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Students' Achievement, Skill and Confidence in Using Stepwise Problem-Solving Strategies

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The main purpose of this study was to examine the effects of Problem-Solving Strategy Steps (PSSS) on students' achievement, skill, and confidence. The study was conducted in a two-year college classroom with 70 students from two different groups enrolled in a physics course. One of them was randomly selected as an experimental group (EG) and the other was the control group (CG). The students included in the EG were instructed by PSSS and traditional instruction while the students in the CG were instructed by only traditional instruction. The study was conducted in Newtonian Mechanics. The data of the research were collected with the Physics Achievement Test (PAT), the Problem-Solving Strategy Steps Survey (1P4S), and the Problem-Solving Confidence Questionnaire (PSCQ). The results indicated that there was a significant difference between the means of the EG and the CG in favor of the EG. Also, the use of problem-solving strategy steps contributed to the critical and analytical skills of the students.

Keywords: Higher education; physics education; problem solving; problem-solving strategy steps; problem-solving confidence.

INTRODUCTION

"Problem solving as a goal-directed behavior requires an appropriate mental representation of the problem and the subsequent application of certain methods or strategies in order to move from an initial, current state to a desired, goal state" (Metallidou, 2009). Problem solving is a decision-making process. Metacognition has a significant role in this process. Therefore declarative knowledge, procedural knowledge, and conditional knowledge of metacognitive are quite important for problem solving. Problem solving improves metacognitive skills (prediction, planning, monitoring, and evaluation) and metacognitive beliefs (self-efficacy, motivation etc.) (Desoete, Roeyers, & De Clercq, 2004). Problem solving also provides the point of view of critical and analytical thinking.

Problem solving is accepted as an important activity of teaching and learning science and engineering in schools (Bascones, Novak & Novak, 1985; Heller, Keith & Anderson, 1992; Gok 2010a; Larkin & Reif, 1979; Reif, Larkin & Brackett, 1976; Reif, 1981). Many scientists teach the concepts, principles, and formulas regarding the course subjects and then they conventionally solve several sample problems. After they finish the instruction, the students are usually asked whether or not they comprehended the subjects, concepts, principles, etc. Even though most of the students claim that they understand the fundamental principle(s)/concept(s), they are not able to solve the concept-related problems. The students have difficulty learning how to solve a problem. They cannot develop any systematic problem-solving strategies in this way. As a result, the students do not reflect their success.

Several studies on developing an effective instruction for problem solving have been conducted (Dufrense, Gerace & Leonard, 1997; Heller et al., 1992; Garrett, 1986; Gok, 2012a; Larkin & Reif, 1979). While some of

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State of the literature

- Studies on problem solving generally focus on the difference in metacognition between the expert and novice problems solvers.
- Students usually have difficulties while solving problems. Thus, some strategies have been proposed by researchers.
- Limited research exists on problem-solving strategies covering both conceptual learning and quantitative problem solving.

Contribution of this paper to the literature

- Problem-solving strategy steps including conceptual learning, solution, and crosscheck are proved to be statistically effective in problem solving.
- Problem-solving strategy steps enhance problem-solving confidence and problem- solving skills of the students.
- Problem-solving strategy steps improve the creativeness, performance, and awareness of the students.

the studies aimed to identify the differences between the expert and novice problem solvers (Chi, Feltovich, & Glaser, 1981; Larkin, 1979; Reif et al., 1976; Reif & Heller, 1982; Van Heuvelen, 1991), some of them focused on general and specific problem-solving strategies (Bagno & Eylon, 1997; Heller et al., 1992; Heller & Hollabaugh, 1992; Pol, 2005; Polya, 1945; Reif, 1995). Some researchers concentrated on metacognition in problem solving (Amigues, 1988; Anderson & Nashon, 2007; Kapa, 2007; Meijer, Veenman, & Van Hout-Walters, 2006; Metallidou, 2009). Recently, studies have focused on computer-assisted problem-solving approaches (Gok, 2010b; Kowalski, Gok, & Kowalski, 2009; Pol, 2005).

Gok (2011) modified general and specific problem-solving strategies and reported three problem-solving strategy steps (PSSS) as follows:

1. Identifying the Fundamental Principle(s)-this step primarily includes planning and description. Students should:

comprehend the concept(s)/principle(s);
determine known and unknown variables;
visualize the problem in the light of their own knowledge;
represent the problem with the help of a sketch or a diagram, if necessary;
associate the problem with daily life;
restate the problem in their own words.

