International Journal on New Trends in Education and Their Implications
January 2013 Volume: 4 Issue: 1 Article: 14 ISSN 1309-6249

A COMPARISON OF ACHIEVEMENT IN PROBLEM-BASED, STRATEGIC AND TRADITIONAL LEARNING CLASSES IN PHYSICS

Assoc. Prof. Dr. Gamze SEZGİN SELÇUK
Dokuz Eylül University
Education Faculty of Buca
Department of SSME
İzmir, TURKEY

Assist. Prof. Dr. Serap ÇALIŞKAN
Dokuz Eylül University
Education Faculty of Buca
Department of SSME
İzmir, TURKEY

Assoc. Prof. Dr. Mehmet ŞAHİN
Dokuz Eylül University
Education Faculty of Buca
Department of EE
İzmir, TURKEY

ABSTRACT

The purpose of this study was to compare the effects of problem-based learning, strategic learning and traditional learning on pre-service teachers' physics achievement. Pretest–posttest quasi experimental research design was employed in the study. The classes were randomly assigned as control and experimental groups. Students in the first experimental group (n= 18) received problem-based physics instruction, students in the second experimental group (n= 20) received strategy-based traditional physics instruction, and students in the control group (n= 20) received only traditional physics instruction. Data were collected via the Revised Physics Achievement Test (R-PAT) and the Physics Self-Efficacy Scale (PSES). Pre-test scores of the instruments were used as covariates. Analysis of covariance (ANCOVA) showed a statistically significant difference between the experimental and control groups in the favor of experimental groups after treatment. However, no statistically significant difference between two experimental groups (problem-based versus strategy-based instruction) was found.

Key Words: Problem-based learning, strategic learning, traditional learning, physics achievement.

INTRODUCTION

Science studies and particularly physics are among the school subjects with which students in Turkey have the most difficulty. Research has shown that physics classes in Turkey are largely implemented with traditional methods of instruction. As is recognized, traditional teaching methods render the teacher the dominant figure in the classroom while making the student a passive participant. This kind of model from the very beginning leads students into the path of traditional learning strategies such as memorization and replication. Lack of student achievement in classes where these strategies are used may be explained by the failure of students to use learning strategies effectively or by the fact that they do not know how to learn. According to the results of many studies conducted abroad, it has been found that effective learning strategies have a positive impact on the cognitive and affective products of education. Problem-based learning is a teaching method that emerged more than 30 years ago as a reaction to the deficiencies brought about by traditional teaching approaches (Barrows, 2002). It has been established that this method has a positive effect on many student endeavors such as problem-solving and determining learning deficiencies and difficulties (that is, on gaining the skills to use effective learning strategies), the capability of thinking creatively and critically, as well as the capacity to use cooperative and communicative skills. In this context, the present study sought to compare the effects of problem-based learning, strategic learning and traditional learning on pre-service teachers' physics achievement. These learning strategies and problem-based learning methods are presented in detail below.

Learning Strategies

Learning strategies (LS) were defined as "behaviors and thoughts that a learner uses for processing information during learning" (Weinstein and Mayer, 1986; Mayer, 1988). In the education literature, there are various different classifications of LS. Cognitive psychologists divide LS into two main categories: cognitive and metacognitive. Vaidya (1999) describes these strategies as follows: Cognitive strategies (CS) are used in cognitive processes by helping a person to manipulate information such as note taking or asking questions, through various rehearsal, elaboration and organizational strategies. Vaidya (1999) argues that cognitive strategies tend to be task specific, that is, certain cognitive strategies are helpful only when learning or processing certain tasks. Metacognitive strategies (MS) are described as executive in nature (Vaidya, 1999), used for planning, monitoring, and evaluating learning and for regulating progress (Najar, 1999).

Cognitive strategies are further classified as (a) surface and (b) deep (or higher level) CS. Surface CS refer to processes such as repetition, reciting, and highlighting (rehearsal) which help store new information in the short-term memory only (memorization). Deep or higher level CS involves processes such as elaboration and organization which promote long-term retention of information (Somuncuoğlu and Yıldırım, 1999).

