USING PEN-BASED TECHNOLOGY IN ONLINE MATHEMATICS COURSE: AN EVALUATION STUDY

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Abstract

This study aims to evaluate mathematics course offered through online distance education from the online students' perspective and it focuses on displaying the impact of the related technology on students. This research study employed as a case study within the nature of qualitative methodology. Thirty-two undergraduate students participated the study. These students are from the state university. The research process was taken a total of 16 weeks throughout the course of the investigation. Semi-structured interview and observation techniques were used to collect the data. The data was analyzed through the content decoding approach. The results in the study indicated the presence of expression and interaction problems within the courses in which the evaluations had been performed; however, the results also revealed that overall, the participants had positive opinions regarding the use of digital pens within online mathematics courses. The study also revealed that the use of digital pen technology increases the interaction between instructor and students as well as peer-to peer interaction among the students themselves and gives on-site and immediate feedback, and raises the overall level of student participation.

Keywords: Online Distance Learning, Digital Pen Technologies, Online Mathematics Course, Mathematics Education

Introduction

Individuals' differentiated requirements, transformations in technology and education, and global changes bring distance education in the foreground as an alternative education system (Schunk, 2008). It is stated that distance education model and applications have significant contributions in solving problems in higher education (Alkan, 2005). Changes in information and communication technologies, one of the indispensable factors in development of distance learning, provide renewal and expansion to distance learning as well as bring new dimension to distance learning systems (İsman, 2008; Ozgur, 2005; Thorpe, 2005). However, emerging technologies make a redefinition of distance learning necessary (Schlosser & Simonson, 2009). One of the most important contributions of using information and communication technologies in distance learning is that it offers the faculty members who are teaching in online learning environments the ability to increase the cooperation and especially the interaction between students (Beldarrain, 2006; Watson 2010).

Interaction, in order to ensure effective teaching and learning, is an important factor need to be taken into account in distance learning environments as well as in face to face learning environments. Studies in the literature show that interaction plays a great role on quality and learner's achievement, motivation and satisfaction in distance learning (Fulford & Zang, 1993; Jung et al., 2002; Liao, 2006; Moore & Kearsley, 2005; Nehme, 2008; Schaffer & Hannafin, 1993). The related studies indicated that interactive technologies need to be used in order to

facilitate knowledge construction, get feedback to distance students and increase interaction in online distance learning environment.

Although it is a small part of the technological revolution that offers tremendous potential in reshaping the human interaction, distance education is central focus of this revolution (Parker, 1999). A variety of digital technologies are frequently used in order to ensure the effective interaction in online distance learning environments. Kiryakova states that (1999) the quality of distance education is based on the use of internet as a medium of education and developments in digital technologies. In order to increase efficiency in distance education, digital technologies such as the touch whiteboard, personal mobile computers, virtual worlds, tablet computers, digital drawing tablets and digital pen have been used since 2000s. Digital technologies used in distance education are useful in facilitating students' communication and they allow the use of electronic handwriting providing information exchange between students and teachers (Loch & McDonald, 2007). It is thought that related technologies are expected to provide student and faculty member's active participation in online learning process. Digital technologies play an important role in conducting courses based on especially formulas such as mathematics, numerical calculations and visuals through online distance education.

In mathematics course, mainly the use of symbols, graphics and presentation of process steps of mathematical problems are important. Mathematics course is known to be a lesson has its own unique language. In the course, students are expected to use mathematical language properly and demonstrate their solutions with numbers, mathematical or special symbols in problem solving. In face to face courses such as mathematics, boards are usually used by both students and teachers. However, in the online mathematics courses, instructors present studies with slides or while scanning the working papers, they transfer them to the students in the distance education environment. Generally, responses to the mathematics problems asked to students are expected to be delivered through keyboard. However, students' learning mathematical thinking, discussing logical inference and alternative solutions by providing student-teacher interaction are the principles of mathematics teaching (Baki, 2006). In traditional face to face classroom environment, while faculty members explain mathematical concepts to students step by step typing the symbol and graphics manually, they may experience limitations in online distance learning environment in this context (Smith & Ferguson, 2005; ElSheikh & Najdi, 2013). The most important feature of the pen based technologies such as tablet PC, graphics tablet or digital pen is that users can easily write symbols and graphical information electronically (Loch & Donovan, 2006). It is emphasize that pen based technologies in distance learning allow more rapid distribution and communication methods for mathematics teaching. Galligan, Loch, McDonald and Taylor (2010) stated that for the distance students, learning experiences could carry out of simple text format and all symbols and graphics could be written and delivered quickly.