2. Solving- this step principally involves implementation. Students should:

determine the equations/formulas concerning the problem;
divide the problem into sub-problems, if necessary;
solve the problem qualitatively and then quantitatively.

3. Checking- this step mainly comprises monitoring, setting, and controlling. Students should:

check the solution to ascertain whether or not it is correct;
revise the units, the signs, and the magnitudes of the variables;
explore alternative ways for solving the problem.

Most students generally solve qualitative and quantitative problems with the help of solved problems. They only focus on the correct results of the problems. They usually do not use any systematic problem-solving strategies for solving a problem. Therefore, it could be said that the traditional problem-solving procedure is not effective in developing students' problem-solving skills. Problem solving is necessary to define concepts/principles, to analyze procedures, and to evaluate and interpret the solution. In this study, problem-solving strategy steps were used to enhance the students' problem-solving skills. The main purpose of this research was to examine the effects of problem-solving strategy steps on students' physics achievement, problem-solving skills, and problem-solving confidence. The research questions that were investigated are as follows:

1. *Are there any differences between the experimental group and the control group students' physics achievement?*
2. *Are there any differences between the experimental group and the control group students' problem-solving strategies?*
3. *Are there any differences between the experimental group and the control group students' problem-solving confidence?*

METHOD

Participants

This study was conducted in Torbali Technical Vocational School of Higher Education, Dokuz Eylul University in Izmir, Turkey. The sample of this research consisted of a total of 70 students randomly assigned to two different groups enrolled in a physics course. The experimental group consisted of 38 students and the control group included 32 students.

Instruments

The data used in this study and the answers regarding the research questions were collected and analyzed by three statistical tools. The Physics Achievement Test "PAT" was developed for this research by the researcher, the Problem-Solving Strategy Steps Survey "1P4S" (Gok, 2011) and Problem-Solving Confidence Questionnaire "PSCQ" (Gok, 2012b) were used. The details of the instruments are as follows:

Physics Achievement Test (PAT)

The PAT was developed to assess students' knowledge about Newtonian Mechanics. The PAT consisting of 20 multiple-choice questions (quantitative problems) related to applications of Newton's laws, was used as pretest and posttest. The reliability and validity of the test were examined by the researcher. Internal consistency reliability was found to be $\alpha = 0.75$.

Problem-Solving Strategy Steps Survey (1P4S)

1P4S developed by Gok (2011) was administered to both groups as pretest and posttest. The English version of the survey was translated into Turkish. Statistical analyses of the survey and content review were performed by the researcher.

Three factors were extracted from the statistical analyses data found by Exploratory Factor Analysis (EFA). Items with factor loadings below 0.40 were disregarded. The first factor of the 1P4S is "identifying the fundamental principle (IFP)" in which students determine the concept(s) or the principle(s). The second factor of the 1P4S is "solving (SLV)" in which students execute the plan. The last factor of the 1P4S is "checking (CHK)" in which students control the solution procedure, the units, signs, and magnitudes of the variables. Some statistical values of these factors were as follows: IFP consisted of thirteen items (α=0.92), SLV included six items (α=0.52), and CHK comprised of six items (α=0.85). Overall 1P4S consisted of 25 items with reliability of α=0.93.

Problem-Solving Confidence Questionnaire (PSCQ)

PSCQ developed by Gok (2012b) was administered to both groups as pretest and posttest. The English version of the survey was translated into Turkish. Statistical analyses of the survey and content review were performed by the researcher. Two factors were extracted from the statistical analyses data found by Exploratory Factor Analysis (EFA). Items with factor loadings below 0.40 were disregarded. The first factor of the PSCQ is "high confidence (HC)" which describes students having self confidence about their problem-solving skills. The second factor of the PSCQ is "low confidence (LC)" which indicates that students do not have sufficient confidence in problem solving. The similar statistical procedures for the PSCQ as the 1P4S were performed. HC consisted of fourteen items (α=0.94) and LC included six items (α=0.90). Overall, the PSCQ comprised of 20 items with reliability of α=0.90.

