concepts and principles of the problems presented by the instructor. Then the instructor analyzed the students' answers according to the applied methods (PI and FE). The instructor calculated the answers of the EG students before the peer discussion (BPD) and after the peer discussion (APD). The performance of the students in the experimental group before the peer discussion was 64.8 whereas the performance of the students in the control group was 53.8 (Figure 2). After the peer discussion, the performances of the EG students increased to 76.6. This finding demonstrated that the peer discussion had a positive effect on the students' problem solving skills over time.

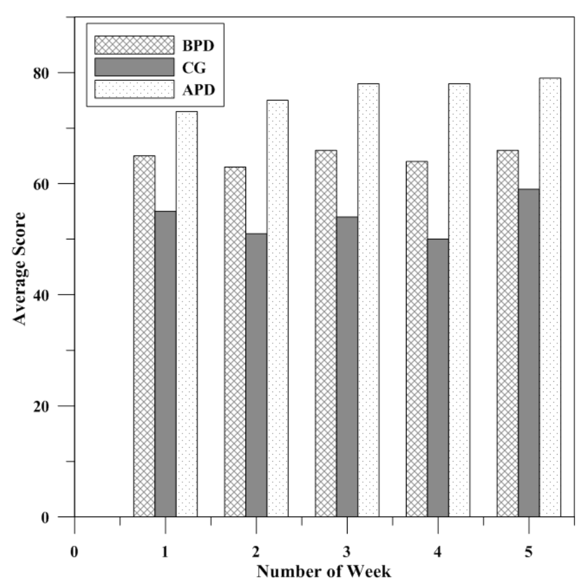

Figure 2: The results of the first step for the EG and the CG (BPD: Before Peer Discussion, CG: Control Group, APD: After Peer Discussion).

b) 2nd Step- *Solving*

In this step, the students solved the problem qualitatively and quantitatively after the determination of the fundamental concepts and principles. The results for both groups were similar to the results obtained (Figure 3) before the peer discussion. The performance of the students was 64.6 for the EG and 60.4 for the CG. After the peer discussion, the scores of the EG students increased to 75.4. This step indicated that peer discussion enhances the performance of the students.

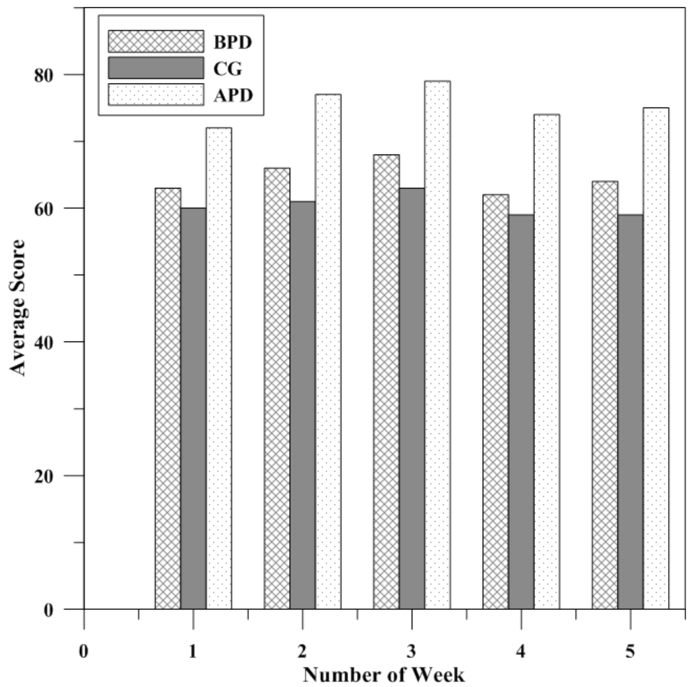

Figure 3: The results of the second step for the EG and the CG.

3rd Step- *Checking*

Students checked the problem solving methods in this step. Results similar to those of the first and second steps were found. The performance of the EG students before the peer discussion was 65.6 whereas the performance of the CG students was 60.8 (Figure 4). After the peer discussion, the performance of the EG students increased to 74.6. This finding demonstrated that peer instruction has a positive effect on the problem solving skills of the students compared to formal education.

