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THE EFFECT OF COMPUTER-AIDED 3D MODELING ACTIVITIES ON PRE-SERVICE TEACHERS' SPATIAL ABILITIES AND ATTITUDES TOWARDS 3D MODELING

Ali Ihsan Benzer,
Bunyamin Yildiz

Abstract. *The computer-aided 3D modelling which is one of the innovative technologies can offer great opportunities to improve students' skills. The aim of this research was to examine the effects of computer-aided 3D modeling activities on pre-service teachers' spatial abilities and attitudes towards 3D modeling and the relevant course. The study group of the research was composed of 55 pre-service IT teachers at a state university in Turkey. The research was carried out in quasi-experimental design based on pre-post test model. The experimental research was carried out with the experimental group for 14 weeks. During the 3D modeling learning/teaching process, a five-stage education framework based on problem-based and project-based learning approaches was used. "Purdue Visualization of Rotations Test" and "Attitude Scale towards 3D Modeling and 3D Modeling Course" were used as data collection tools in the research. As a result, it was found out that computer-aided 3D modeling activities improved the spatial abilities of pre-service teachers also increased their attitudes towards 3D modeling and the course. It was concluded that the education of computer-aided three-dimensional modeling offers important opportunities to improve spatial abilities.*

Keywords: *3D modeling education, 3D modeling, 3D modeling attitude, pre-service teachers, spatial ability.*

Ali Ihsan Benzer, Bunyamin Yildiz
Hatay Mustafa Kemal University, Turkey

Introduction

Spatial ability is one of the leading cognitive competencies that can affect the success of individuals in their daily and professional lives. Therefore, developing spatial ability has become one of the main objectives of education. Spatial ability has been the subject of debate for nearly a hundred years (Bishop, 1980; Sorby, 1999). Galton's work in 1918 has been referred to as the main source of research on spatial ability (Friedman, 1992). When the literature on spatial ability is examined, it was seen that terms such as "spatial skill", "visuo-spatial ability", "spatial thinking", "spatial reasoning" and "spatial sense" which have a similar meaning were used instead of the term "spatial ability". So far, many definitions have been made about spatial ability. Still, there is no consensus on the definition of spatial ability (Kösa & Karakuş, 2018). Linn and Petersen (1985) described spatial ability as the ability to describe, transform, create and remember symbolic and non-linguistic information. Tartre (1990) defined spatial ability as the entire of mental skills related to understanding, changing, reorganizing, or interpreting relations in visual terms. Lohman (1996) defined spatial ability as the ability to create and keep in mind, and retrieve, and transform visual images. When the definitions are considered together, spatial ability can be defined as the capability to perform manipulative operations on visual images in mind and to remember, understand and analyze relations between visual images. In the literature, there are studies in which spatial ability is subdivided into two components as spatial visualization and spatial orientation (Clements, 1998; McGee, 1979; Tartre, 1990) or spatial relations and spatial visualization (Olkun, 2003; Olkun & Altun, 2003; Pellegrino, Alderton, & Shute, 1984) or into three components as spatial perception, mental rotation and spatial visualization (Linn & Petersen, 1985).

Spatial ability that is one of the important components of multiple intelligences (Gardner, 2011) and one of the important individual differences (Lubinski, 2010), can vary depending on gender (Battista, 1990; Erkek, Işıksal, & Çakıroğlu, 2017; Ganley & Vasilyeva, 2011; Hacıömeroğlu & Hacıömeroğlu, 2017; Yenilmez & Kakmacı, 2015; Yıldırım Gül & Karataş, 2015), age and spatial experience (Salthouse, Babcock, Skovronek, Mitchell, & Palmon, 1990).