Procedure

The quasi-experimental design was used in this study (Campbell & Stanley, 1963; Cook & Campbell, 1979). The study was conducted with two groups. One of them was the experimental group (EG), and the other was the control group (CG). The students included in the EG were instructed by Traditional Instruction (TI) with Problem-Solving Strategy Steps (PSSS) while the students included in the CG were instructed by only TI. All sections were taught by the same instructor. The instructor established a detailed timeline of the procedures for the research. During the study, both groups received the same lectures using the same PowerPoint slides. The study was conducted in a physics course (concerning Newtonian Mechanics) during five weeks. The primary objective of the course was to encourage the students to describe and explain the principles of kinematics, first law, second law, and third law, superposition, and kinds of force. Before and after the instruction to both groups, the Physics Achievement Test (PAT), Problem-Solving Strategy Steps Survey (1P4S), and Problem-Solving Confidence Questionnaire (PSCQ) were administered as pretest and posttest.

Both groups were instructed by TI. The instructor primarily presented the lectures, and then the instructor solved the sample problems from the textbook. All of the solved problems were quantitative. The students were asked to solve the same problems in groups. The PSSS was used to solve the problems in the EG, but the problems were conventionally solved in the CG. About 25 problems were solved in the research.

Quantitative problems asked in the EG were divided into three subsections according to the PSSS. The subsections consisted of three questions: How do you *identify the fundamental concept(s)/principle(s)* of the problem? How do you *solve* the problem? How do you *check* the solution to the problem? Three or four minutes were given to students to formulate individual answers for each step of the problems. The answers to each step were discussed and analyzed in class by the instructor. During the implementation, the instructor observed and walked around the class and encouraged the students while they were solving the problems.

Quantitative problems asked in the CG were solved without following any stepwise problem-solving strategies. The students generally focused on the correct result of the problem with the help of formulas in this type problem. The students were given approximately ten minutes to deduce individual answers. The instructor discussed their answers.

Table 1. Descriptive results of the experimental and the control groups for PAT

		Pretest		Posttest		Fractional Gain
Group	N	M	SD	M	SD	g
EG	38	16.57	9.93	61.31	11.19	0.54
CG	32	15.00	10.16	32.18	12.88	0.20

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

Table 2. ANOVA Test results for PAT score of the experimental and the control groups

Instrument		SS	df	MS	F	p
PAT Pretest	Between Groups	43.39	1	43.39		
	Within Groups	6855.26	68	100.81	0.43	0.514
	Total	6898.57	69			
PAT Posttest	Between Groups	14738.91	1	14738.91		
	Within Groups	9781.09	68	143.84	102.47	0.000
	Total	24520	69			

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

Table 3. Descriptive results of the experimental and the control groups for 1P4S

	EG				CG			
	Pretest		Posttest		Pretest		Posttest	
	M	SD	M	SD	M	SD	M	SD
IFP	31.18	5.38	57.11	4.29	32.66	8.52	40.16	6.90
SLV	13.55	3.84	25.92	3.26	11.41	5.99	15.47	3.67
CHK	12.11	3.21	24.08	2.81	12.50	4.21	16.56	2.96
1P4S	56.84	9.47	107.11	6.54	56.56	15.73	72.19	9.67

All groups solved four or five quantitative problems in a 75-min class. Problems were designed by the instructor to engage students in thinking about conceptual issues. Also, most of the problems were context-rich problems (Heller & Hollabaugh, 1992).

At the beginning of the study, the researcher provided a handout on problem-solving strategy steps from the research of Gok (2011) to the students in the EG. The students learned how to use the problem-solving strategy steps from the handout in the solution of the sample problems. The students in the EG were given all kinds of physics problems on instructed topics (Newtonian Mechanics) as sample problems. The handout contained 10 sample problems.

Data Analysis Process

The PAT, 1P4S, and PSCQ were administered as pretest and posttest to the students in the EG and the CG who were enrolled in the physics course. Students were given the option of not participating in the test. The data collected were analyzed using SPSS 15.0 statistical analysis program. Also, fractional gain and analysis of variance (ANOVA) were performed.

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

This equation was developed by Hake (1998). In this formula, <g> is shown the fractional gain, posttest% is represented the percentage score on the posttest, and pretest% is the percentage score on the pretest. Fractional gain is defined as low gain $(g < 0.3)$, medium gain $(0.3 \leq g < 0.7)$, and high gain $(g \geq 0.7)$ (Hake, 1998).

An ANOVA test was conducted to test the statistical difference of the means (PAT, 1P4S, and PSCQ) between the experimental and the control groups.

RESULTS AND DISCUSSION

The comparisons of the groups' PAT results

The results obtained from the research were compared to determine the statistical difference on the achievement test of the groups.