Students use basic strategies (e.g., rehearsal and memorization) to remember facts and formulas, whereas higher level strategies are used to understand main ideas and concepts. Therefore, not all types of LS necessarily improve the acquisition of conceptual understanding. Research also suggests that higher level strategies are expected to promote conceptual understanding (Brown et al., 1983; Entwistle and Ramsden, 1983). Various studies exist in the physics education literature investigating the effectiveness of LS on student learning. Not large in number, these studies employed in general the concept map instruction. There are however, few studies involving strategy instruction such as summarizing and question asking (Sezgin Selçuk et al., 2011). Pankratius (1990) investigated the effect of the degree of concept mapping on achievement. It was concluded that for upper- and middle-class high school physics students involved in the study, mapping concepts prior to, during, and subsequent to instruction led to greater achievement as measured by posttest scores. Similarly, Zieneddine and Abd-El-Khalick (2001) assessed the effectiveness of concept maps as learning tools (or strategies) in developing students' conceptual understanding in a physics laboratory course, and explored students' perceptions regarding the usefulness of concept maps in the laboratory. Koch (2001) developed a metacognitive technique for improving students' reading comprehension of physics texts. The development and application of the metacognitive technique as an effective self-monitoring device was recommended in teaching reading comprehension of physics texts. Harper, Etkina and Lin (2003) used structured weekly journals (reports) for fostering student questions about the learning material. The resulting questions were collected for one quarter and coded based on difficulty and topic. Students also took several conceptual tests during the implementation. The reports contained more questions than typically observed in a college classroom, but the number of questions asked was not correlated to conceptual performance. An investigation of the relationships among different types of questions and performance on these tests revealed that deeper-level questions that focus on concepts, coherence of knowledge, and limitations were related to the variance in student conceptual performance.

Problem-Based Learning

Problem-based learning (PBL) was first implemented in medical education by McMaster University, Canada in the 1960s (Barrows and Tamblyn, 1980). Soon, this method was adopted at Maastricht University in Holland and other places in Europe as well (Sezgin Selçuk and Sahin, 2008). PBL is described as a constructivist teaching model based on the assumption that learning is a product of cognitive and social interactions originating in a problem focused environment (Greeno et al., 1996). The theoretical philosophy of this approach is derived from John Dewey and discovery learning (Rhem, 1998). Fundamentally, PBL is an educational method in which students develop critical thinking and problem-solving skills in addition to developing an understanding of grasping essential concepts through the analysis of real-life problems (Duch, 1995). Learning takes place throughout a process where learners try to solve real-life problems in groups of seven to eight people. Barrows (1996) labels the main characteristics of PBL as follows: (a) Learning is student-centered, (b) Learning takes shape in small groups of students, (c) Teachers should act as moderator and facilitator, (d) The problems provide motivation for learning and organizational focus, (e) Problems provide the basis for the advance in clinical problem-solving skills, (f) Self-directed learning aids the acquisition of new information.

Today, the problem-based learning approach is used in various fields of education, mainly in medical education (Barrows, 1996), engineering (Nopiah et al., 2009), law (Moust, 1998), in-service teacher training (Sezgin Selçuk and Sahin, 2008) and science education (Ram, 1999; Sungur et al., 2006) besides at senior high school level (Barrows and Kelson, 1993). Moreover, it is becoming more and more popular. Although the literature on PBL supports the benefits and effectiveness of this approach in various fields, it has been noted that there are few studies concerning physics education through PBL (Duch, 1996; Fasce et al., 2001, Raine and Collett, 2003;van Kampen et al., 2004; Sezgin Selçuk and Tarakçı, 2007; Sahin, 2010; Sahin and Yorek, 2009; Williams, 2001).The scope of this study is the discipline of physics; and the study is based on related studies on PBL.