Pen-based technology studies in education

Literature enlighten that tablet computers and digital pens were used as tools. In addition, Loch and Donovan (2006) stated that non-interactive technologies such as slides prepared before lessons and not appropriate to make changes during lessons should be questioned. Instead of this, they stated that digital technologies like digital cameras and tablet computers that maximized interaction join students in real time problem solving and showing diagrams. Galligan, Loch, McDonald and Taylor (2010) stated that tablet computers and other related technologies as well as digital pens could be used for mathematics teaching in distance learning. Moreover they could play supportive and empowering role both for teachers and students in enhancing learning opportunities.

Anderson et al. (2007) focused on using digital pen technologies to increase interaction in courses conducted through slides. In the study, it was concluded that using pen based technologies to facilitate interaction increase cooperation in learning environment, made it possible for students to share their answers including symbols and shapes through slides and problem solving process can be seen. Casas, Ochoa and Puente (2009) investigated the use of tablet PC, and pen-based technologies to support engineering education. In the study, it was found that students feel more comfortable while expressing themselves in pen based environment, and they could store the changes they do in digital contexts. In terms of teachers, it made courses more dynamic and interactive, help maintaining students' interest alive throughout the course; facilitated discussion and group work activities and improved quality of education. In another study, it was concluded that the use of "My Test" application which was developed related to computer based assessment with tablet pc one of the pen based technologies made the software more efficient, flexible, usable and useful compared to its use in traditional computer environment (Siozos et al., 2009).

It was seen that almost all the studies in the related literature focused on the research of contribution of the pen based technology use to the learning process in face to face courses such as Mathematics, Geometry, Computer Programming in traditional or computer based environment. In addition, Radu and Seifert (2011) suggested that interviews could be conducted on students' experiences when using online technology for learning mathematics. In this study, unlike other studies, possible limitations in mathematics courses offered through online distance education were put forward in the student perspective, and the role of pen-based technologies were discussed in the context of minimizing the limitations. This study aims to evaluate mathematics course offered through distance education from the online students' perspective and it focuses on displaying the impact of the related technology on students

Methodology

Study design

This study was a qualitative research in which case study design was used. The reason for using case study method is that case studies enable the researcher in-depth and rich data collection (Yin, 1994; Patton, 2002; Creswell, 2007).

Participants

The participants were 36 distance students (prospective teachers) enrolled in computer education and instructional technology related undergraduate courses through a blended learning program in a large university on the north coast of Turkey. About 44 % of the participants are male and about 56 % of the participants are female. The participants were selected according to the requirements of study (Morse, 1991) and they attend their courses through online distance education environment supported by online web conferencing solution. In related online distance learning environment, students could share their sounds and images by asking to speak with the permission of the instructor, and could communicate with each other and with the instructors in writing through chat box. In the list of participant, the students and the instructors who were present in the lesson at that moment were listed. In "Share" section in the environment, instructor could share digital objects (slides, animation, video, files, etc.), desktop and a screenshot of any application currently running and all students could see the current sharing simultaneously. Also, students could perform the same functions after the authorization of the instructor. More than one student could connect to system as voice and video and they could share. Sample screenshot of the related online distance-learning environment is shown in

Figure 1. Figure 1 is related with the mathematics course conducted through online distance education.

