The effects of online and face to face problem based learning environments in mathematics education on student’s academic achievement

Fatih Gürsul, Hafize Keser

a06340 Cebeci Cankaya, Ankara, Turkey
bAnkara University, 06590 Cebeci Çankaya, Ankara Turkey

Received October 25, 2008; revised December 12, 2008; accepted January 2, 2009

Abstract
This study aims at finding out the effects of the online and face to face problem based learning environments in mathematics education on student’s academic achievement. The study was conducted at Department of Computer Education and Instructional Technologies, Faculty of Education, Hacettepe University. The subjects were 42 freshman students attending to this department at the Autumn term of 2006-2007 academic year. These students were put into two groups as online problem-based learning and face-to-face problem-based learning. The research was conducted on Mathematics-I while implementing the topic of ‘derivation’. The rubric for the students’ performance to evaluate their problem-based skills is used as data collection tool. The statistical techniques used are ranked mean, Mann-Whitney U test. According to the results, the ranked mean scores (7.70) of achievement level of the students at the online problem-based learning group had higher than the students in the face-to-face problem-based learning group (3.30), which was also statistically significant (U = 1,500, p < 0.05).

© 2009 Elsevier Ltd. All rights reserved

Keywords: Problem Based Learning, Online Problem Based Learning, Face to Face Problem Based Learning, Academic Achievement

1. Introduction

Today, information has a key role in economic development in developed communities. On the other hand, technology plays a significant role in the development of the educational process. Rapid development of information technologies has led to the birth of information societies and made it necessary for societies to follow it and adjust themselves to new technological advances. The rapid increase in information and the number of students have brought about several problems and these new technologies has taken a part in the development of educational process and the quality imposed into the educational institutions has become compulsory (Keser, 1998).

Educational technology has played a key role in inclusion of new technologies in educational process. Seattler (2004) defines the educational technology as “Educational technology is a complex, integrated process including people, procedures, ideas, devices, and organizations, for analyzing problems, and devising, applying, evaluating
and managing solutions to those problems are considered as including in all aspects of human learning. In educational technology, the solutions to problems take the form of all learning resources that are designed and/or selected as messages, people, materials, devices, techniques, and settings.”

As educators, we generally wonder why some students find it difficult to learn while other find it easy. Why are students well equipped to learn some skills but not others? Why can’t all students learn all skills equally better? Student learning differs since both their habits and the thinking process differs depending on what the student is trying to learn (Jonassen & Grabowski, 1993). The learning process has been released from being teacher-dependent and instead become learner-dependent (Erdem and Akkoyunlu, 2002). For this reason, the teachers should be a guide for students in order to put themselves into discipline, to achieve self-control and have self-motivation (Anderson, 2004).

Constructivism is a learner-centered approach and evolved as a solution to the problems mentioned above. Constructivist approach is that there is no correct “meaning” of the world that we are struggling to understand. Instead, there are many ways to structure the world, and there are many meanings or perspectives for any event or concept (Duffy & Jonassen, 1992). In other words, learning takes place as a result of discussion based on evidences guided by the socio-cultural context and constructing a personal information network via adaptation and placement (Simske, 2004).

One of the important methods of constructivist approach is problem-based learning (PBL) approach. Problem-based learning draws on essentially constructivist principles of learning, advocating learner centered engagement with course materials and content as well as learner interaction with peers as central to the process associated with learning how to practice theoretical knowledge to professional contexts (Edwards & Hammer, 2004). It is seen that the roots of problem-based learning can be traced back to John Dewey (Dewey, 1926). Researchers have provided a number of definitions regarding problem-based learning. Bubonis (2001) defined problem-based learning as a curricula and learning approach which exposes the students to an ill-structured problem taken from real life and develops the students’ problem solving strategies, knowledge, experiences and skills during the problem-solving process. Cunningham and Corderio (2000) emphasized that the key to problem-based learning is the use of a real-life problem in problem solving process. In addition Duch et al. (2008) stated that problem-based learning is an educational strategy helping the students to construct the questioning and communication skills which they need in their daily lives.