Purpose and Significance of the Study

The purpose of this study was to compare the effects of problem-based learning, strategic learning and traditional learning on pre-service teachers' physics achievement. An answer was sought to the research question, "Are there any significant differences between the post-test mean achievement scores in the three groups (after a review of the pre-test mean achievement scores and the physics mean self-efficacy scores).

A review of the literature failed to reveal any study conducted on this subject, either in Turkey or abroad. It is therefore believed that this study will provide a new perspective for research on physics education and act as a guide in prospective studies.

METHOD

Study group

The study group consisted of 58 freshmen (female=45, male=13) student teachers who were enrolled in the Department of Secondary Mathematics Education and Department of Secondary Chemistry Education of a state university in Turkey. The students ranged in age from 18 to 20 years. Physics is compulsory in these departments, and it is offered in two successive semesters (fall and spring) as Physics I (4 credits) and Physics II (4 credits) at the introductory level as calculus-based. Physics I focuses on mechanics concepts and Physics II focuses on electricity and magnetism concepts.

Research Design

Pretest–posttest quasi experimental research design was employed in the study. The classes were randomly assigned as control and experimental groups. Students in the first experimental group (n= 18) received problem-based physics instruction, students in the second experimental group (n= 20) received strategy-based traditional physics instruction, and students in the control group (n= 20) received only traditional physics instruction.

Instruments

Revised Physics Achievement Test (R-PAT)

The research made use of a revised form of the Physics Achievement Test developed by Çalışkan (2007). The original form of the test comprised 37 multiple-choice questions; its reliability was calculated with the KR-20 (Kuder-Richardson 20) formula to be 0.77. In the context of the topics taught during the experimental process of the research, the KR-20 reliability coefficient of the 25-item multiple-choice portion of the test was found to be 0.70. The maximum possible score on the test is 25; the minimum score is 0.

Physics Self-Efficacy Scale (PSES)

A 24-item Likert-type of rating scale developed by Çalışkan (2007) was used in the research to measure the self-efficacy of the students. The reliability test applied to the scale yielded a Cronbach Alpha reliability coefficient of 0.94, and it was seen that the items in the scale could be grouped in 4 dimensions that explained 56.68% of total variance. The descriptors for these dimensions were the following: Belief in Self-efficacy in Solving Physics Problems, Belief in Self-efficacy in terms of Achievement in Physics, Belief in Self-efficacy in terms of being able to Use Knowledge in Physics, and Belief in Self-efficacy in terms of Remembering Knowledge in Physics. Sample items are presented below for each of the sub-dimensions.

Belief in Self-efficacy in Solving Physics Problems: *"I fully believe that I can solve a physics problem, no matter how hard it is." "I am sure that I can set up the necessary formulas to solve a problem in physics."*

Belief in Self-efficacy in terms of Achievement in Physics: *"I believe that I can get a 70 or better grade in physics exams." "I believe that I will not do well in my physics class."*

Belief in Self-efficacy in terms of being able to Use Knowledge in Physics: *"I am sure that I can write up a simple problem on a topic in physics that I've learned." "I believe that I can clearly explain a topic I've learned in physics class to my friend."*

Belief in Self-efficacy in terms of Remembering Knowledge in Physics: *"I believe that I can remember the important formulas I've learned in physics class when the need arises." "I believe that I can remember the basic knowledge I've learned in physics class when the need arises."*

Intervention Instruments

The Turkish translation of the textbook *Physics for Scientists and Engineers with Modern Physics I* by Serway and Beichner, 5th edition (2000) was used as the textbook in the PBL, strategy and traditional groups. During instruction process, scripts which contain information about summarizing and work sheets (i.e. used to write on summaries) developed by the first researcher were used in the summarizing group.

In the PBL group, problem-based learning scenario teaching materials called "kinematics and dynamics scenarios" were used. The PBL scenarios have been organized in two ways as "teacher's" and "student's copy". The tutor copy is a written copy of all of the steps a student needs to take during the scenario (that is, defining the problem, summarizing, producing hypothesis related to the problem, determining the learning goals, reaching new information by researching, doing numerical analysis of the problem if necessary). In the student copy, the previously mentioned parts were left empty for the students to complete. In the beginning of the PBL sessions, the copies of the scenarios were distributed to each student and tutor. During the sessions, small whiteboards and board markers were used by the students.

