REAL-TIME ASSESSMENT OF PROBLEM-SOLVING OF PHYSICS STUDENTS USING COMPUTER-BASED TECHNOLOGY

FİZİK ÖĞRENCİLERİNİN PROBLEM ÇÖZMELERİNİN BİLGİSAYARA-DAYALI TEKNOLOJİ İLE GERÇEK ZAMANLI DEĞERLENDİRİLMESİ

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ABSTRACT: The change in students' problem solving ability in upper-level course through the application of a technological interactive environment-Tablet PC running InkSurvey- was investigated in present study. Tablet PC/InkSurvey interactive technology allowing the instructor to receive real-time formative assessment as the class works through the problem solving strategies was used to improve students` problem solving skills. The method was evaluated by developed problem solving strategies survey as well as quizzes after each chapter of eleven chapters for Advanced Electricity and Magnetism course. Results indicated that the students were used to apply problem solving strategies frequently by the end of the semester.

Keywords: InkSurvey; problem solving strategy steps; tablet pc

ÖZET: Bu çalışmada, öğrencilerin problem çözme yeteneklerinin InkSurvey yazılımlı Tablet bilgisayardan oluşan interaktif ortamdaki değişimi verilmektedir. Öğrencilerin problem çözme becerilerini geliştirmek amacıyla, eğitimciye problem çözme stratejileri uygulayan sınıfı gerçek zamanlı olarak değerlendirmesine olanak sağlayan Tablet bilgisayar/InkSurvey interaktif teknolojisi kullanılmıştır. Yöntem, problem çözme stratejileri ölçeği ve İleri Elektrik ve Manyetizma dersinde görülen onbir konunun her biri için yapılan kısa sınavlar ile değerlendirilmiştir. Elde edilen sonuçlar, öğrencilerin problem çözme stratejilerini dönemin sonuna doğru sıklıkla kullandıklarını göstermiştir.

Anahtar sözcükler: InkSurvey; problem çözme strateji basamakları; tablet bilgisayar

1. INTRODUCTION

Most researchers working on problem solving (Dewey, 1910; Newell & Simon, 1972; Mayer, 1991 etc.) agree that a problem occurs only when someone is confronted with a difficulty for which an immediate answer is not available. However, difficulty is not an intrinsic characteristic of a problem because it depends on the solver's knowledge and experience (Elshout, 1987; Garrett, 1986; Gil-Perez, Dumas-Carre, Caillot, & Martinez-Torregrosa, 1990). So, a problem might be a genuine problem for one individual but might not be for another. In short, problem solving refers to the effort needed in achieving a goal or finding a solution when no automatic solution is available (Schunk, 2000).

One of the fundamental achievements of physics education is to enable students to use their knowledge in problem solving (Heller, Keith, & Anderson, 1992; McDermott, 1991; Reif, Larkin, & Brackett, 1976; Reif, 1981). Therefore, many researchers find that their students do not solve problems at the expected level of proficiency (Redish, Scherr, & Tuminaro, 2006; Reif, 1995; Van Heuvelen, 1991). To improve the teaching and learning of physics problem solving, studies were started in the 1970's (McDermott & Redish, 1999).

Research on developing an effective general instruction for physics problem solving started at least 50 years ago (Garrett, 1986) and changed after the late 1970s with the works of Simon and Simon (1978), Larkin and Reif (1979), Larkin, McDermott, Simon, and Simon (1980), Chi, Feltovich, and Glaser (1981), Larkin (1981), Chi, Glaser, and Rees (1982), Heller and Reif (1984), De Jong and Ferguson-Hessler (1986), Reif, (1995), Dufrense, Gerace, and Leonard (1997), Kozma (2003). Most of the research during this period aimed to identify the differences between experienced and inexperienced physics problem-solvers. These studies show that the experienced problem solvers were individuals with important knowledge, experience and training in physics, and so the process of reaching a solution was both easy and automatic for them. In contrast, the inexperienced problem solvers had less knowledge, experience and training in physics which mean that they were facing real

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problem. In physics problem, inexperienced problem solvers tend to spend little time representing the problem and quickly jump into quantitative expressions (Larkin, 1979). Instructors have found that inexperienced problem solvers carry out problem solving techniques that include haphazard formula-seeking and solution pattern matching (Reif et al., 1976; Mazur, 1997; Van Heuvelen, 1991). By contrast, experienced problem solvers solve problems by interjecting an another step of a qualitative analysis or a low-detail review of the problem before writing down equations (Larkin, 1979) This qualitative analysis used by experienced problem solvers, such as a verbal description or a picture, serves as a decision guide for planning and evaluating the solution (Larkin & Reif, 1979). Although this step takes extra time to complete, it facilitates the efficient completion of further solution steps and usually the experienced problem solver is able to successfully complete the problem in less time than an inexperienced problem solver.