Study procedure and data collection

In the study, the online mathematics course participants enrolled was investigated. The online mathematics courses were recorded and the shared materials were stored in the content management system. Course records and instructional materials were accessible to the students after the end of the courses in a few days. In the online mathematics course, digital pen technology which was one of pen-based technologies, transferred handwriting on any paper or printed material instantly to the digital media through software and offered them to the online demonstration in online learning environment was used. Keeping an action sensor apparatus connected to the computer by USB on a paper straight or cross, handwritings written by a pen were digitized and transferred to the screen by software. A screen display related to a mathematics lesson in which digital pen was used shown in Figure 1. In the "Share" section on the right side of the figure, instructor's writings transferred to the learning environment by digital pen.
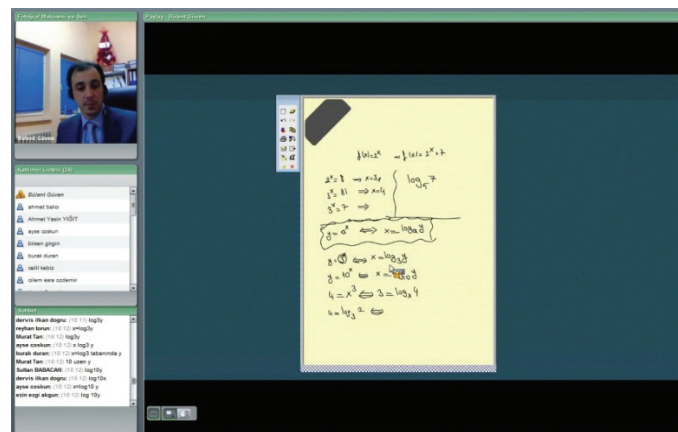

Figure 1. The online distance learning environment where participants received the course

This study was taken a total of 16 weeks. In the online mathematics course, the instructor did not use digital pen by the time fourth week. Then, the instructor started using digital pen in the 5th week and the participants in the 9th week of the study. All participants were allowed to use digital pen. In accordance with the purpose of the study, an open-ended questionnaire was applied to the participants in the 4th week of the study.

In the study, qualitative semi-structured interview form including 10 open ended questions was designed by the authors. The interviews were conducted face to face with seven participants and with 25 participants they were carried out in online media. According to Griffiths (2010), online interviews can performed synchronously through instant communication systems or asynchronously through e-mail. The online interviews were carried out using Skype and Adobe Connect online web conferencing media. The interviews were recorded digitally and transcribed by the authors. Researchers examined the records of the mathematics courses in online distance education as well as semi-structured interviews and observed the participants during the study. Thus, it was aimed to ensure the data diversity and test the consistency of the data (Sowell, 2001).

Data analysis

Data were analyzed using content analysis approach. First of all, the researchers transcribed recordings by converting into text data. The raw data were read three times to explore general

sense of the data (Creswell, 2011). Then, the researchers coded data separately and themes were determined. The researchers encoded data separately. Thus, the coder consistency was tested. Themes were re-revised and the data were interpreted. After data analysis process, the qualitative data obtained from interviews were sent to the participants in order to ensure member checking for establishing the study's credibility (Guba & Lincoln, 1994). In order to determine the credibility and transferability of the study, unbiased and objective researcher observations (Yildirim & Simsek, 2008) were carried out, data were allowed to be checked by the participants and direct quotations from participants' statements were taken. In order to ensure the trustworthiness of the study (consistency and verifiability), as it was stated by Sowell (2001) and Shenton (2004), triangulation was used by applying observation and interview methods together. Attention was paid to the co-observer consistency. However, the raw data were read to the researchers three times and records of data analysis process were kept.

Ethic

In qualitative studies, the implementation of the code of ethics, privacy, and noting voluntary basis is very important (Christians, 2003; Miles & Huberman, 1994). In this study, the participants took part in the study on a voluntary basis. As for the images used in this study, permission was obtained from both the participants and the related instructor. When they quoted from the participants opinions, names were kept confidential and encoded in the [K, number] form. During the interviews, the researchers behaved objectively, and avoided router attitudes and expressions towards participants. It was guaranteed to the participants that the data obtained during the study period were not be used excluded from the research.

Results

The results of the study were examined in two separate sections as before and after using digital pen, to bring out the impact of using digital pen on the students more clearly.