Procedure

The study was conducted during the fall semester in the General Physics I course (which focuses on mechanics concepts). The duration of the study was seven weeks (24 hours of lecture time) from October to November. In all of the groups, the students' physics achievement was measured before (the first week of the fall semester) and after the study. The independent variable was the intervention (the problem-based, the strategy-based and the traditional instruction). The dependent variable were post-test student achievement scores.

During the intervention, the strategic learning group received explicit learning strategies (questioning and summarizing) plus traditional physics instruction in whole-class format. Strategy instruction composed of two training phases called strategy acquisition and strategy application as used in Montague and Bos (1986). The first phase of the intervention involved the strategy acquisition training. This training was implemented during the second week of the semester in four classes (a total of 180 minutes) in a period of one week in the strategy group. On the other hand, strategy application training was started on the third week of the fall semester and was embedded into the content of traditional instruction.

During the second week in the PBL group, a sample scenario whose topic was different from the ones targeted in the research (scenario of heat expansion) was gone through by the teacher and the students. Then, the students were informed about how problem-based learning methods are used (that is, phases of problem-solving process). In the control group, the same topics were covered at the same time using the traditional instruction method.

During the research, the PBL group (subdivided into three small-groups of 6 students) received physics instruction with problem-based learning format (that is, using PBL scenarios concerning kinematics and dynamics concepts), whereas, the control group received physics instruction using a lecture-based format. Instruction in the PBL group was module-based (being comprised of two different modules). The scenarios in the modules which consisted of PBL sessions were selected from the course book the strategic learning and control groups used.

Data Analyses

Data were analyzed using frequency (*f*), percent (*%*), mean (*M*), standard deviation (*SD*)***, and analysis of covariance (ANCOVA) statistics in SPSS 15.0.*** Pre-test scores of the instruments (that is, pre-test achievement and self-efficacy scores) were used as covariates.

RESULTS

The one-way ANCOVA statistical method was selected for the split-plot design measurements before and after the experiment in the three different process groups (problem-based learning, strategic learning, and traditional learning). ANCOVA is used to test the main and interaction effects of the factors, while controlling for the effects of the covariate(s). ANCOVA has four assumptions: Normality, equality of variances, homogeneity of slopes, and independency of scores on the dependent variable. Firstly, a test was carried out to determine whether ANCOVA's assumptions had been met.

The pre-test achievement and self-efficacy scores of the groups were then tested to determine whether there were any significant differences. The students' post-test mean achievement scores adjusted according to the pre-test achievement and self-efficacy scores are presented in Table 1.

Table 1: Descriptive Statistics of Pre-test and Post-test Achievement Scores by Groups

Group	n	M_{pre}	SD_{pre}	M_{post}	SD_{post}	M_{adj}
TIG	20	10.85	2.68	12.55	2.03	13.74
SLG	20	14.95	2.83	18.25	2.77	17.42
PBLG	18	16.77	2.31	19.28	2.05	17.55

Note: TIG: Traditional Instruction Group, SBG: Strategic Learning Group, PBLG: Problem- Based Learning Group
M: Mean, M_{adj} : Adjusted Mean

When the groups are ranked in terms of their adjusted post-test achievement scores in the order of highest to lowest, it can be said that the highest achievement was seen in the problem-based learning group, which was followed, in order, by the strategic learning group and the traditional learning group. The ANCOVA test results carried out to determine whether there were any significant differences between the groups in terms of their adjusted post-test mean achievement scores are given in Table 2.