Reif and Heller (1982) discussed this view of problem solvers by comparing and contrasting the problem solving abilities of inexperienced and experienced problem solvers. Their findings showed that the principal difference between the two was in how they organize and use their knowledge about solving a problem. Experienced problem solvers rapidly redescribe the problem and often use qualitative arguments to plan solutions before elaborating on them in greater mathematical detail. Inexperienced problem solvers rush into the solution by stinging together miscellaneous mathematical equations and quickly encounter difficulties. Inexperienced problem solvers do not necessarily have this knowledge structure, as their understanding consists of random facts and equations that have little conceptual meaning. This gap between experienced and inexperienced problem solvers has been well studied with an emphasis on classifying the differences between students and experienced problem solvers in an effort to discover how students can become more expertlike in their approach to problem solving (Larkin et al., 1980; Priest & Lindsay, 1992; Reif & Allen, 1992). As well as differences in procedures, experienced and inexperienced problem solvers differ in their organization of knowledge about physics concepts. Larkin (1979, 1981) suggested that experienced problem solvers store physics principles in memory as chunks of information that are connected and can be usefully applied together, whereas inexperienced problem solvers must inefficiently access each principle or equation individually from memory. Because of this chunking of information, the cognitive load on an experienced problem solver's short-term memory is lower and they can devote more memory to the process of solving the problem (Sweller, 1988). For inexperienced problem solvers, accessing information in pieces places a higher cognitive load on short-term memory and can interfere with the problem solving process.

Chi et al. (1981) found that experienced problem solvers classify physics problems based on underlying structure or physics principles involved, whereas inexperienced problem solvers look at the surface features of the problem such as the objects mentioned in the problem description. They further hypothesized that these classifications point out that the problem schemata of experienced and inexperienced problem solvers contain different knowledge which influence representations and the approaches used by those experienced and inexperienced problem solvers. Mestre (2001) concluded that experienced problem solvers have extensive knowledge that is organized and used efficiently in problem solving. The experienced problem solvers also approach problem solving differently from the inexperienced problem solvers. The experienced problem solvers classify problems qualitatively and according to major principles whereas the inexperienced problem solvers classify problems quantitatively and according to superficial attributes of the problems. According to these findings, instead of researching the advantages of experienced problem solvers to produce a problem solving instruction, researchers can try to examine students' difficulties in confronting real physics problems and show methods to overcome these difficulties (Chi et al., 1981; Van-Heuvelen, 1991). By researching the characteristics of students' problem solving patterns, a general instruction guideline can be produced to meet the various patterns of physics problem solving found among students. It may be that some inexperienced problem solvers have already had good physics problem solving skills that can be examples for other inexperienced problem solvers.

Over the past 40 years, several physics problem solving methods have been produced by researchers to help students improve their problem solving. Varied physics problem solving models and methods were introduced the logical problem solving model (Heller & Heller, 1995); teaching a

simple problem solving strategy (Reif et al., 1976); systematic modeling method (Savage & Williams, 1990); didactic approach (Bagno & Eylon, 1997); collaboration method (Harskamp & Ding, 2006); computer-assisted instruction (Bolton & Ross, 1997; Pol, 2005) and translating context-rich problem (Heller et al., 1992; Heller & Hollabaugh, 1992; Yerushalmi & Magen, 2006). Most of the researchers examined on general and specific problem solving strategies. The most notably general strategies are Polya's (1957) and Dewey's (1910) problem solving strategy steps. Dewey (1910) cited for his four steps problem solving strategy (problem's location and definition, suggestion of possible solution, development by reasoning the bearings of the solution, and further observation and experiment leadings to its acceptance or rejection). Polya (1957) cited for his four steps problem solving strategy. The first step is the understanding of the problem, by identifying the unknown, the data, and the condition, and then drawing a figure and introducing suitable notation. The second step is devising a plan, in which the solver seeks a connection between the data and the unknown. If an immediate connection is not found, the solver considers related problems or problems that have already been solved, and uses this information to devise a plan to reach the unknown. In the third step, carrying out the plan, the steps outlined in part two are carried out, and each step is checked for correctness. In the final step looking back, the problem solution is examined, and arguments are checked.

Reif et al. (1976) tried to teach students a simple problem solving strategy consisting of the following four major steps: Description, planning, implementation, and checking. Problem solving strategy steps have been developed by Reif (1995) in his textbook "Understanding Basic Mechanics". According to Reif's problem solving strategy steps, his steps include analyze the problem, in which a basic description of the situation and goals is generated, and a refined physics description according to time sequences and intervals is developed. The second step is construction of a solution, in which basic useful relations are identified and performed until unwanted quantities are eliminated. The final step is called checks, and asks the solver if the goal has been attained, the answer is with known quantities, and there is consistency within the solution with units, signs, and sensibility of values.