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Spatial ability is an important factor that can affect success in the fields of mathematics and geometry (Battista, 1990; Bulut & Köroğlu, 2000; Guay & McDaniel, 1977; Tartre, 1990; Ünlü & Ertekin, 2017), engineering (Sorby, 1999; Sorby & Baartmans, 2000; Yue, 2008), chemistry (Bodner & Guay, 1997; Carter, Larussa, & Bodner, 1987; Pribyl & Bodner, 1987; Wu & Shah, 2004), physics (Delialioğlu & Aşkar, 1999; Kozhevnikov, Motes, & Hegarty, 2007), geology (Kali & Orion, 1996; Uttal & Cohen, 2012), architecture (Arslan & Dazkir, 2017), health, medicine and dentistry (Hegarty, Keehner, Khooshabeh, & Montello, 2009; Nguyen, Mulla, Nelson, & Wilson, 2014). Spatial ability which can affect success in various fields and can lead to significant individual differences in learning environments is often neglected in educational and instructional settings (Lubinski, 2010).

Science, mathematics, and engineering are among the fields where spatial ability receives the biggest emphasis for success. Similarly, spatial ability plays a critical role for student achievement in Science, Technology, Engineering, and Mathematics (STEM) education, which is an innovative teaching approach (Stieff & Uttal, 2015; Uttal & Cohen, 2012; Wai, Lubinski, & Benbow, 2009). Developing spatial abilities of students studying in STEM education, one of the popular educational approaches of today, can increase their academic achievement (Stieff & Uttal, 2015).

Even if spatial ability that is critical to success in many fields is considered as an inborn characteristic, whether the spatial ability can be changed or to what extent it can be changed by the environment is one of the important research topics of interest (Ben-Chaim, Lappan, & Houang, 1988). This situation attracts the interest of many researchers and leads to many studies to be done on the development of spatial ability.

According to many studies in the literature, it is possible to develop spatial abilities through appropriate training activities (e.g. Alkan & Erdem, 2011; Baki, Kösa, & Güven, 2011; Demirkaya & Masal, 2017; Güven & Kösa, 2008; Kösa & Kalay, 2018; Kösa & Karakuş, 2018; Kurtuluş & Uygan, 2010; Olkun, 2003; Rafi, Anuar, Samad, Hayati, & Mahadzir, 2005; Sorby, 1999; Sorby & Baartmans, 2000; Uygan & Kurtuluş, 2016).

Computer-aided 3D design and modeling programs, which have become widespread in recent years, offer significant opportunities for the development of spatial ability. It has been reported that the 3D modeling activities using SketchUp software have improved the spatial abilities of engineering students (Martín-Dorta, Saorín, & Contero, 2008), pre-service mathematics teachers (Kurtuluş & Uygan, 2010; Uygan & Kurtuluş, 2016), 8th grade students (Toptaş, Çelik, & Karaca, 2012), the 3D modeling and design activities using Tinkercad software have improved the spatial abilities of 6th grade students (Dere, 2017) and design activities using AutoCAD software have improved the spatial abilities of engineering students (Kösa & Karakuş, 2018) in researches conducted to improve spatial abilities.

There is a close interaction between the computer-aided 3D design and modeling process and the spatial ability (Huang, Chen, & Lin, 2019). It is because various perspectives are employed in the modeling process carried out through computer-aided 3D modeling software and 3D objects may require formative operations such as scaling, rotation, cutting, and bending.

3D modeling, which is the process of developing the mathematical representation of a three-dimensional object through special software (Spallone, 2015), is widely used in the fields of cinema, advertising, medicine, industry, engineering, forensics, architecture, games, culture and education (O'Malley, 2015). The widespread use of 3D printer technology in industry and education settings (Huang et al., 2019; Kuzu Demir, Çaka, Tuğtekin, Demir, İslamoğlu, & Kuzu, 2016) and decreased costs of 3D printing technologies in recent years push up the interest in 3D design and modeling technologies (Huang & Lin, 2017; Huang et al., 2019). Also, as a result of the developments in the field of informatics since the 1980s, computer-aided 3D modeling and design courses have been given place in higher education curricula (Huang & Lin, 2017; Varinlioğlu, Alaçam, Başarır, Genca, & Üçok, 2016; Yue, 2008). Similarly, there is an increasing interest in 3D modeling in Turkey and 3D modeling courses are introduced to curricula for associate degree and undergraduate degree programs related to technical fields and design. Finally, Turkish Council of Higher Education (CoHE) as the body regulating Turkish higher education institutions, updated the curriculum of teacher training programs in 2018. In this scope, "Modeling and Design in Education" course related to 3D modeling has been added to the curriculum of the Computer Education and Instructional Technologies program (CoHE, 2018).