Table 2: ANCOVA Results for Post-test Achievement Scores adjusted according to Pre-test achievement and self-efficacy scores, by Groups

Source of Variance	Sum of Squares	df	Mean Square	F	p	η_p^2
Pre-test achievement	79.134	1	79.134	19.529	.000	.269
Self-efficacy	.303	1	.303	.075	.786	.001
Group	58.320	2	29.160	7.196	.002	.214
Error	214.767	53	4.052			
Corrected Total	1020.914	57				

According to the ANCOVA results, it was found that there was a significant difference between the post-test mean achievement scores adjusted according to the pre-test achievement and self-efficacy scores of the students in the three separate groups [$F_{(2, 53)}$=7.196, p<.001]. Related to this, the Bonferroni test results comparing the adjusted post-test mean achievement scores (Table 3) showed that achievement in the traditional learning group of students (M=13.74) was significantly lower than in the strategic learning (M=17.42) and problem-based learning (M=17.55) groups. No significant difference was observed between the post-test mean achievement scores of the students in the strategic learning and problem-based learning groups. The partial eta-squared value obtained was interpreted as recommended by Stevens (1992), where effect sizes were grouped as "small" for $\eta_p^2 \leq .01$, “medium for” $\eta_p^2 = .06$, and “large” for $\eta_p^2 = .14$. Accordingly, when the partial eta-squared value (η^2= .214) obtained in terms of the group variable is considered, it can be seen that this variable has a large impact on the students' post-test mean achievement scores.

Table 3: Bonferroni Test Results

(I) Group	(J) Group	Mean difference (I-J)	p
TG	SLG	-3.679*	.001
	PBLG	-3.811*	.004
SLG	TG	3.679	.001
	PBLG	-.132	1.000
PBLG	TG	3.811*	.004
	SLG	.132	1.000

*The mean difference is significant at the .05 level.

International Journal on New Trends in Education and Their Implications
January 2013 Volume: 4 Issue: 1 Article: 14 ISSN 1309-6249

DISCUSSION

The effects of three different instructional approaches on physics achievement were compared in this study. The results of the study indicated that there were a statistically significant difference between the experimental and control groups in the favor of experimental groups after treatment. However, no statistically significant difference between two experimental groups (problem-based versus strategy-based instruction) was found.

The finding that both approaches had positive influences in improving students' physics achievement supports the strategy-based teaching and problem-based learning studies conducted in the domain of achievement in physics (Sezgin Selçuk, Karabey, & Çalışkan, 2011; Sezgin Selçuk, 2010; Van Kempen, Banahan, Kelly, McLoughlin, & O'Leary, 2004; Sezgin Selçuk, Sahin, & Açıkgöz, 2011; Çalışkan, 2011).

Also, the finding of this study is consistent with the findings of PBL instruction research in different subject matters and grade levels. For instance, the research conducted on PBL revealed that PBL-based science instruction resulted in higher student achievements (Chin and Chia, 2004). Perhaps the success of the PBL model on course achievement can be attributed to the cognitive and motivational effects. Cognitive effects positively contributing to the ability of students to apply knowledge are stimulated by PBL. In addition to this, PBL enhances inherent interest (that is, motivational effects) in the subject matter (Dolmans et al., 2001). It is thought that students' active engagement in the PBL process might have a positive impact on their learning and this in turn can enhance their success in physics.

The finding of this study is also consistent with the findings of strategy instruction research in different subject matters and grade levels, from secondary school to university. For instance, the research conducted on questioning (Cuccio-Schirripa and Steiner 2000; Sezgin Selçuk et al. 2011) and summarizing (Friend 2001; Sezgin Selçuk et al. 2011) revealed that strategy instruction resulted in higher student achievements.

Perhaps the success of questioning and summarizing on course achievement can be attributed to the cognitive and metacognitive nature of these strategies. In the process of questioning and summarizing, students focus on the content of the course, investigate the learning material, organize new knowledge, establish relationships between new knowledge and prior knowledge, and check if the learning material has been learned, that is, if it is used actively (Rosenshine et al. 1996).