To sum up the definitions above, PBL is an instructional learner-centered learning approach that empowers students to conduct research, to integrate theory and practice, and to design knowledge and skills to develop a viable solution to a defined ill-structured problem (Savery, 2006). PBL is not only the solution of the difficulty but also the discovery of the method of accomplishing this result (Mulford, Silins, Leithwood, 2006).

Today, problem-based learning is becoming more widespread all around the world. For instance, 80 percent of the medical faculties in the US use problem-based learning approach (Bubonis, 2002, p.2). Considering the literature review on problem-based learning, it can be concluded that this approach, appearing as a traditional and campus-based one, is also an approach that works online when integrated with a proper and rational technology (McLinden et al, 2006). Although there is a vast amount of research and literature available on face-to-face problem based learning (Barrows, 1993; Bubonic, 2001; Duch, 1995; Cunningham & Corderio, 2000; Greening, 1998; Major, 1998; Major & Palmer, 2001; Savery & Duffy, 1996; Savin-Baden & Major, 2004), few studies have studied PBL when utilized in the online environment.

By taking Barrows and Myers’s face-to-face problem-based learning as a model, Malopinsky et al. (2000) defined the online problem-based learning as consisting of four phases. They specified them as the following: presentation phase, exploration phase, integration phase, solution phase and reflection phase. Orill (2000) designed the online problem-based learning approach as consisting of seven phases. These are problem identification, task determination, data collection, hypothesis development, discussion of solutions, feedbacks, and finalizing and presenting the solution upon a revision of the solution in the light of feedbacks.

Researchers have identified the sub-dimensions of online and face-to-face problem-based learning cycle in several ways (Delisle, 1997; Exley ve Dennick, 2004; Derry, 2005). In this treatise, the sub-dimensions covering all these dimensions have been considered by the researcher as the following 1) Problem identification, 2) known and unknown information about problem , 3) task sharing , 4) data collection, 5) analysis, 6) generalizing the solution of the problem, 7) cooperation in problem solving, 8) reporting, 9) feedback, 10) presenting the solution.
Problem-based learning approach and collaborative learning approach are used together in some researches (Mayer, 2004; Valaitis et al., 2005; Ozdemir, 2005; Lopez-Ortiz, 2006; Kennedy, 2007). Collaboration requires some kind of cooperation for a common purpose. The idea of collaboration is as old as the history of humanity. Throughout the history, human beings have been able to overcome a number of problems such as warming, starvation, earthquakes, wars, and droughts only through collaboration.

Imagine a family tree in your mind. At the top of tree, most members of this family tree are active learning. Collaborative learning can be fixed as the branch of this. As for problem-based learning, it constitutes the branch of collaborative learning. All group working styles cannot focus on a specific event, but this can take place in problem-based learning (Rhem, 1998).

Collaborative learning is an instructional technique including the students’ group works in order to attain a common purpose under the conditions including the elements such as positive dependence, individual responsibility, the development of face-to-face interaction, the development of collaboration technique, and gaining the habit of group work (Felder and Brent, 1994). Additionally, in problem-based learning, students solve a real-life problem while in collaborative learning they carry on the problem-solving process via first-hand experiences (Bhattacharya, 1998).

The rapid growth of online learning, its tendency to becoming widespread and the requirements for innovations in education online collaborative problem-based learning inevitable. The combination of these three important components above - problem-based learning, collaborative learning and online learning- is a hot field of study for research.