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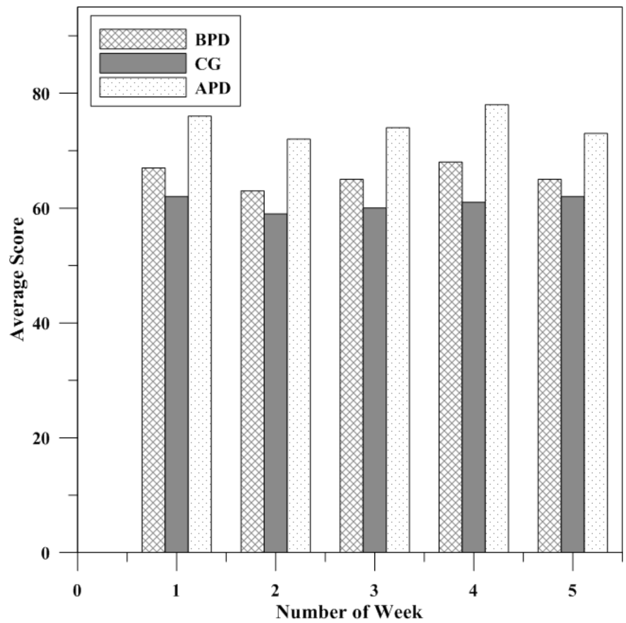

Figure 4: The results of the third step for the EG and the CG.

The Comparisons of the Groups' PSCQ Results

The results from the research were compared to determine the statistical difference in the PSCQ of the groups. Table 4 shows the descriptive statistics (mean and standard deviation) of the PSCQ scores before instruction (pre-test) and after instruction (post-test) for the students in the experimental and control groups.

Table 4. PSCQ Results of the EG and the CG.

	EG				CG			
	Pre-test		Post-test		Pre-test		Post-test	
Factors	M	SD	M	SD	M	SD	M	SD
Interested	14.50	1.45	19.00	.98	13.96	2.07	15.57	3.05
Endeavored	18.33	2.46	26.80	2.01	18.17	1.36	20.08	4.01
Confident	13.88	4.25	24.19	3.70	13.16	4.83	15.19	3.96
PSCQ	46.71	4.89	70.00	5.24	45.30	6.01	50.85	8.03

ANOVA was performed to test the statistics of the means regarding the PSCQ of the EG and the CG. As seen in Table 5, the difference in the pre-test scores between the EG and the CG is not statistically significant [$F_{(1\text{-}96)}$=1.54; p=0.217]. When the groups' post-test scores were compared, a significant difference in the means between the EG and the CG [$F_{(1\text{-}96)}$=180.29; p<0.05] was found.

Table 5. ANOVA Test for the PSCQ Scores of the EG and the CG.

Instrument		SS	df	MS	F	p
PSCQ Pre-Test	BETWEEN GROUPS	47.76	1	47.76	1.54	0.217
	WITHIN GROUPS	2970.41	96	30.94		
	TOTAL	3018.17	97			
PSCQ Post-Test	BETWEEN GROUPS	8794.77	1	8794.77	180.29	0.000
	WITHIN GROUPS	4682.85	96	48.78		
	TOTAL	13477.63	97			

The Bonferroni test was used to determine the change in the scores of the groups. According to the results, there was a significant difference between the EG (M=70.00) and the CG (M=50.85) in the change in the scores. The increase in the EG mean scores was 29.11% as shown by the analysis of the groups' pre-and post-test scores. The increase for the CG was 6.96%. The results indicated that PSSS was effective in improving the problem solving confidence of the students during problem solving.

Table 6. ANOVA Test for the Sub-Factor Scores of the EG and the CG.

Instrument (PSCQ)		SS	df	MS	F	p
Interested Pre-Test	Between Groups	6.88	1	6.88	2.03	0.157
	Within Groups	324.42	96	3.37		
	Total	33.31	97			
Interested Post-Test	Between Groups	282.12	1	282.12	48.91	0.000
	Within Groups	553.71	96	5.76		
	Total	835.83	97			
Endeavored Pre-Test	Between Groups	0.57	1	0.57	0.15	0.693
	Within Groups	351.54	96	3.66		
	Total	352.12	97			
Endeavored Post-Test	Between Groups	1083.87	1	1083.87	99.00	0.000
	Within Groups	1051.03	96	10.94		
	Total	2134.90	97			
Confident Pre-Test	Between Groups	12.45	1	12.45	0.59	0.444
	Within Groups	2025.95	96	21.10		
	Total	2038.40	97			
Confident Post-Test	Between Groups	1941.42	1	1941.42	130.57	0.000
	Within Groups	1427.31	96	14.86		
	Total	3368.74	97			