CONCLUSION

This study provides some evidence for positive effects of using strategy instruction (questioning and summarizing) and problem-based learning on student teachers' physics achievement. Explicit learning strategy instruction was more effective than traditional instruction in improving physics achievement of the participating students. Also, in the light of the research findings, teaching physics with the PBL method rather than traditional methods has been proved to be far more effective with boosting success in physics. These results suggest that the use of the learning strategies and the PBL approach in physics instruction may foster pre-service teachers' success. On the other hand, the fact that there was no significant difference between the effects on achievement in physics of two different methods of instruction that stimulate contemporary and active learning processes and also, because the two methods similarly render the student active and able in class to conduct his/her own learning process, it can be concluded that both of the methods have a similar effect on student learning. At the same time, outside of physics achievement, it appears that it would be worthwhile to probe into other variables in the realm of conceptual learning or into variables in the affective realm, such as attitude and motivation, to determine whether there are indeed any differences in the effectiveness of these methods.

International Journal on New Trends in Education and Their Implications
January 2013 Volume: 4 Issue: 1 Article: 14 ISSN 1309-6249

IJONTE's Note: This article was presented at World Conference on Educational and Instructional Studies - WCEIS, 07- 09 November, 2012, Antalya-Turkey and was selected for publication for Volume 4 Number 1 of IJONTE 2013 by IJONTE Scientific Committee.

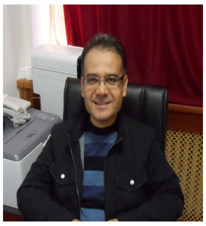
BIODATA AND CONTACT ADDRESSES OF AUTHORS

Gamze SEZGİN SELÇUK is an associate professor of physics education at Dokuz Eylül University in Turkey. She completed her undergraduate studies in the Department of Physics Education at the same university. She received her master's degree at Ege University in the field of General Physics. She received her PhD degree in Curriculum and Instruction at Dokuz Eylül University. Her research studies during her doctoral studies were mainly on learning strategy use in physics education and teacher training. Her research interests include problem-based learning, learning and problem solving strategies, teaching methods and teacher training in physics.

Assoc. Prof. Dr. Gamze SEZGİN SELÇUK
Dokuz Eylül University, Department of SSME (Physics Education)
35160, İzmir, TURKEY
E. Mail: gamze.sezgin@deu.edu.tr

Serap ÇALIŞKAN is assistant professor of physics education at Dokuz Eylül University in Turkey. She completed her undergraduate studies in the Department of Physics Education at the same university. She received her master's degree and PhD degree at Dokuz Eylül University in the field of Physics Education. Her research interest is problem solving; problem solving strategies; strategy instruction; self-efficacy and teaching and learning methods in physics. Dr. Çalışkan has published or presented several articles in distinguished journals and conference presentations.

Assist. Prof. Dr. Serap ÇALIŞKAN
Dokuz Eylül University, Department of SSME (Physics Education)
35160, İzmir, TURKEY
E. Mail: serap.caliskan@deu.edu.tr



Mehmet ŞAHİN is an associate professor of science education. He received his BSc (1996), with honors in Physics Education. He also has a double major diploma in Physics (1996). He has a PhD (2004) in Science Education from The Ohio State University. He worked as a research assistant in various places, including the Middle East Technical University, The Ohio State University- The Eisenhower National Clearinghouse (ENC), and Dokuz Eylul University where he currently teaches science education courses. He worked for three years in a Problem-Based Learning Program in Engineering Faculty of Dokuz Eylul University. His research interests include physics/science teacher education; problem-based learning; professional development; and action research. Dr. Şahin has published or presented several articles in distinguished journals and conference presentations.

Assoc. Prof. Dr. Mehmet ŞAHİN
Dokuz Eylül University, Department of EE (Science Education)
35160, İzmir, TURKEY
E. Mail: mehmet.sahin@deu.edu.tr

REFERENCES

Barrows, H.S. & Tamblyn, R.M. (1980). Problem-based learning: An approach to medical education. New York: Springer.