The steps of the University of Minnesota problem solving strategy include focus the problem, which involves determining the question and sketching a picture, and selecting a qualitative approach. The next step, describe the physics, includes drawing a diagram, defining symbols, and stating quantitative relationships. The plan a solution entails choosing a relationship that includes the target quantity, undergoing a cycle of choosing another relationship to eliminate unknowns and substituting to solve for the target. The step execute the plan involves simplifying an expression, and putting in numerical values for quantities if requested. The final step is evaluation of the answer, which means evaluating the solution for reasonableness, and to check that it is properly stated (Heller & Heller, 1995). In this research, researcher presents the selected and modified three steps problem solving strategy based on the problem solving strategies reported by the researchers mentioned before. The developed problem solving strategy steps could be summarized as follows:

Identifying the Fundamental Principle(s); in the first and most important step, a student should accurately identify and understand the problem. A student should examine both the qualitative and quantitative aspects of the problem and interpret the problem in light of his/her own knowledge and experience. This enables a student to decide whether information is important and if other information is needed. In this step students must: (i) simplify the problem situation by describing it with a diagram or a sketch in terms of simple physical objects and essential physical quantities; (ii) restate what you want to find by naming specific mathematical quantities; (iii) represent the problem with formal concepts and principles.

Solving; a student uses qualitative understanding of the problem to prepare a quantitative solution. Dividing the problem into subproblems is an effective strategy for constructing the solution. Thus, the solution process involves repeated applications of the following two steps: (i) choosing some useful subproblems, (ii) carrying out the solution of these subproblems. These steps can then be recursively repeated until the original problem has been solved. The decisions needed to solve a problem arise from choosing subproblems. The two main obstacles can be: (i) lack of needed information, (ii) available numerical relationships which are potentially useful, but contain undesirable features. These choices are promoted if there are only few reasonable options among which a student needs to choose. An effective organization of knowledge has crucial importance in making easy the

decisions needed for problem solving. The organization done after applying the particular principle is facilitated by all of a student's previously gained technical knowledge. The final step contains plugging in all the relative quantities into the algebraic solution to determine a numerical value for the wanted unknown quantity (ies).

Checking; in the final step, a student should check the solution to assess whether it is correct and satisfactory and to revise it properly if any shortages are detected by following this checklist; (i) Has all wanted information been found? (ii)Are answers expressed in terms of known quantities? (iii)Are units, signs or directions in equations consistent? (iv) Are both magnitudes and directions of vectors specified? (v) Are answers consistent with special cases or with expected functional dependence? (vi) Are answers consistent with those obtained by another solution method? (vii) Are answers and solution as clear and simple as possible? (viii) Are answers in general algebraic form?

1.1. Difficulty Level of Problems

In present study, the difficulty level of the problems was determined as remarked in Table 1. The difficulty level of each problem was considered in the range of 0 and 11 points. Problem content explains contexts familiar to the majority of introductory students through direct experience: newspaper, television or standard textbook problems. Hints related to problem express problems have which a hint of one set of related principles to solve the problem. Given information describes problems with no extraneous information or missing information in the problem statement. Clarity of problem represents problems that specify a particular unknown variable. Numerical approach implies problems that could be solved with one set of related principles. Conception number states problems solved with one or more concept. Mathematical approach denotes problems solved with one or more mathematical process. In conception number and mathematical approach, points are given based on the number of concepts and/or mathematical approaches used in the problem (Heller et al., 1992).

Table 1: Scoring of a Problem by Difficulty Level

Analysis of Difficulty Level of Each Problem			
Problem content	1 point		
Hints related to problem	1 point		
Given information	1 point		
Clarity of the problem	1 point		
Numerical approach	1 point		
Conception number	up to 3 points	0-2	1 point
		2-4	1 point
		>4	1 point
Mathematical approach	up to 3 points	0-2	1 point
		2-4	1 point
		>4	1 point

1.2. Tablet PC and InkSurvey

Many students often have difficulty listening to the lectures and taking notes when complex information is delivered at a rapid rate. Some of the recent studies have been integrated Tablet PC applications with software packages to prevent these drawbacks and promote active learning and real-time communication. Researchers have designed and introduced several software such as DyKnow (Berque, 2006; Ferro, 2008; Hrepic, 2007; Stanton, 2008), Classroom Presenter (Anderson, Anderson, McDowell, & Simon, 2005; Koile & Singer, 2006), Ubiquitous Presenter (Wilkerson, Griswold, & Simon, 2005; Price & Simon, 2007) and InkSurvey (Kowalski, Kowalski, & Campagnola, 2005; Kowalski, Kowalski, & Hoover, 2007) for use on Tablet PC as well as other pen-based computing devices to provide an interactive learning environment in large social and/or science classroom. In this study, InkSurvey program was chosen for use on Tablet PC. The advantages and disadvantages of the Tablet PC & InkSurvey will be presented as follows:

1. Tablet PC has an operating system allows which digital "ink" to be written or drawn on the computer screen by using a special pen. Handwritten text can also be saved as written or it can be

translated into typed text. Tablet PCs can be facilitated by a variety of program (e.g., Classroom Presenter, Ubiquitous Presenter, and DyKnow). In this research the free web-based tool, InkSurvey, (Kowalski et al., 2005) was selected to promote the student interaction with the instructor to build on correct ideas to achieve a more mature understanding. With InkSurvey, the instructor poses open-format questions and students use Tablet PCs to facilitate constructing and submitting their responses. Using open-format questions and responses for real-time assessment has significant advantages over using the multiple choice and short answer formats that restrict classroom response systems (clickers) with more valid feedback about student understanding and misconceptions. Other advantages are; easier construction for the instructor, greater freedom in assessing higher level thinking skills, clearer alignment with demonstration the mastery of the learning objectives in the exam setting, and a greater opportunity to refine the communications skills for students. However, the greatest single advantage of the combination of Tablet PCs & InkSurvey and an open-format question format is the richness of the student responses received. The addition problem solving strategies this combination provides the responses that can disclose the essential details of student thought processes at every strategy step of the journey involved in the solution of a problem.

　　　　2. InkSurvey allows for differentiated learning. Problem solving strategy steps can be simultaneously activated for students, enabling all students to respond to the first strategy step and those students who have mastered the concept at this level to continue to another, more advanced step. This feature is also used for student input to multiple questions before class meetings. Besides, both InkSurvey and Camtasia can be used to record the audio and video material of the lecture. In the application of Interactive Learning Package ("ILP"-Tablet PC, InkSurvey, and Problem Solving Strategy Steps) each student goes to the blackboard (Tablet PC window) to answer an open-ended question by using developed problem solving strategy steps after an in-class explanation or discussion led by the instructor. In the student's web browser, the activated questions/problems appear on a menu and the student can choose to respond with text (entered using the keyboard as PDF or Word Document) or digital ink (sketches, free-hand equations, etc.). Further advantages of InkSurvey can be listed as follows; synchronizes files on multiple computers, displays student's submission to instructor and/or to class, locks student's input to current slide, responds in real-time, replays the lecture step-by-step, works in flexible, mobile and distance learning environments, transmits instructor presentations to student computers for their annotation, uses on Tablet PCs, interactive whiteboards, and i-phone.

　　　　On the instructor's page, the questions (problems) are constructed and activated and all student responses are displayed. Figure 1A and Figure 1B illustrate Tablet PC windows of a student and the instructor in the process of answering a question.
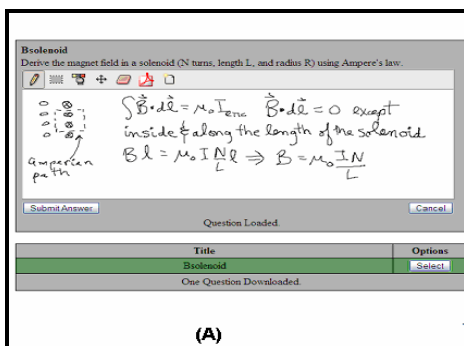

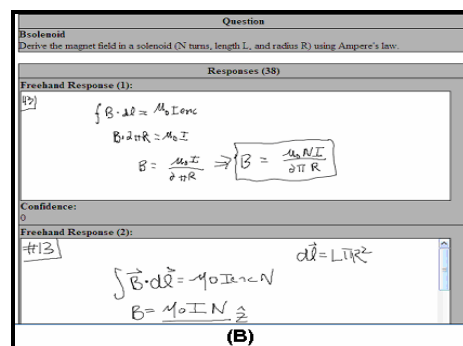*Figure 1A*: Student view of InkSurvey　　　　*Figure 1B:* Students' response prepared to submit B

　　　　Each question is divided into three parts in accordance with developed problem solving strategy steps. Student sends the solution of each part separately. Responses can be either anonymous or linked with identifiers. The instructor refreshes his/her web page and student submissions are displayed on the instructor's web page as they accumulate. A student can pose questions to the instructor on the blackboard and instructor can respond by giving verbal guidance to the class as a whole. As the instructor scrolls through the answers being submitted, he/she may offer comments to the class to realign students' thinking about particular misunderstandings. If students have difficulty

with the concepts, then a similar question might be asked in a later class period to probe their understanding and their long term learning. On the other hand, if the students demonstrate that they have mastered the material, both instructor and students are ready to move on to new material. For example, it is easy to see from the first two submissions in Figure 1A and Figure 1B that these students used a circular path for their line integral when it should have been rectangular. The instructor can give guidance, such as a comment to the class about the direction of the magnetic field and how that influences the choice of path in the line integral. The open-ended responses that students submit are automatically archived and statistically analyzed later on.