Concerning the sub-factors, ANOVA was performed to test the statistical difference of the means of the sub-factors (Interested, Endeavored, and Confident) between the groups. As presented in Table 6, the difference in the pre-test scores between the EG and the CG is not statistically significant [$F_{(1\text{-}96)}$=2.03, p=0.157; $F_{(1\text{-}96)}$=0.15, p=0.693; and $F_{(1\text{-}96)}$=0.59, p=0.444], respectively. When the groups' post-test scores were compared, there was a significant difference in the means between the EG and the CG [$F_{(1\text{-}96)}$=48.91, $p<0.05$; $F_{(1\text{-}96)}$=99.00, $p<0.05$; and $F_{(1\text{-}96)}$=130.57, $p<0.05$], respectively.

The Bonferroni test was used to determine the change in the sub-factor scores of the groups. There was a significant difference between the EG and the CG. These differences for the sub-factors (Interested, Endeavored, and Confident) were found in favor of the EG. The increases for the sub-factors in the EG

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were 22.50% (Interested), 28.23% (Endeavored), and 34.36% (Confident). The increases for the sub-factors in the CG were 8.05% (Interested), 6.36% (Endeavored), and 6.76% (Confident).

Discussion

The effects of peer instruction (PI) and formal education (FE) on students' performance, skills, and confidence were examined in this study. The research was performed on two groups enrolled in a physics course. The students included in the experimental group (EG) were instructed by PI with problem solving strategy steps (PSSS). Whereas the students included in the control group (CG) were instructed by FE with PSSS. Problem solving (fundamental and applied/technical problems) strategy steps consist of Identifying the Fundamental Principle(s), Solving, and Checking. The data of the study were collected with the Physics Achievement Test (PAT) and the Problem Solving Confidence Questionnaire (PSCQ). The problem solving skills of the students in both groups were evaluated by PSSS in the class.

The PAT findings showed that the problem solving strategy steps used with both applied methods (PI and FE) had a positive effect on students' problem solving performance in both groups. This finding was supported with the normalized gain. The normalized gain for both groups was obtained as the *medium gain*. The performance of the EG students was higher than the performance of the CG students. In particular, the performance of the students in the EG increased after instruction by approximately 49%. This result confirmed the findings of Crouch & Mazur (2001), Crouch et al. (2007), Lasry et al. (2008), Gok (2011a), Gok (2012a), and Gok (2012b). Students should be allowed the time required to comprehend the concepts, to explore the principles, and to provide the transfer of knowledge during discussions with their peers in PI. The instructor should manage the time and the class, interact with the students, and give the students feedback during the discussion. The combination of PI with PSSS was more effective for the student performance than the combination of FE with PSSS. PI and PSSS are able to improve the problem solving performance and skills of the entire class and benefit critical thinking and the decision-making process.

The PSCQ for the three sub-factors (Interested, Endeavored, and Confident) was higher in the EG than in the CG. The PSCQ results supported the findings of the PAT. The problem solving confidence of the students in the EG improved by 29% after instruction. Similar results were found for the Interested factor (22.5%), the Endeavored factor (28.23%), and the Confident factor (34.36%). These ratios for the CG were approximately 8%. Specifically, the students in the EG had self-confidence in problem solving after PI and PSSS.

Evaluating the problem solving skills of the students in both groups showed that the problem solving skills of the students showed similarity before the peer discussion. The problem solving skills of the EG improved after peer discussion by 10% in all the strategy steps (identifying the fundamental principles, solving, and checking). The peer discussion enhanced the students' understanding, solving, and checking habits. The results of the study confirmed the findings of Bolton & Ross (1997), Nicol & Boyle (2003), Smith et al. (2011), Smith, Wood, Adams, Wieman, Knight, Guild & Su (2009), Perez, Strauss, Downey, Galbraith, Jeanne & Cooper (2010). Consequently, the peer discussions in the EG helped the students to verbalize, think, interact with peers, explore alternative solutions methods, evaluate the solution methods in more detail, interpret different explanations, arrive at an answer, and improve their performance.

Conclusions

The main goal of this research was to report the effects of peer instruction (PI) and formal education (FE) on students' performance, skill, and confidence. When the results of the study were generally evaluated, the combination of PI with PSSS was effective on the performance, skill, and confidence of the students in the experimental group compared to the combination of FE with PSSS. The increase in performance, skill, and confidence is likely the result of an effective interactive learning environment created by PI and PSSS. With practice, this method requires very little effort and is preferable in various classroom settings and disciplines.

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