Barrows, H.S. & Kelson, A. (1993). Problem-based learning in secondary education and the Problem-based Learning Institute (Monograph). Springfield: Southern Illinois University School of Medicine.

Barrows, H.S. (1996). Problem-based learning in medicine and beyond: A brief overview. New Directions for Teaching and Learning, 68: 3-11.

Brown, A.L., Bransford, J., Ferrara, R., & Campione, J. (1983). *Learning, remembering, and understanding*. In P.H. Musen (Ed.), Handbook of child psychology: Vol. III (pp. 77-166). New York: Wiley.

Chin, C., & Chia, L.G. (2004). Problem-based learning: using students' questions to drive knowledge construction. Sci. Educ., 88(5): 707-727.

Cuccio-Schirripa, S., & Steiner, H. E. (2000). Enhancement and analysis of science question level for middle school students. Journal of Research in Science Teaching, 37(2), 210–224.

Çalışkan, S. (2007). *Problem çözme stratejileri öğretiminin fizik başarısı, tutumu, özyeterliği üzerindeki etkileri ve strateji kullanımı*, Yüksek lisans tezi, Dokuz Eylül Üniversitesi: İzmir.

Çalışkan, S. (2011). Instruction of learning strategies: Effects on conceptual learning, and learning satisfactions. *Asia Pacific Forum on Science Learning and Teaching*, 12 (1), Article 8.

Dolmans, D.H.J.M., Wolfhagen, I.H.A.P., Van der Vleuten, C.P.M., Wijnen, W.H.F.M. (2001). Solving problems with group work in problem based learning: Hold on to the philosophy. Med. Educ., 35: 884-889.

Duch, B. (1995). Problem based learning in physics: The power of students teaching students. About Teaching, 47, 6-7. Retrieved on March 2 2010 from http://www.udel.edu/pbl/cte/jan95-what.html

Duch, B. (1996). Problem-based learning in physics: The power of students teaching students. J. College Sci. Teach., 25(5): 326-329.

Entwistle, N. & Ramsden, R. (1983). *Understanding student learning*. London: Croom Helm.

Fasce, E., Calderón, M., Braga, L., De Orúe, M., Mayer, H., Wagemann, H. & Cid, S. (2001). Problem based learning in the teaching of physics to medical students. Comparison with traditional teaching. Rev. Med. Chil., 129(9): 1031-1037.

Friend, R. (2001). Effects of strategy instruction on summary writing of college students. Contemporary Educational Psychology, 26(1), 3–24.

Greeno, J.G., Collins, A.M. & Resnick, L. (1996). Cognition and Learning. In:Calfee RC, Berliner DC (eds) Handbook of Educational Psychology, New York: Macmillan. pp. 15-46.

Harper, K., Etkina, E., & Lin, Y. (2003). Encouraging and analyzing student questions in a large physics course: Meaningful patterns for instructors. *Journal of Research in Science Teaching, 40*(8), 776–791.

Koch, A. (2001). Training in metacognition and comprehension of physics texts. *Science Education,* 85(6), 758–768.

Mayer, R. (1988). *Learning strategies: An overview*. In Weinstein, C., E. Goetz, & P. Alexander (Eds.), *Learning and Study Strategies: Issues in Assessment, Instruction, and Evaluation* (pp. 11-22). New York: Academic Press.

Moust, J. (1998). The problem-based education approach at the Maastricht Law School. The Law Teacher, 32(1): 5-36.

Najar, R.L. (1999). *Pathways to success: Learning strategy instruction in content curriculum*. HERDSA Annual International Conference, (12-15 July 1999), Melbourne.

Nopiah, Z.M., Zainuri, N.A., Asshaari, I., Othman, H. & Abdullah, S. (2009). Improving generic skills among engineering students through problem based learning in statistics engineering course. Eur. J. Sci. Res., 33(2): 270-278.

Pankratius, W. J. (1990). Building an organized knowledge base: concept mapping and achievement in secondary school physics. Journal of Research in Science Teaching, 27(4), 315–333.