Teaching innovative thinking skills among the 21st century skills (Ananiadou & Claro, 2009; Binkley, Erstad, Herman, Raizen, Ripley, Miller-Ricci, & Rumble, 2012; Voogt & Roblin, 2012) is one of the goals of contemporary education systems. Students can design original and innovative products through 3D modeling and design software and convert their designs into tangible concrete objects via 3D printers. For this reason, 3D modeling

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and design technologies can also offer great opportunities to gain innovative thinking skills to the students (Huang et al., 2019; Kostakis, Niaros & Giotitsas, 2015). In addition, 3D modeling and design education has begun to occupy an important place in STEM education and Maker movement, which are innovative teaching approaches (Bicer, Nite, Capraro, Barroso, Capraro, & Lee, 2017; Bull, Chiu, Berry, Lipson, & Xie, 2014; Taylor, 2016).

Problem of Research

Developing the spatial abilities of pre-service teachers and organizing activities to improve their spatial abilities can help pre-service teachers to contribute more to their students in their future professional lives (Özcan, Akbay, & Karakuş, 2016). Spatial ability is regarded as an indispensable factor for success in STEM, Science, Technology, Engineering, Art and Mathematics (STEAM), and Maker movement trainings. One main goal of the STEM, STEAM, and Maker movement trainings is to teach innovative thinking skills to students. Bearing this in mind, it seems to be a promising topic of interest to address development of the spatial abilities and attitudes towards 3D modeling of pre-service teachers who will be able to assume big responsibilities in those trainings.

The review of the related literature yielded only few studies examining effects of 3D modeling activities using 3D modeling software on participants' spatial abilities and attitudes towards 3D modeling.

The aim of this research was to examine the effects of computer-aided 3D modeling activities on the spatial abilities of pre-service information technologies (IT) teachers and their attitudes towards 3D modeling and 3D modeling course.

The research was carried out in search of answers to the following questions:

a) Do computer-aided 3D modeling activities lead to a meaningful improvement in the spatial abilities of the pre-service teachers?
b) Do computer-aided 3D modeling activities lead to a meaningful improvement in the attitudes of the pre-service teachers towards 3D modeling and the relevant course?

Research Methodology

General Background

This research tested the hypothesis that computer-aided 3D modeling activities positively affect the spatial abilities of participants and their attitudes towards 3D modeling. For this reason, the post-positivist paradigm was adopted to carry out the research which employed experimental design and quantitative data were collected using reliable measurement tools. This was an experimental research based on quantitative methodology. Experimental researches are performed in order to explain and predict the possible relationship between dependent and independent variables by manipulating independent variables in the supervision of the researcher (Creswell, 2012; Karasar, 2016). A control group was used for comparisons with the experimental group. Since the participants could not be assigned to groups randomly, quasi-experimental design was used in the research (Creswell, 2012). This research was conducted in the spring semester of 2016-2017 academic year. The research was carried out for one semester (14 weeks).