Table 1 shows PAT scores before instruction (pretest) and after instruction (posttest) as well as the normalized gains (*g*) for the students included in the EG and the CG. The difference between the EG and the CG was considered significant for *p* values less than 0.05. As presented in Table 1, the descriptive statistics and normalized gains for students' academic performance were firstly performed on the pretest and posttest data. It was calculated that the fractional gain of the CG was low (0.20) while the fractional gain of the EG was medium (0.54).

Table 4. ANOVA Test Results for 1P4S Scores of the Experimental and the Control Groups

Instrument		SS	df	MS	F	*p*
1P4S Pretest	Between Groups	1.36	1	1.36		
	Within Groups	10992.93	68	161.66	0.00	0.927
	Total	10994.29	69			
1P4S Posttest	Between Groups	21180.12	1	21180.12		
	Within Groups	4478.45	68	65.86	321.60	0.000
	Total	25658.57	69			

Table 5. ANOVA Test Results for Sub-Factors (IFP, SLV, and CHK) of the Experimental and the Control Groups

Instrument		SS	df	MS	F	p
IFP Pretest	Between Groups	37.64	1	37.64		
	Within Groups	3320.93	68	48.84	0.77	0.383
	Total	3358.57	69			
IFP Posttest	Between Groups	4990.27	1	4990.27		
	Within Groups	2155.80	68	31.70	157.41	0.000
	Total	7146.08	69			
SLV Pretest	Between Groups	80.03	1	80.03		
	Within Groups	1657.11	68	24.37	3.28	0.074
	Total	1737.14	69			
SLV Posttest	Between Groups	1897.84	1	1897.84		
	Within Groups	810.73	68	11.92	159.18	0.000
	Total	2708.57	69			
CHK Pretest	Between Groups	2.71	1	2.71		
	Within Groups	931.58	68	13.70	0.19	0.658
	Total	934.29	69			
CHK Posttest	Between Groups	981.43	1	981.43		
	Within Groups	564.64	68	8.30	118.19	0.000
	Total	1546.07	69			

Table 6. Descriptive Results of the Experimental and the Control Groups for PSCQ

	EG				CG			
	Pretest		Posttest		Pretest		Posttest	
	M	SD	M	SD	M	SD	M	SD
HC	29.60	6.51	58.95	6.17	28.01	7.12	33.12	6.81
LC	13.68	4.75	25.52	3.45	14.53	4.46	16.88	5.35
PSCQ	43.29	8.72	84.48	6.95	42.63	9.08	50.00	9.59

An ANOVA test was conducted to test the means of the PAT of the experimental and the control groups. As seen in Table 2, it was found that the difference in pretest scores between the EG and the CG was not statistically significant [$F_{(1\text{-}68)}$=0.43; p=0.514]. However, when the groups' posttest scores were compared, it was found that there was a significant difference between the means of the EG and the CG [$F_{(1\text{-}68)}$=102.47; p<0.001]. This difference was found to be in favor of the EG. The increases in mean scores for both groups (the EG and the CG) were 44.74% and 17.18%, respectively. When the findings of the PAT were interpreted, problem-solving strategy steps were positively effective on students' problem-solving performance. The results have been confirmed by the findings of Gok (2012a), Heller et al. (1992), Heller & Hollabaugh (1992), and Walsh, Robert, & Bowe (2007).

The comparisons of the groups' 1P4S results

The results obtained from the research were compared to determine the statistical difference on the problem-solving strategy steps survey of the groups. Table 3 shows descriptive statistics (mean and standard deviation) of 1P4S scores before instruction (pretest) and after instruction (posttest) for students in the experimental group and control group. The mean scores (total and sub-factors) of the experimental group were higher than the mean scores of the control group. The difference between the groups was considered significant for *p* values less than 0.05.

An ANOVA test was conducted to compare the means of the 1P4S of the experimental group and the control group. As seen in Table 4, it was found that the difference in pretest scores between the EG and the CG was not statistically significant [$F_{(1\text{-}68)}=0.00$; $p=0.927$]. However, when the groups' posttest scores were compared, it was found that there was a significant difference in the mean between the EG and the CG [$F_{(1\text{-}68)}=321.60$; $p<0.001$]. This difference was found to be in favor of the EG. The increases in mean scores for both groups (the EG and the CG) were calculated as 40.22% and 12.46%, respectively. The results indicated that the PSSS had enhanced the problem-solving skills of the students in the EG.