Results related to the findings before using digital pen

In the semi-structured interviews, the students were asked open ended questions to state their general opinions about their 4-week online distance mathematics course without using digital pen, and their assessment about the course in the context of interaction, feedback and motivation. Analyzing the answers given by the students, it was stated that the findings before the use of digital pen were grouped into three themes as "the problems experienced in the course", "alternative solutions" and "perceived constraints".

Table 1: Results Related to the Findings before Using Digital Pen and Themes

Themes	Frequency	Percent
The problems experienced in the course		
Display of Mathematical Expression Problem	26	81.3 %
Feedback Problem	17	53.1 %
Alternative solutions		
Screenshot Sharing	28	87.5 %
Audio Connection	19	59.4 %
Perceived constraints		
Lack of interest and motivation	12	37.5 %
Lack of Interaction Feeling	9	28.1 %

The participants frequently stated that they had difficulties in the process in which both they and the instructors did not use digital pen. Most of the participants (81.3 %) declared that they had problems in displaying the mathematical expressions in mathematics courses in online distance education environment. *"…we have difficulties in writing the symbols, formulas and signs not exist on the..."* [K-12], *"I had a problem in the expression of mathematical symbols. For example, I couldn't write a square root, numerator and denominator"* [K-18], *"It is really hard to express the answer and solution of the question in writing in virtual media and it makes the solution nonsense"* [K-3]. In the observation of the related mathematics courses, it was seen that students tried to express themselves through "chat box" and they had difficulties in expressing mathematical symbols. The screenshots gained in researcher observations regarding to what students expressed on the situation are shown in Figure 2. However, most of the participants (53.1 %) stated that feedbacks to the questions they asked to the instructor in the learning environment were insufficient and this constituted a barrier to understand the current topic: *"We were asking what we couldn't perceive in difficult problems to the teacher. It was likely that the teacher couldn't understand where we asked. Because, we couldn't see the operation steps."* [K-3], *"we had problems while the teacher was explaining the misunderstood parts. I couldn't get full answer for some of the questions. It seemed that there was a communication gap between us."* [K-16].
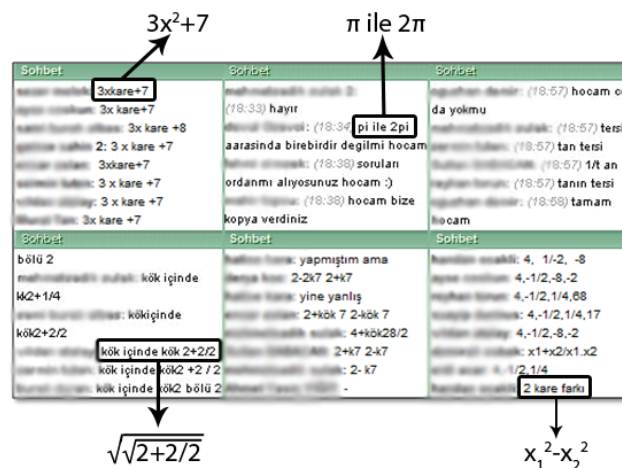