Participants

The minimum sample size required for research was calculated using the G*power program: the input parameters were the tail=one, the effect size $d = .70$, $p = .05$, power = .80. As a result, the minimum number of participants for each group was found as 26. Participants of the research were 55 pre-service IT teachers studying at Computer Education and Instructional Technology (CEIT) program of a state university. The experimental group (EG) consisted of 27 fourth-year pre-service IT teachers taking the elective course in which 3D modeling activities were carried out. The control group (CG) consisted of 28 third-year pre-service IT teachers who were not enrolled in the elective course. The participants included 30 male and 25 female pre-service IT teachers. Prior to the implementation, the participants were informed about the purpose of the research and they all participated on voluntary basis. The volunteer participants were then assured about the confidentiality of their answers and use of the data for scientific purposes only. The ROT test was applied to all pre-service IT teachers studying at CEIT program for the selection

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and determination of the CG. When the ROT test scores obtained were analyzed, it was seen that the mean score of the third-year pre-service teachers' group was the closest one to the mean score of the EG. Since courses taken by these two groups were a lot similar than others, the third-year and the fourth-year pre-service teachers were decided to match by taking into account ROT test results.

Instruments

Two data collection tools were used in the research. These tools were "Purdue Visualization of Rotations Test (ROT)" and "Attitude Scale towards 3D Modeling and 3D Modeling Course (AS3DM)".

The ROT was a shorter version of the Purdue Spatial-Visualization Test: Visualization of Rotations (PSVT: R) which was developed by Guay in 1976. The original PSVT: R had 30 multiple-choice items (Maeda & Yoon, 2013). The ROT test used in this research was constructed by removing 10 questions from the PSVT: R by Bodner and Guay (1997).

The shorter version ROT, a paper-and-pencil test, consisted of 20 multiple-choice items. The purpose of the test was to measure participants' abilities to comprehend and visualize the rotation of 3D objects mentally. In this research, the ROT test which was constructed by Bodner and Guay (1997) and translated into Turkish by Yılmaz (2012) was used to measure the spatial ability of the participants after obtaining the necessary permissions.

Each item in the ROT test consisted of three parts. In part one, the respondent was expected to understand the relation between the given object and rotated version of the object in space. Part two required the respondent to visualize rotation of the given object in the same way as the object given in the previous part. In the last part, it was required to choose the correct rotation among five options.

In responding to the ROT, being quick was equally important to giving the correct answer. During the implementation of the test, the participants were given 10 minutes to respond to 20 questions, as recommended by Bodner and Guay (1997). The responses were evaluated against the answer key sent by Bodner. Each correct answer was scored as 1 and each wrong and blank answer as 0. The scores of the test ranged from 0 to 20.

The validity of ROT test has been validated in most studies so far. Bodner and Guay (1997) reported the reliability coefficients in the range of 0.78 and 0.85. The ROT test has been used in many studies to measure spatial ability (e.g. Akıllı & Seven, 2014; Alkan & Erdem, 2011; Anvari, Tran, & Kavakli, 2013; Battista, 1990; Brownlow, McPheron, & Acks, 2003; Brudigam & Crawford, 2012; Carter et al., 1987; Harris, Peck, Colton, Morris, Neto, & Kallio, 2009; Karaçöp & Doymuş, 2013; Morgil, Yavuz, Oskay, & Arda, 2005; Pribyl & Bodner, 1987; Poulin, O'Connell, & Freeman, 2004; Unal, Jakubowski, & Corey, 2009; Wang, Chang, & Li, 2007).

"Attitude Scale towards 3D Modeling and 3D Modeling Course (AS3DM)" was used to examine pre-service teachers' attitudes towards 3D modeling and 3D modeling course. The scale was developed by Benzer (2018) with both validity and reliability verified. The scale had three factors as "Importance", "Interest", and "Anxiety". It was a 5point Likert type scale with responses as "Strongly Agree", "Agree", "Neutral", "Disagree" and "Strongly Disagree". Of the items, 16 were positive statements, while the rest of 14 were reversely stated. The overall scale yielded the reliability coefficient of 0.94. Specifically, the sub-scales were found to be reliable at 0.90, 0.91, and 0.82, respectively (Benzer, 2018).

Procedure

Before carrying out the main research, a pilot research was conducted on 3D modeling activities and data collection tools at the vocational college of a state university. In the planning of the activities to be carried out during the implementation process, it was taken advantage of two domain experts` views, reference books regarding 3D modeling, 3D modeling videos shared on online video sharing websites.