Due to the reasons mentioned above, many studies have been and are still being conducted on problem-based learning. The studies generally compare problem-based learning environment with traditional educational environments (Deveci, 2004; Katwibun, 2005; Gunhan, 2006; Tandogan, 2006; Uslu, 2006; Tavukcu, 2006; Ciftci et al., 2007; Arici and Kidiman, 2007; Akinoglu and Tandogan, 2007; Gulsum and Sungur, 2007). A small number of the studies on problem-based learning deal with a comparison of online collaborative learning and traditional learning environments (Mayer, 2004; Valaitis et al., 2005; Ozdemir, 2005; Lopez-Ortiz, 2006; Kennedy, 2007). We have been able to find only one research, carried out by Luck and Norton (2004) on the comparison of online problem-based learning and face-to-face problem based learning approaches. Also, this study was not based on mathematics but on the subject Educational Management at Department of Pre-School Education and Management. On the other hand, we have not been able to find any studies comparing the students’ achievements or group achievements in online collaborative problem-based learning and face-to-face collaborative problem-based learning in the field of mathematics. The purpose of this study is to obtain findings which will be helpful for eliminating this gap and ambiguity.

2. Method

2.1. Research Model

For this study, the experimental method, one of the quantitative research models, was used. The experimental research explains the cause-effect relation; in other words, the effect of one variable on other variables is examined. Since this paper examined the effect of online and face-to-face problem-based learning on student success, we used the experimental method.

2.2. Participants

These students were put into two groups as online problem-based learning and face-to-face problem-based learning. These groups were formed using random sampling technique via the SPSS (Statistical Package for Social Sciences for Windows, 11.0) program. Through this program, each group was divided into 5 sub-groups, in both online problem-based learning and face-to-face learning groups, 4 subjects in 8 sub-groups and 5 subjects in the other two sub-groups. The research was conducted on Mathematics-I during the implementation of the subject ‘derivative’.
2.3. Data Collection Tools

In this research two different data collection tools were used. The first one is the rubric for the students’ performance to evaluate their problem-based skills. The second one is the materials used by students and designed by the researcher in Blackboard Learning Management System.

2.3.1 The Rubric

With regard to the scope of the study, the rubric scale is developed in order to examine the students' performances on ill-structured problems. The structure of the rubric was determined to be holistic in compatible with the purpose.

The phases followed during the development of rubric are summarized below. Rubric development is the process of preparing a measuring instrument required for testing (generally) psychological structures which cannot be observed directly or performances on a certain activity. The first stage of this process is to define the psychological and psycho-educational characteristics to be tested. The objective of the rubric in this study was designed so as to be the solution of a given ill-structured problem and student activities during the solution process.

In the second phase, the scale models were determined based on literature by the researcher. Then, the candidate evaluation rubric form was developed and revised in accordance with the opinions of field/subject specialists. The rubric for the candidate was designed with 19 sub-dimensions regarding 8 sequential dimensions.

In the third phase, validity and reliability studies are conducted on the rubric for the candidate form. As it is known, while rubric development studies for psychological structures consist of practices with broad participation, this is not the case for this kind of rubrics. Therefore, the validity study of the rubric was approached as "content validity". The validity of the measuring instrument was ensured by resorting to learned opinions again. Inter-rate reliability is used for reliability study. For this, two field specialists assessed the activities of 10 groups via the rubric developed and the correlation between the two specialists' assessment results. Pearson's correlation coefficient was calculated as 0.995. Also, the average point given by the specialist 1 was found to be 9.85 and by the specialist 2 to be 11.15, through Mann-Whitney U Test conducted between two assessment sets. Table 1 shows the Mann-Whitney U Test results regarding the assessment results of specialists.

<table>
<thead>
<tr>
<th>Specialists</th>
<th>N (groups)</th>
<th>Mean Rank</th>
<th>Rank Sum</th>
<th>U</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specialist 1</td>
<td>5</td>
<td>9.85</td>
<td>98.50</td>
<td>43.500</td>
<td>.622</td>
</tr>
<tr>
<td>Specialist 2</td>
<td>5</td>
<td>11.15</td>
<td>111.50</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As can be seen from Table 1, considering the Mann-Whitney U Test results (U=13,500, p=.622>0.05), there is not any statistically meaningful difference between the assessment results of specialists.