Figure 2. The students' difficulties in display of mathematics expression

Most of the participants expressed that they developed alternative solutions such as audio connection (59.4 %) and image sharing (87.5 %) and they tried to apply these solutions when the problems arose in their courses to overcome the problems they had in mathematics classes in distance education as follows: *"I had to ask certain question parts or points of what I couldn't' understand verbally connected to the system. It was time consuming but you now I had no choice."* [K-19] and *"I solved the asked question but how I would show it…then I opened Paint and then I transferred the screen shot to Connect. I solved it there. Both my friends and teacher saw it. Besides this I solved a problem on a paper and took the photo of it. I sent it to the teacher"* [K-24]. For example, writing with a digital pen, the lecturer given the related course allowed the other students simultaneously to see operation steps of the question asked at that moment and solved by a student. It was seen that alternative solutions stated by the participants were often used in researcher observations, also. For example; a student connected to the learning environment from his house solved the mathematics problem asked by the lecturer on a paper, took the photo of the solution paper and using "Desktop Image Sharing" function of the system, he shared it on the media and told how he solved the problem verbally. The screenshot related to the situation is shown in Figure 3. Researcher in his observations concluded that the practices carried out by the students as alternative solutions were time wasting and decreased the control of the course.
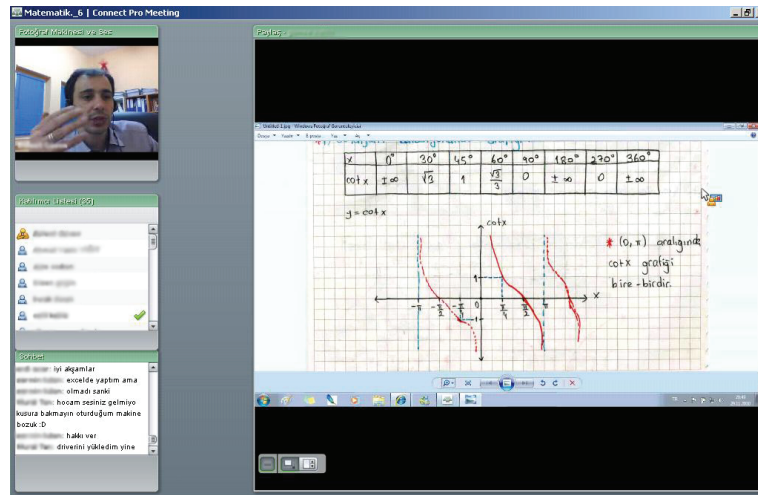
Figure 3. A participant's explanation his solution sharing his desktop

Findings related to the process of digital pen use

As of the 5th week of the study, the instructor who gave mathematics course through online distance education started using of digital pen. On the other hand, participants started using digital pen in the 9th week. At the end of the study, 10 open ended questions; how digital pen in mathematics classes in the current learning environment effects interest and motivation, interaction, instructor's feedbacks, the course process, advantages and disadvantages of functions of digital pen were asked. When the gained qualitative data were analyzed, it was seen that the findings were grouped under three themes. The frequency and percentage values for the code and themes are presented in Table 2.

Table 2:   Findings Related to the Process of Using Digital Pen and Themes

Themes	Frequency	Percent
Interest of Mathematics Course		
Participation	14	43.7 %
Willingness	21	65.6 %
Comparison of Learning Environment		
Student's Role	13	40.6 %
Teacher's Role	8	25 %
Contribution to learning process of Digital Pen		
Representation of symbols and problem solving steps	26	81.2 %
Feedback	16	50.0 %
Interaction	14	43.7 %

In the interviews after the courses where digital pen used, the participants frequently emphasized that digital pen had a significant contribution to the learning process. Especially, it was stated that it eased the presentation and feedback of process steps and mathematical symbols, increased interaction. With the contribution of it, courses were more active, also. For example; three of the participants regarding to presentation of process steps and mathematical symbols expressed their thoughts as follows; *"I had wrote the answers of solved questions to the teacher. Unfortunately time was completed until we would write. But with digital pen, my teacher and friends could see my solution from beginning to end. They asked questions whenever they wanted"* [K-11], *"it couldn't be understood exactly when the solution was told verbally but everybody could see it immediately when we used digital pen. With digital pen, it was very easy to project any mathematical problem with its symbols and steps on a screen"* [K-24] and *"as it was easy to write symbols and expressions on a paper, I could express symbols that I couldn't write before to my teacher and*

friends and I showed whatever I couldn't understand before step by step to my teacher" [K-6]. Figure 4 demonstrates a screenshot from the course record which K-6 was solving the mathematical problem asked to him/her in.