Today, however, many instructors teach large scale class in the traditional manner. In fact, large class is one of the most commonly mentioned obstacles to using active learning strategies in the classroom. For instance each step of the problems is barely explained in the class due to limited course time. Fortunately, technology can facilitate the use of active learning methods (problem solving strategies) even with larger numbers of students. In this study, Tablet PC equipped with InkSurvey was used to investigate the effect of students' problem solving abilities. This research examined following research questions:

1. Are there any effects of Interactive Learning Model on students' problem solving ability?
2. Are there any effects of Interactive Learning Model on students' problem solving achievement?

2. METHODOLOGY

2.1 Procedure and Participants

In order to determine the success in teaching problem solving strategy steps, the instructor arranged quiz questions at different difficulty levels. The students included in the study group were required to solve those problems while using Tablet PC, InkSurvey, and Problem Solving Strategy Steps. Quiz problems were provided in three parts (Identifying the Fundamental Principle, Solving, and Checking) to improve the problem- solving skills of students. The instructor looked over each student's solution part stepwise and gave feedback according to the evidence of conceptual understanding, usefulness of description, match of equations with description, reasonable plan, logical progression, and appropriate mathematics. Researcher evaluated the solutions of each student's solution according to defined problem solving strategy steps by taking difficulty level of problem into account. Score for each problem according to problem solving strategy steps was considered in the range of 0 and 5 points. Identifying the fundamental principle(s) of problem is 2 points, solving of problem is 2 points and checking of problem is 1 point. Besides, the overall grading was done in reference to the difficulty level of problem as represented in Table 1.

The study was performed on Advanced Electricity and Magnetism course at the Colorado School of Mines. The research was conducted in the spring semester of 2008 and implemented on a single selected group (62 students) under observation. The instructor taught various concepts to the students throughout a semester via open-ended questioning by Interactive Learning Model ("ILM"- Interactive Learning Package & Socratic Method). During the semester, data was collected through chapter quizzes and problem solving strategies survey.

2.2 Instrument: Problem Solving Strategies Survey

A student's skills related to problem solving by InkSurvey and Tablet PC were elicited at the beginning (pre-test) and end (post-test) of the semester through problem solving strategies survey. Researcher developed this survey with the help of literature review. As a result of the literature review, the survey was consisted of 40 items. Firstly, to test verification and validation of this survey, the survey was applied numerous science and engineering students at Colorado School of Mines. The varimax rotation and principal component analyses were conducted to test the validity of the survey. The items were selected considering the rule anticipating that the item factor load should be over .40 as a result of varimax rotation (Coombs & Schroeder, 1988) and the difference between two loads should be at least .10 if the item takes place at more than one factor. For this reason, the survey item number was decreased to 25 items. One of the pre-analysis regarding construct validity of the survey

was Bartlett's test of sphericity test. This test is based on the assumption that factor analysis for the variables would be appropriate if the correlation between variables is close to the value of 1. The result of Bartlett's test of sphericity was obtained as 12343.77 for the survey. Besides, as a result of principal component analysis, the value of Kaiser-Meyer-Olkin (KMO) was found as .90 for the survey. KMO test checks whether partial correlations are small and distribution is sufficient for factor analysis. It is expected to have KMO value over .60. Therefore, KMO value found for the survey could be defined as "good" (Hutcheson & Sofroniou, 1999). As a result of rotation analyses conducted with principal component analysis and varimax method, three subscales for the survey were determined. All of the three factors can explain 63.86% percentages of the total variance. Some statistical results obtained from the survey were given in Table 2. According to Kline (1994), the acceptable variance ratio in the survey is 41%. Also, Scherer, Wiebe, Luther, and Adams (1988) accept the variance ratio rating from 40% to 60% in social sciences as enough. So, the ratio of 63.86% can be claimed as suitable to evaluate the present survey as with three factors. The subscales of the survey consisted of Identifying the Fundamental Principle, Solving, and Checking. Item examples related to these subscales were given as follows respectively. "I define the concepts of the problem", "I put the given variables on the related-equations", and "I check my calculations for errors". As a result of the internal consistency reliability analysis which was applied to ensure the reliability of the survey, Cronbach's alpha reliability coefficient for the survey was found as .86. This result is quite high value for a survey (Hutcheson & Sofroniou, 1999). All statistical analyses were carried out with 15.0 SPSS (Statistical Package for the Social Science) for Windows.

Table 2: Selected Statistical Results of the Survey

Subscales	Identifying the Fundamental Principle	Solving	Checking
Eigenvalues	8.45	7.81	7.29
Variance Explained	24.12	22.03	17.71
Cumulative Proportion of Variance Explained	24.12	46.15	63.86
Cronbach's Alpha Values	.80	.81	.85

3. RESULTS

Results of the study were presented and analyzed below by following the order of the listed research questions.