The fourth stage is where the application takes place. An important characteristic of alternative assessment approaches is that the students are aware of measuring criteria and instruments. For that reason, the rubric developed was assigned to the groups in both environments (face-to-face and online) before the application. At the end of the performance activity, the products of both groups were analyzed by two field specialists.

2.3.2 Teaching Material

In this study, we designed a teaching material introduced on the web in order to develop problem-based learning activities. For this, we used Blackboard Learning Management System, which allows one to design teaching materials on the web (e.g. Hacettepe, University of Cincinnati, University of Newcastle, University of Leicester, Ohio University, University of Cambridge use Blackboard Learning Management System for problem-based learning
practices). The material designed on Blackboard and the pilot scheme of the problem-based learning environment was carried out on the teacher candidates taking the subject Computer at their first grades at Department of Primary School and Pre-School Education, Faculty of Education, Hacettepe University, (N=70). The purpose of this pilot scheme was to determine any possible problem and difficulty on Blackboard (Gursul and Altun, 2007). The Blackboard environment was revised and operationalized in accordance with the results obtained from the pilot scheme.

Prior to the study, the well-structured and ill-structured sample problems were analyzed regarding the subject derivative. Problem 1 used in the study was inspired by a research project titled “The ‘Catwalk’: Representing What You Know” and broadcasted on an educational television station in USA (This program can be watched on the link .learner.org/channel/workshops/pupmath/workshops/wk6trans.html). The problem 2, on the other hand, was adapted in Turkish from a problem under the title “Fundamental Concepts of Differential Calculus” on web page of Wofforg Academics (Original problem can be accessed on the link http://www.wofford.org/ecs/ScientificProgramming/DifferentialCalculus/material.htm).

Online problem-based research groups were exposed to mathematics instruction through the use of Blackboard Teaching Management System. The training of the groups was completed by the researcher within seven weeks’ time. Software on web, e-mails, e-groups and e-books were used in a way that would enable this environment to provide the students with opportunities for developing their skills and methods in order to adapt to and change new situations. For student-student and student-teacher interaction, we used both simultaneous lesson-counseling through Microsoft Msn Messenger and the instruments as phone and e-mail. In order to minimize the problems experienced between the teacher and students, during the online simultaneous learning, we announced the students about which group would be provided with online teaching at which hours through online communication, and the rules to be complied with in online environment. Each group took a one-hour simultaneous lesson a week with the teacher at the hours announced previously. In addition, each group was provided with the opportunity of having simultaneous negotiation with the teacher (via mto191@hotmail.com, an address taken for the lesson) between 8.30 am and 5.00 pm on Monday, Wednesday, Thursday and Friday and between 1.00 pm and 2.30 pm on Tuesday.

As for the group provided with mathematics instruction through face-to-face problem-based learning, the practice lasted for seven weeks. The process was carried out by the researcher in classroom.

3. Findings

The problem of the study was determined as to be “Is there a statistically meaningful difference between group achievement levels during online and face-to-face problem-based learning?” The achievement scores of the groups is equal to the total scores of the groups in problem-based learning phases.

The results of the analysis of Mann-Whitney U Test regarding this sub-goal have been presented in Table 2. According to the result of the analysis, the average rank of achievement scores of the group in the online environment (7.70) is higher than the average rank of achievement scores of the group in the face-to-face environment (3.30). This difference is statistically meaningful (U=1,500, p<0,05).

<table>
<thead>
<tr>
<th>Environments</th>
<th>N (Groups)</th>
<th>Mean Rank</th>
<th>Total Rank</th>
<th>U</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Online</td>
<td>5</td>
<td>7,70</td>
<td>38,50</td>
<td>1,500</td>
<td>0,021</td>
</tr>
<tr>
<td>Face-to-face</td>
<td>5</td>
<td>3,30</td>
<td>16,50</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Considering this finding, it has been discovered that there is a meaningful difference between group achievements in the online environment and the face-to-face environment, when problem-based learning is addressed together with all of its sub-dimensions. This difference is in favor of online problem-based learning.