While two of the participants, regarding the feedback expressed their opinions as follows; *"using the digital pens, I could ask the misunderstood points neatly and I could get more clear answers from teacher. Mutual misunderstandings were removed."* [K-8] and *"…it could draw shapes. Thereby my teacher could not only understand the question I asked clearly and answer it without wasting time but also he could point out the errors I made in problem solving. This was the most important benefit for me. I could understand immediately, too."* [K-16]. Another participant said that *"…it created a better interaction between us and the teacher in lessons. I could understand the lessons better and communicate what I know comfortably. It was good."* [K-4]
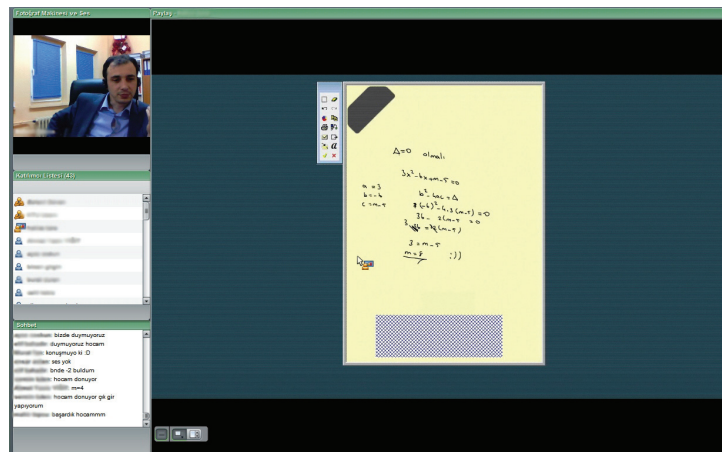

Figure 4. A participant's solving mathematical problem asked to him/her

It was mentioned that using digital pen in online mathematics courses increased students' interests and participations. In researchers' observations, also, it was seen that students' participation level increased in online mathematics courses in which digital pen was used, students were more willingly to the course and asked more questions to the faculty member, and sent less message about extracurricular topics. Most of the participants (65.6 %) expressed that the use of a digital pen increased the willingness and interest in online mathematics. *"... digital pen increased interest towards the course fairly. It was both intriguing and very helpful indeed. I sometimes studied Math over the nights. I was looking forward the fallowing question to answer it promptly."* [K-7] and *"courses were more enjoyable. It was a different pen and useful. I could say that my motivation increased. I thought my friends were so. Because we needed to show what we think comfortably. This pen enabled it"* [K-21]. 43.7 % of the participants stated that the use of digital pen in related courses increased participation: *"like all my friends, when compared the previous weeks, I started not to miss especially the math class. Because I began to like Mathematics course. I meant that I studied more by means of this pen."* [K-31] and the *"digital pen provided students to participate in the course, be more active and follow the course"* [K-20].

In the interviews, the participant expressed their opinions about comparison of mathematics courses in online distance education and traditional face to face classroom environment in terms of student and teacher roles. Participants stated that distance education students using digital pen were more advantageous compared to the students in formal education. It was emphasized that distance education students were more advantageous as they connected to the learning environment as voice and video and writings written by digital pen could be seen both by students and by faculty members simultaneously: *"For example compared to the formal students, I could solve problems more comfortably and show them to my teacher and friends. I did not feel the pressure and anger while solving on the whiteboard in front of everybody. As to me, distance education students were more comfortable in this issue"* [K-10], *"According to the formal distance education courses in mathematics processed with a digital*

pen and process your math class, I think it melts the difference between us and our students in formal education course, according to them, allows us to be more active" [K-27]. 25 % of the participants mentioned that faculty members in distance education mathematics courses could not experience the complications that experienced in the traditional classroom environment and they could have more effective courses. Relative participants expressed their opinions as follows: *"In formal education environment, board was used. While using the board, teachers and students were back to back and there wasn't communication. Whereas, in distance education, teacher using digital pen could write and see in the same time and students could see what the teacher simultaneously. I thought this relaxed the teacher more"* [K-8], *"In distance education environment, our teacher could make more activities and group works. And what he wrote could be seen by everybody. He could see and control immediately. Our learning was more advantageous compared to the environment in formal education"* [K-29].

The results of the interviews with the participants were matching with the results in the researcher's observations. It was seen that alternative practices that students tried to do before using digital pen were time consuming and made the classroom management difficult in terms of faculty member. Performed observations seemed to support the statements of the participants.

Discussion and conclusion

In many pen based technology studies in the literature, it was realized that pen based technologies were used to ease classroom interaction and communication in face-to-face learning environments. In this study, digital pen, one of the pen based technologies, was used in online mathematics course by distance students and using the digital pen in the online mathematics course was evaluated from the distance students' perspectives.