Raine, D.J. & Collett, J. (2003). Problem-based learning in astrophysics. Eur. J. Phys., 24(2): 41–46.

Ram, P. (1999). Problem based learning in undergraduate education. J. Chem. Educ., 76(11): 22-26.

Rhem, J. (1998). Problem based learning: An introduction. The National Teaching & Learning Forum, 8(1). Retrieved on 2 March 2010, from http://www.ntlf.com/html/pi/9812/pbl_1.htm

Rosenshine, B., Meister, C., & Chapman, S. (1996). Teaching students to generate questions: a review of the intervention studies. Review of Educational Research, 66(2), 181–221.

Sahin, M. & Yorek, N. (2009). A comparison of problem-based learning and traditional lecture students' expectations and course grades in an introductory physics classroom. Sci. Res. Essay, 4(8): 753-762.

Sahin, M. (2010). Effects of problem-based learning on university students' epistemological beliefs about physics and physics learning and conceptual understanding of Newtonian mechanics. (DOI: 10.1007/s10956-009-9198-7). J. Sci. Educ. Technol., 19(3): 266-275.

Serway, R. A., & Beichner, R. J. (2000). Physics for scientists and engineers with modern physics 2 (5th ed.). USA: Saunders College.

Sezgin Selçuk, G. & Tarakçı, M. (2007). Physics teaching in problem-based learning. Sixth International Conference of the Balkan Physical Union. AIP Conference Proceedings, 899(1): 844-844.

Sezgin Selçuk, G. & Sahin, M. (2008). Probleme dayalı öğrenme ve öğretmen eğitimi (Problem-based learning and teacher education). Buca Eğitim Fakültesi Dergisi, 24: 12-19.

Sezgin Selçuk, G. (2010). The effects of problem-based learning on pre-service teachers' achievement, approaches and attitudes towards learning physics. *International Journal of the Physical Sciences*, 5(6), 711-723.

Sezgin Selçuk, G., Sahin, M. & Açıkgöz, K. (2011). The Effects of Learning Strategy Instruction on Achievement, Attitude, and Achievement Motivation in a Physics Course. Research in Science Education, 41(1), 39-62 (DOI: 10.1007/s11165-009-9145-x).

Sezgin Selçuk, G., Karabey, B. ve Çalışkan, S. (2011). Probleme-dayalı öğrenmenin matematik öğretmen adaylarının ölçme ve vektörler konularındaki başarıları üzerindeki etkisi. *Mustafa Kemal Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 15 (8), 313-322.

Stevens, J. (1992). Applied multivariate statistics for the social sciences*, Lawrence Erlbaum Associates (Hillsdale, NJ).*

Somuncuoğlu, Y., & Yıldırım, A. (1999). Relationships between achievement goal orientations and use of learning strategies. Journal of Educational Research, 92(5), 267–278.

Sungur, S., Tekkaya, C., & Geban, O. (2006). Improving achievement through problem based learning. J. Biol. Educ., 40(4): 155-160.

Vaidya, S. R. (1999). Metacognitive learning strategies for students with learning disabilities. Education, 120 (1), 186–190.

Van Kampen, P., Banahan, C., Kelly, M., McLoughlin, E., & O'Leary, E. (2004). Teaching a single physics module through problem based learning in a lecture-based curriculum. Am. J. Phys., 72(6): 829-834.

Weinstein, C. E., & Mayer, R. E. (1986). The teaching of learning strategies. In M. C. Wittrock (Ed.), Handbook of research on teaching (pp. 315–327). New York: Macmillan.

Williams, B.A. (2001). Introductory physics: A problem-based model. In Duch B et al. (eds) The Power of Problem-Based Learning: A Practical `How To' for Teaching Courses in Any Discipline, Sterling, VA: Stylus.

Zieneddine, A., & Abd-El-Khalick, F. (2001). Doing the right thing versus doing the right thing right: concept mapping in a freshmen physics laboratory. European Journal of Physics, 22(5), 501–511.