An ANOVA test of the sub-factors was performed to test the statistical difference of the means of the sub-factors (IFV, SLV, and CHK) between the experimental group and the control group. As shown in Table 5, it was calculated that the differences in the pretest scores between the EG and the CG were not statistically significant [$F_{(1\text{-}68)}=0.77$; $p=0.383$, $F_{(1\text{-}68)}=3.28$; $p=0.074$, $F_{(1\text{-}68)}=0.19$; $p=0.658$], respectively. However, when the groups' posttest scores were compared, it was found that there were significant differences in the means between the EG and the CG [$F_{(1\text{-}68)}=157.41$; $p<0.001$, $F_{(1\text{-}68)}=159.18$; $p<0.001$, $F_{(1\text{-}68)}=118.19$; $p<0.001$], respectively. These differences between the sub-factors (IFP, SLV, and CHK) were found to be in favor of the EG.

The pretest and posttest results of the IFP revealed that the increase in mean scores (39.89%) was in favor of the EG. The increase for the CG was found to be 11.53%. Similar results have been obtained by Crouch & Mazur (2001), Gok (2012a), Gok (2012c), Lasry, Mazur, & Watkins (2008), Mazur (1997), Watkins & Mazur (2010). This result indicated that the usage of the first step -identifying fundamental principle(s)- was positively effective in enhancing conceptual learning of the students in the EG.

When the results of the pretest and posttest for the SLV were investigated, the highest increase was observed for the EG (41.23%). This increase was 13.54% for the CG. These findings indicated that the students in the EG used stepwise problem-solving strategies. When the results of the tests for the CHK were examined, the increases in mean scores were found to be 39.90% in the EG and 13.53% in the CG. These findings were in favor of the EG. These results showed that the students in the experimental group crosschecked the solution process and they analyzed and re-examined the solution of the problems.

The comparisons of the groups' PSCQ results

The results obtained from the research were compared to determine the statistical difference on the PSCQ of the groups. Table 6 shows descriptive statistics (mean and standard deviation) of PSCQ scores before instruction (pretest) and after instruction (posttest) for students in the experimental group and the control

Table 7. ANOVA Test Results for PSCQ Scores of the Experimental and the Control Groups

Instrument		SS	df	MS	F	p
PSCQ Pretest	Between Groups	7.67	1	7.67	0.01	0.756
	Within Groups	5369.32	68	78.96		
	Total	5376.99	69			
PSCQ Posttest	Between Groups	20644.81	1	20644.81	302.59	0.000
	Within Groups	4639.48	68	68.23		
	Total	25284.29	69			

Table 8. ANOVA Test Results for Sub-Factors (HC and LC) of the Experimental and the Control Groups

Instrument		SS	df	MS	F	p
HC Pretest	Between Groups	39.69	1	39.69	0.85	0.359
	Within Groups	3163.80	68	46.53		
	Total	3203.49	69			
HC Posttest	Between Groups	11583.18	1	11583.18	276.82	0.000
	Within Groups	2845.40	68	41.84		
	Total	14428.57	69			
LC Pretest	Between Groups	12.46	1	12.46	0.58	0.448
	Within Groups	1452.18	68	21.36		
	Total	1464.64	69			
LC Posttest	Between Groups	1300.17	1	1300.17	66.63	0.000
	Within Groups	1326.97	68	19.51		
	Total	2627.14	69			

group. The mean scores (total and sub-factors) of the experimental group were higher than the mean scores of the control group. The difference between the groups was considered significant for *p* values less than 0.05.

An ANOVA test was conducted to the differences in the means of the PSCQ between the experimental group and the control group. As seen in Table 7, it was found that the difference in the pretest scores between the EG and the CG was not statistically significant [$F_{(1\text{-}68)}=0.01$; $p=0.756$]. However, when the groups' posttest scores were compared, it was found that there was a significant difference in the means between the EG and the CG [$F_{(1\text{-}68)}=302.59$; $p<0.001$]. This difference was found to be in favor of the EG. The increase in mean scores for the EG was calculated as 41.19%. The increase for the CG was found to be 7.37%. Problem-solving strategy steps were positively effective in enhancing the students' confidence in the EG and it was observed that the students increased their motivation by problem solving with the help of stepwise problem-solving strategies.