It was seen that when supporting technologies as digital pen wasn't used, students used entirely a different language instead of mathematical expressions and both students and teachers had ambiguity for these answers. Also it was stated that answering the questions with keyboards that provide only alphabetic and numeric entry caused problems in learning environment. It was concluded that digital pen enabled students and faculty members to express themselves mathematically more comfortable. It was seen that faculty member and students could easily transferred and used their own hand writings to digital media with digital pen in online mathematic courses, special mathematical expressions and geometric shapes could be easily shared on the screen as they shared on the board in classical classroom environments. Similarly, Galligan, Loch, McDonald and Taylor (2010) indicated that slides could not respond to instantaneous needs in face-to-face or online distance mathematics courses and corrections on these slides could not be done immediately while responding to the students' questions. And also, pen based technologies allowed electronic handwriting while explaining mathematical content to the students. In another study, attention was drawn to fact that mathematical content (graphics, shapes, etc.) could be written with handwriting electronically, and thus it had a positive effect on education and training (Weitz, Wachsmuth & Mirliss, 2006).

It was underlined that before using the digital pen in online distance education environment in the study process, students had many problems in participating actively in course. In order to overcome the problem, distance education students preferred to share mathematical problems in the media by solving them on a paper and scanning them or taking their photos and writing them with a keyboard. In this case, transferring the solution to digital media or overcoming microphone problems caused loss of time and this loss of time distracted the attention and reduced the students' attention. It was seen that while presenting in face to face classroom environment, if faculty member stood in front of the projection device, students couldn't see writings and their attention would distract; in online distance education environment, simple

audible expression or using slides caused loss of time. In the study of Brophy & Walker (2005), it was concluded that the use of pen-based technologies in the face to face classroom environment prevented loss of time, the attention of the students wouldn't distract, students could see the problem solving stages and they could take notes with their handwritings in electronic media.

It was realized that the slides and pictures prepared for the mathematics course in online distance education were prepared and used as static visual materials having limited interaction. In online environment during mathematics problem solving, instead of seeing operation step by step, students could see all at once. In addition, it was not usually possible to interfere with the course materials and take notes on them. However, it was hard for the faculty member to see in which step the student made mistake. It was concluded in this study that digital pen applications offered solutions to the mentioned problems, allowed students and teachers to interfere with the materials shared on the screen, share their writings immediately and it made available to observe in which step the students made mistake. It was emphasized in Anderson, et al. (2007), pen-based technologies used in normal classroom environments enable to show both student and tutorial in which step they were in an operation process, and also it contributed to state student's interpretations in these operations, too. It was stated in another study that commonly used and non-interactive course materials in "ppt" and "pdf" format turned into interactive materials with pen based technologies and mathematical symbols could easily be written on these materials (Loch & Donovan, 2006). In Reins's (2007) study it was stated that problem solving had operation steps in mathematics course and using digital pen in these operations was effective in visualization in students' minds and also in filling gaps or instant note taking, digital pen was very useful (Loch & Donovan, 2006).

When the findings of the study were examined, it was concluded that using digital pen in online distance education environment increased the interaction between student and the teacher, enable to give feedback appropriately on time and promote student participation. This result showed consistency with the results of Siozos, Palaigeorgiou, Triantafyllakos and Despotakis (2009) that pen based technologies allowed students to answer the open ended mathematical questions with their own handwritings and enable teachers to give healthy feedback to these answers. Also in this study, it was concluded that as using digital pen in online mathematics course decreased loss of time, prevented distraction and provided active participation, it increased students' interest to the course. Similarly, in another study, it was concluded that using the relevant technologies made participants active, it increased student motivation (Casas, Ochoa & Puente, 2009).

As a result, it can be said that enabling pen-based technologies to use by distance students and online mathematics teachers is very important to facilitate interaction and learning mathematics in online distance education mathematics courses. A training program can be designed for distance students and online mathematics teachers not to have problems in using digital pen integrated in online distance education environment. There are several limitations to the study. First, the findings of the study are based on a total of 32 online students' perspectives. Second, study process was short time for a qualitative study. Future studies investigating using digital pen technology with more online students in a longer process is required.

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