In order to determine why these differences found in their achievement scores in this practice applied to the online and face-to-face problem-based learning environments, we conducted a comparison of achievement on each sub-dimensions. While designing this practice, we followed 10 sub-dimensions for both the online and face-to-face groups for problem-based learning approach. These sub-dimensions were listed as problem identification, known and unknown information about the problem, task sharing, data collection, analysis, generalizing the solutions, cooperation in the solution of problem, reporting, feedback and presenting the solution, respectively.

According to the results, the ranked mean scores (7.70) of the achievement level of the students at the online problem-based learning group was higher than the students in the face-to-face problem-based learning group (3.30), which was also statistically significant (U = 1,500, p < 0.05). The ranked mean scores of the achievement level for the known and unknown information about the problem, data collection, data analysis, generalizing the solutions, and reporting in the online problem-based learning group were higher than the ones in the face-to-face problem based learning group. However, this result is not statistically significant. Considering sharing the responsibility, feedback and presenting the solution, the score in the online problem-based learning group is higher than the one in the other group, which is also statistically significant.

4. Results

When all sub-dimensions are considered as a whole, the achievement level of the groups during the process of face-to-face and online problem-based learning is more in favor of online groups. This difference is statistically significant. The achievement scores of the groups in online environment, regarding the sub-dimensions of problem identification, known and unknown information about the problem, data collection, data analysis, generalizing the solution and reporting, is higher than that of groups in face-to-face environment. Yet, this difference is not statistically significant. The achievement scores of the groups in the online environment, with respect to the sub-dimensions of task sharing, cooperation in the solution of problem, feedback and presenting the solution, is higher than that of the groups in face-to-face learning. This difference is statistically significant. Under these conditions in which the group work is used extensively, the online groups are especially more successful, in terms of the sub-dimensions of task sharing, cooperation and problem-solving and cooperation in solution.

5. Discussion and Suggestions

Collaborative learning in the online environments contributes to the complex thinking skills of students (Slavin, 1996). The individuals in the different places will have the opportunity of developing the solutions and the projects together in the problem-based environment. Luck and Norton (2004) studied and compared student opinions and experiences regarding the online and face-to-face problem-based learning approaches. According to the research findings, although there was not any difference in the group achievements and the individual, the online problem-based group had higher achievement level than face-to-face problem-based achievement group regarding the sub-dimension of cooperation. Lopez-Ortiz (2006) stated they thought that a course carried out via online problem-based learning approach fulfills its objectives and is useful. These studies seem to support our findings.

Based on the researcher’s experiences during the application process, it can be said that it will make the decision-making process easier to assign a leader or to guide for each group in the simultaneous discussion groups. In addition, the process can be managed more effectively by making the students’ participation in group discussions on online more planned and organized. In order to reduce the problem of teacher-learner interaction, an assistant teacher may be provided in a way that will help the teacher. While carrying out such practices, one should pay attention not to include days such as festive holidays with the aim of not disrupting learner motivation and preventing process delays. The application will be more efficient and affective if the students at online practice have computers and access to the internet at home or dormitory where they stay.

The appropriate instruments and methods should be selected so as to make teacher-learner and learner-learner interaction more effective. Another study on this issue could form groups by taking students’ cognitive skills and
gender factor into account. In this study, the results obtained from the online and face-to-face problem-based learning environments could be compared in terms of these variables.

This study has been conducted on ten groups, half of which in online problem-based learning environment (21 persons) and half of which in face-to-face problem-based learning environment (21 persons). This has been regarded as the limitation of the study. The number of groups and students could be higher in other similar studies in order to obtain more reliable generalization.

5. Acknowledgements

This study has been extracted as a summary from the doctorate thesis titled “The Effect of The Online and Face-to-face Problem-Based Learning Approaches on Student Achievement Level and Their Attitudes towards Mathematics” and conducted under Prof. Dr. Hafize Keser in Educational Sciences Institute, Ankara University.

6. References