1. Are there any effects of Interactive Learning Model on students' problem solving ability?

Researcher gave the problem solving strategies survey to participants to test the effect of Interactive Learning Model (ILM). For each test, mean (M) scores and standard deviations (SD) were obtained to test if there are any significant differences between pre and post test mean performance scores of the study group. Pre and post test scores showed improvement of students' strategy use with significant statistical difference. Table 3 indicates a significant difference between the pre and post test in the study group taught with Interactive Learning Model, in favor of the post test. This points out that the calculated t-value of 26.61 for the study group's pre-test and post-test mean scores are significant at .05 probability level. The increase in mean scores (21.4%) can be interpreted as the achievement the ILM. Also Cohen's d values support this outcome by large effect size. Cohen's d value (Cohen, 1988) was defined as any value over .8 as large effect size, while those between .5 and .8 are considered medium.

Table 3: Statistical Results Obtained from the Problem Solving Strategies Survey

	Pre-Test		Post-Test			
Subscales	M	SD	M	SD	t-value*	Cohen's d
Identifying the Fundamental Principle	44.81	3.61	56.03	3.04	13.26	3.42
Solving	18.75	2.91	26.64	2.25	11.74	3.03
Checking	17.84	3.26	25.48	3.03	9.40	2.42
Total	81.40	4.29	108.15	3.45	26.61	6.87

* Statistically significant (defined as $p<.05$), df=60 and critical value t =2.00

2. Are there any effects of Interactive Learning Model on students' problem solving achievement?

During the semester, the instructor taught the chapters included in the curriculum of on Advanced Electricity and Magnetism course using the Interactive Learning Model. The only way to check if the teaching method works properly was quizzes and/or exams. Researcher elected to observe the students' problem solving strategies applied on the quizzes instead of on the exams. One of the reasons was that two exams were taken by students for this course. The comparison of these exams wouldn't give any definitive results for the achievement of the teaching method. Also, researcher realized that in the exams, students were worried about their grades more than applying the problem solving strategy steps. Therefore, during this "teaching method adaptation" period, only quiz questions were asked with varying difficulty levels and graded with respect to the criteria given in Table 1. The difficulty level of the problems was changed during the semester randomly.
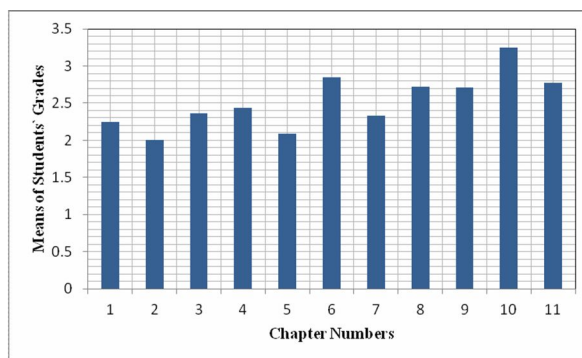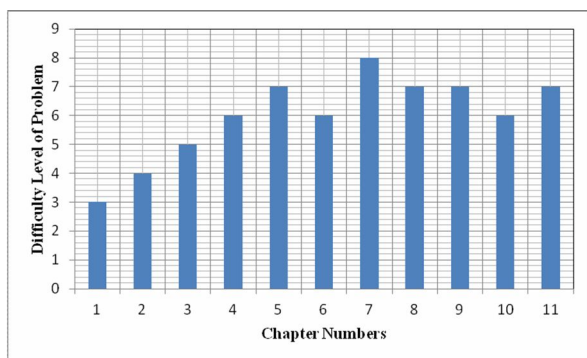

Figure 2A: Degree of difficulty versus chapter numbers *Figure 2B:* Means of problem solving strategy steps Chapters respectively; Lorentz Force Law, Magnetic Force, Biot-Savart Law, Application of Ampére's Law, Ohm's Law, Electromotive Force, Faraday's Law, Induced Electric Field, Magnetization, Field of a Magnetized Object, Auxiliary Field.

The evaluation of the problem solving strategy steps with various difficulty levels are presented in Figure 2A and Figure 2B. In the graph, the y axis shows the difficulty level of the problem and means of student's grade which score with the approach mentioned in the previous section while the x axis represents the numbers of chapter. Submitted students` quizzes were obtained from the blackboard as remarked in Figure 1B. Initially (for the 1st chapter) the arithmetic mean of problem solving strategy steps (AMPS) was found as 2.25 over 5. When the difficulty level of the problem was increased, the AMPS declined. However, AMPS started to increase for the 3rd and 4th chapters. After students got used to solving the problems with the same difficulty level (at as the 5th chapter), the difficulty level of the problems was increased by the instructor. The decrease in AMPS was observed. This result was interpreted as the student's insufficient application of problem solving strategy during the adaptation period to the problem solving strategy steps. At the 6th chapter, the difficulty level was decreased back to level 6 to overcome this problem and the increase in AMPS scores was found. For chapter 7, the difficulty level was selected as level 8, Even though the AMPS declined, it wasn't as much as the decrease for the 5th chapter. Towards the end of semester, the difficulty levels were stabilized at level 7 and AMPS were found close to each other (8th, 9th, 10th, and 11th). These results showed that although students were inexperienced for using problem solving strategy steps at the beginning of the semester, they became experienced for the second half of the semester in the application of the ILM.