An ANOVA test was performed to test the statistical difference between the means of the experimental group and the control group sub-factors (HC and LC). As presented in Table 8, it was found that the differences in pretest scores between the EG and the CG were not statistically significant [$F(1\text{-}68)=0.85$; $p=0.359$, $F(1\text{-}68)=0.58$; $p=0.448$], respectively. When the groups' posttest scores were compared, it was found that there were significant differences in the means between the EG and the CG [$F(1\text{-}68)=276.82$; $p<0.001$ $F(1\text{-}68)=66.63$; $p<0.001$], respectively. These differences between the sub-factors (HC and LC) were found to be in favor of the EG. The increases for sub-factors of the EG were found to be 41.91% (HC) and 39.47% (LC), respectively. Also, the increases for sub-factors of the CG were 7.30% and 7.84%, respectively. When the students in the EG solved the problems, they believed in themselves because of using stepwise problem-solving strategies. This finding showed that there is a relationship is between performance and confidence.

CONCLUSION

The main goal of this study was to report the effects of stepwise problem-solving strategies on students' achievement, problem-solving skills and problem-solving confidence. When the results of the research were evaluated, the PSSS positively improved the achievement, skills, and confidence of the students in the experimental group (EG).

The combined method of PSSS and traditional instruction was implemented with the students in the EG involved three steps (IFP, SLV, and CHK). The first step (IFP) of the PSSS was *useful* for understanding and exploring the problems. This step was the starting-point of the problem solving. The students understood the concepts/principles concerning the problems. They determined known and unknown variables, and represented the problems in physics terms. The students in the EG could indicate the details easily. The second step (SLV) of the PSSS was *important* for solving the problem qualitatively and quantitatively. The students determined the equations of the principles and they found the target variables. The last step (CHK) of the PSSS was *helpful* in analyzing the problems. The students evaluated the results of the problems from the point of the units, signs, and magnitudes of the variables.

When the PAT results were examined, the performance of the students in the EG was higher than the performance of the students in the CG. Although the same problems were solved in the two groups, the students in the EG obtained higher scores than the students in the CG. This result showed that stepwise problem-solving strategies were positively effective in facilitating the students' problem-solving performance.

Also they learned how to solve a problem with the help of problem-solving strategy steps. On the other hand, it could be said that the students in the CG only focused on the correct results by means of the some formulas/equations. It was not important for them to identify, explore, and understand the concepts/principles. When the findings of the 1P4S and the PSCQ were interpreted, it could be said that the students' problem-solving skills and confidence was enhanced by means of this teaching method (TI with PSSS). Also the use of problem-solving strategy steps improved the creativeness and awareness of the students. Problem-solving strategy steps are very useful, important, and helpful to comprehend, solve, and analyze the problems.

The PSSS is preferable with practice as it needs very little effort in various science courses. Based on these results, future research can be expanded with the use of different approaches like, extending the research period, giving students homework problems requiring the use of stepwise problem-solving strategies, evaluating their examination papers for stepwise problem-solving strategies and investigating gender differences in problem solving.

REFERENCES

Amigues, R. (1988). Peer interaction in solving physics problems: Sociocognitive confrontation and metacognitive aspects. *Journal of Experimental Child Psychology*, *45*, 141-158.

Anderson, D. & Nashon, M. (2007). Predators of knowledge construction: Interpreting students' metacognition in an amusement park physics program. *Science Education*, *91*(2), 298-320.

Bagno, E. & Eylon, Bat-S. (1997). From problem solving to a knowledge structure: An example from the domain of electromagnetism. *American Journal of Physics, 65*, 726-736.

Bascones, J., Novak, V., & Novak, J. D. (1985). Alternative instructional systems and the development of problem-solving skills in physics. *European Journal of Science Education*, *7*(3), 253-261.

Campbell, D. T. & Stanley, J. C. (1963). *Experimental and quasi experimental designs for research*: A handbook for research on interactions. Boston, MA: Houghton Mifflin.

Chi, T., Feltovich, P., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. *Cognitive Science, 5*, 121-152.

Cook, T. D. & Campbell, D. T. (1979). *Quasi-experimentation: Design and analysis issues for field settings*. Chicago, IL: Rand-McNally College.

Crouch, C. H. & Mazur, E. (2001). Peer instruction: Ten years of experience and results. *American Journal of Physics, 69*, 970–977.

Desoete, A., Roeyers, H., & De Clercq, A. (2004). Children with mathematics learning disabilities in Belgium. *Journal of Learning Disabilities, 37,* 50-61.