4. CONCLUSIONS AND DISCUSSION

When the studies (Anderson et al., 2005; Hrepic, 2007; Kowalski et al., 2005; Kowalski, Gök, & Kowalski, 2009; Price & Simon, 2007; Stanton, 2008) conducted on Tablet PC were examined it can be told that studies performed on physics education haven't enough. In the present study, problem solving strategies were combined with educational technologies applied in physics education. Also,

this study investigated the student's problem solving skills. For this research, problem solving strategy steps were developed and used to understand the analysis of problem solving with InkSurvey and Tablet PC. The research focused on a set of questions regarding achievement in problem solving and problem solving strategies. Statistical analysis of the results helped to interpret the answers to the research questions. The statistical analysis showed that the study group's achievement increased due to an effective Interactive Learning Model, a systematic explanation of problem solving strategy steps, and an application of these strategies in these steps. The problems asked in the class were created having different difficulty levels. Changing difficulty levels showed that the Interactive Learning Model increased the student's ability to use problem solving strategies with even very difficult problems. The interactive environment was created by Tablet PC/InkSurvey and the positive effects of these tools on the teaching method can't be denied. Because of the encouraging results, the ILM is recommended for any engineering, science, and social courses. Also this learning model seems to have been beneficial even for elementary and higher education. The future work is recommended for the detailed investigation of these computer-based strategies in problem-solved courses at all levels.

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Genişletilmiş Özet

Bu araştırmada InkSurvey yazılım programı ile bir Tablet bilgisayardan oluşan interaktif bir öğrenme ortamı oluşturulmuştur. Oluşturulan bu eğitim ortamına problem çözme strateji basamakları entegre edilerek öğrencilerin problem çözme becerileri incelenmiştir. Geliştirilen problem çözme basamakları için problem çözme ve problem çözme stratejileri üzerine yapılan araştırmalar değerlendirilmiştir. Yapılan çalışmalar sonucunda üç basamaktan oluşan problem çözme basamakları belirlenmiştir. Problem çözme basamakları "problemin temel prensiplerin belirlenmesi, problemin çözümü ve problemin kontrol edilmesi" şeklindedir. Bu geliştirilen problem çözme stratejilerinin öğretimi için Tablet bilgisayardan ve InkSurvey yazılımından faydalanılmıştır. Tablet bilgisayarlar öğrencilerin kolaylıkla üzerinde not alabileceği, grafik çizebileceği, denklemler yazabileceği ve daha birçok özelliği bünyesinde bulunduran bir bilgisayar teknolojisidir. Tablet bilgisayarın gösterdiği bu özellikler diğer dizüstü bilgisayarlara göre üstünlükleridir. Tablet bilgisayar teknolojisine uyumlu eğitime yönelik geliştirilmiş birçok yazılım programı bulunmaktadır. DyKnow, Classroom Presenter, Ubiquitous, InkSurvey gibi yazılım programları Tablet bilgisayar teknolojisiyle beraber eğitimdeki yerini almıştır. Bu yazılım programlarının birbirlerine göre bazı avantajları ve dezavantajları bulunmaktadır. Söz konusu araştırma için InkSurvey yazılım programı tercih edilmiştir. InkSurvey yazılım programının tercih edilmesinin nedeni InkSurvey yazılım programının çoktan seçmeli sorular yerine açık-uçlu problemlerin çözümlenmesi için tasarlanmış olmasıdır. Ayrıca bu yazılım programı araştırmanın yapıldığı üniversitede geliştirilmesi de tercih nedeni olmuştur. InkSurvey yazılım programının temeli 2005 yılında Fizik bölümünde atılmış olup sürekli kendisini yenilemesi ve geliştirmesi nedeniyle son zamanlarda dikkatleri üzerine çekmiştir. InkSurvey yazılım programı iki temel esasa dayanmaktadır. Birincisi, eğitimci gerek sınıf içinde gerekse sınıf dışında öğrencilerine problemleri on-line olarak yöneltmektedir. Öğrenciler ise problemlerin çözümünü yine on-line olarak eğitimciye göndermektedir. Eğitimci de ders esnasında öğrencilerin problem çözümlerini analiz etmektedir. Son olarak eğitimci analiz sırsında öğrencilerin kavram yanılgılarını, çözülen problemlerde yaşanılan sorunları sınıf ortamında gidermeye çalışmaktadır. Bu teknolojinin (Tablet bilgisayar ve InkSurvey programı) kullanımı eğitimciye öğrencilerini sınıf ortamında gerçek zamanlı olarak değerlendirme yapmasına izin vermektedir.

Söz konusu araştırmada Tablet bilgisayar üzerinde kullanılan InkSurvey yazılımı ile problem çözme stratejilerinin sentezlenmesi tasarlanmıştır. Bu sentezi bir araya getirmek içinde Sokratik Yöntem kullanılmıştır. Bu üç etkenin bir araya gelmesiyle araştırmacı tarafından "Etkileşimli Öğrenme Modeli-ILM" olarak adlandırılan bir sistem denenmiştir. Bu amaçla uygulanan metodun değerlendirilmesi ve kullanabilirliğini göstermek için problem çözme strateji basamakları ve ölçeği geliştirilmiştir. Geliştirilen problem çözme stratejileri ölçeği yine araştırma öncesinde geliştirilen problem çözme strateji basamaklarına göre düzenlenmiştir. Ölçek maddelerinin geliştirilmesi sırasında bazı istatistiksel analizlerden (temel bileşenler analizi, varimaks döndürme yöntemi vb.) yararlanılmıştır. İstatistiksel analizler için 15.0 SPSS (Statistical Package for the Social Science) programı kullanılmıştır. Ölçek ile ilgili bazı istatistiksel veriler aşağıda sunulmuştur.

Problem çözme stratejileri ölçeğinin Kaiser-Meyer-Olkin (KMO) değeri .90 olarak bulunmuştur. Bu değer ilgili araştırmalara göre ölçeğin faktör analizi için uygun olduğunu göstermektedir. Ayrıca faktör analizinin sonucunda ölçeğin üç faktörde toplandığını ve elde edilen alt faktörler ölçeği %63.86 gibi bir değerle açıkladığı yönünde bulunmuştur. Bu sonuçlara ek olarak ölçeğin Cronbach Alfa değeri ise .86 olarak elde edilmiştir. Geliştirilen ölçek öğrencilerin problem çözme becerilerini ölçmek üzere araştırmada ön ve son test olarak kullanılmıştır.

Araştırma 2008 bahar döneminde Colorado School of Mines üniversitesinde yürütülmüştür. Araştırma için İleri Elektrik ve Manyetizma dersi seçilmiştir. Bu dersin seçilmesinin nedeni fizik bölümünde sadece bu derste Tablet bilgisayar ve InkSurvey yazılım programı kullanılmasıdır. Araştırma derse kayıtlanan 62 öğrenci üzerinde uygulanmıştır. Ayrıca araştırmada İleri Elektrik ve Manyetizma dersine kayıtlı öğrencilerin 11 konunun ara sınavlarından aldıkları notları da değerlendirilerek problem çözme basamakları incelenmiştir.

Araştırmada sırasında öğrencilere yöneltilen problemlerin her biri için zorluk dereceleri göz önünde bulundurulmuştur. Her bir problemin zorluk derecesi 0 ile 11 puan arasında

derecelendirilmiştir. Problemlerin zorluk derecesi "problemin içeriği, probleme ilişkin ipuçları, probleme ilişkin verilen bilgi, problemin açıklığı, problemin sayısal yaklaşımı, problem içindeki kavram sayısı ve problem çözümünde kullanılan matematiksel işlem sayısı" gibi faktörler dikkate alınarak hesaplanmıştır. Problemin zorluk derecesi için son iki basamak üç alt bölüme ayrılmıştır. Problemin içindeki kavram sayısı dört ve üzeri ise üç puan, yine aynı şekilde problemin içindeki matematiksel işlem sayısı dört ve üzeri ise üç puan olarak çözümler değerlendirilmiştir. Bunun yanı sıra problem çözme strateji basamakları içinde bir ölçüt geliştirilmiştir. Buna göre problemin temel prensibin belirlenmesi iki puan, problemin çözümüne iki puan ve son olarak da problemin kontrol edilmesine bir puan verilmiştir.

Araştırmadan elde edilen istatistiksel sonuçlar değerlendirildiği zaman, Tablet bilgisayar ve InkSurvey ile öğrencilerin problem çözme strateji basamaklarını daha etkili ve verimli bir şekilde kullandıklarını ve kendilerine olan güvenin arttığını göstermiştir. Ayrıca öğrencilerin problem çözme becerilerinin gelişimi için de geliştirilen ILM yönteminin yararlı olduğu görülmüştür. Geliştirilen ILM yöntemi sayesinde eğitimci sınıftaki her bir öğrencinin problem çözümlerini görmesi ve çözümleri tek tek analiz etme fırsatına sahip olmuştur. Geliştirilen model ile sınıftaki her bir öğrencinin derse aktif katılımı sağlanmıştır. Bu araştırmanın sonuçlarına dayalı olarak, derslere uygun seçilecek yazılım programları ve Tablet bilgisayar teknolojisinin desteğiyle değişik öğretim yöntemleri kullanılarak ilköğretimden üniversite eğitimine kadar fen, mühendislik, tıp, sosyal vb bilimlerdeki etkisinin araştırılması önerilir.