Dufrense, R., Gerace, W., & Leonard, J. (1997). Solving physics problems with multiple representations. *Physics Teacher*, *35*, 270-275.

Garrett, R. M. (1986). Problem-solving in science education. *Studies in Science Education*, *13,* 70-95.

Gok, T. (2010a). A new approach: Computer-assisted problem-solving systems. *Asia-Pacific Forum on Science Learning and Teaching, 11*(2), 1-22.

Gok, T. (2010b). The general assessment of problem solving processes and metacognition in physics education. *Eurasian Journal of Physics and Chemistry Education, 2*(2), 110-122.

Gok, T. (2011). Development of problem solving strategy steps scale: Study of validation and reliability. *The Asia-Pacific Education Researcher, 20*(1), 151–161.

Gok. T. (2012a). The impact of peer instruction on college students' beliefs about physics and conceptual understanding of electricity and magnetism. *International Journal of Science and Mathematics Education, 10*, 417-436.

Gok. T. (2012b). Development of problem solving confidence questionnaire: Study of validation and reliability. *Latin American Journal of Physics Education, 6*(1), 21-26.

Gok. T. (2012c). The effects of peer instruction on students' conceptual learning and motivation. *Asia-Pacific Forum on Science Learning and Teaching, 13,* 1(10).

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand student survey of mechanics test data for introductory physics courses. *American Journal of Physics, 66*, 64-74.

Heller, P., Keith, R., & Anderson, S. (1992). Teaching problem solving through cooperative grouping. Part 1: Group versus individual problem solving. *American Journal of Physics*, *60*, 627-636.

Heller, P. & Hollabaugh, M. (1992). Teaching problem solving through cooperative grouping. Part 2: Designing problems and structuring groups. *American Journal of Physics, 60*, 637-644.

Kapa, E. (2007). Transfer from structured to open-ended problem solving in a computerized metacognitive environment. *Learning and Instruction, 17,* 688-707.

Kowalski, F., Gok, T., & Kowalski, S. (2009). Using Tablet PCs to strengthen problem- solving skills in an upper-level engineering physics course, *39th ASEE/IEEE Frontiers in Education Conference,* October 18- 21, 2009, San Antonio, TX.

Larkin, H. (1979). Processing information for effective problem solving. *Engineering Education, 70,* 285-288.

Larkin, H. & Reif, F. (1979). Understanding and teaching problem-solving in physics. *European Journal of Science Education*, *1*, 191-203.

Lasry, N., Mazur, E., & Watkins, J. (2008). Peer instruction: From Harvard to the two-year college. *American Journal of Physics, 76*(11), 1066-1069.

Mazur, E. (1997). *Peer instruction: A user's manual.* Upper Saddle River, NJ: Prentice Hall.

Meijer, J., Veenman, J., & van Hout-Wolters, B. (2006). Metacognitive activities in text Studying and problem-solving: Development of a taxonomy. *Educational Research And Evaluation*, *12*, 209-237.

Metallidou, P. (2009). Pre-service and in-service teachers' metacognitive knowledge about problem-solving strategies. *Teaching and Teacher Education, 25*, 76-82.

Pol, H. (2005). Solving physics problems with the help of computer-assisted instruction. *International Journal of Science Education*, *27*, 451-469.

Polya, G. (1945). *How to solve it.* New Jersey: Princeton University Press.

Reif, F., Larkin, H., & Brackett, C. (1976). Teaching general learning and problem-solving skills. *American Journal of Physics*, *44*, 212-217.

Reif, F. (1981). Teaching problem solving: A scientific approach. *The physics Teacher*, *19,* 310-316.

Reif, F. & Heller, I. (1982). Knowledge structures and problem solving in physics. *Educational Psychologist*, *17*, 102-127.

Reif, F. (1995). Millikan Lecture 1994: Understanding and teaching important scientific thought process. *American Journal of Physics*, 63, 17-32.

Van-Heuvelen, A. (1991). Learning to think like a physicist: A review of research-based instructional strategies. *American Journal of Physics*, *59*, 891-897.

Walsh, N., Robert, H., & Bowe, B. (2007). Phenomenographic study of students' problem solving approaches in physics. *Physical Review Special Topics-Physics Education Research, 3*, 1-12.

Watkins, J. & Mazur, E. (2010). *Just in time teaching and peer instruction.* In Scott, S. & Mark, M. (Eds.), Just in Time Teaching: Across the Disciplines, and Across the Academy, Stylus Publishing.

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