The main implementation was carried out in the computer laboratory for 14 weeks, three hours per week as an elective course. The aim of this course was to teach students how to work with 3D objects, develop 3D designs, models and animations, and how to perform tasks related to materials, mapping, camera and lighting on models they constructed. According to Huang et al. (2019), the aim of the 3D modeling course in technical and vocational education is to integrate theories and practices so that students can use the knowledge they learned to produce work. The course content is presented in Table 1.

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Table 1. Course content.

Week	Topics
1	Introduction to 3D modelling
2	User Interface
3	3D objects and their properties
4	3D objects and their properties
5	2D objects and their properties
6	2D objects and their properties
7	3D animation
8	Modeling techniques
9	Modeling techniques
10	Cameras
11	Rendering
12	Materials and Mapping
13	Materials and Mapping
14	Lighting

During the implementation, architectural modeling was practiced by means of table, chair, vase, house, sofa set, and building modeling activities. As a part of the implementation, 3D modeling activities were realized with the aid of 3ds Max software, commercial software by Autodesk. The company offers students a three-year license of 3ds Max free of charge for educational purposes. The software enables 3D modeling through imaging of an object from the top, right, left, front and other viewpoints on the planes x, y, and z in space.

Kozma (1994) pointed out that using the media and appropriate teaching methods together can positively affect learning. Therefore, it is important that computer-aided 3D modeling and design teaching should be performed with useful teaching methods and techniques effectively and efficiently to meet the needs of 21st-century learners. Teaching and activities during the implementation period were built upon problem-based and project-based learning approaches, which are contemporary learning approaches. Problem-based and project-based learning are student-centered and teacher-supported innovative approaches in which students are responsible for their own learning and can manage their own learning process in collaboration, learning takes place around real-life problems, and necessary learning opportunities are extended for the 21st century (Bell, 2010; Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991; Kocaman-Karoğlu, 2016; Ravitz, Hixson, English, & Mergendoller, 2012). Such models of learning help students combine theoretical knowledge with practical skills (Savery, 2006). Problem-based and project-based learning hold the potential to increase students' achievement and motivation for learning issues and environments, and also foster their interests and attitudes (Bell, 2010; Demirel & Dagyar, 2016; Hmelo-Silver, 2004; Hung, Hwang, & Huang, 2012; Musa, Mufti, Latiff, & Amin, 2011; Kaufman & Mann, 1997; Sezgin-Selcuk, 2010).

When students experience success, they may become more likely to develop positive attitudes and self-confidence towards teaching (Usta, 2016). To assure a sense of accomplishment for all of the pre-service teachers and the planning of the teaching and activities for an effective and efficient learning-teaching process, a method was adopted, which was stepwise (Chien, 2006), simple to complex (Olkun, 2003), got more difficult gradually (Martín-Dorta et al., 2008), was inductive (Dere, 2017), allowed cooperation (Martín-Dorta et al., 2008), and held learning in the master-apprentice framework (cognitive apprenticeship strategy) (Huang et al., 2019). Apart from that, the teaching process was divided into stages. The stages followed for the teaching process were classified and determined by benefiting from the research of Justi and Gilbert (2002). Justi and Gilbert (2002) divided the competence levels of the modeling process related to the field of science into five stages. The education framework used in this research consisted of five stages, as shown in Figure 1. The stages of the teaching/learning process are described below.

1. **Learning prior knowledge:** This stage covered the process of teaching to learners the basic knowledge about the topic and the ability to use the interface of the software. Knowledge was usually provided by the instructor.
2. **Learning to use 3D models:** This stage was dedicated to demonstrating the construction steps of the

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pre-planned 3D models by the instructor, creating of the demonstrated 3D models by pre-service teachers (Demonstration-practice teaching) (Huang et al., 2019) and discussing differentiated methods for building 3D models. The primary objective of this stage was to make sure that each pre-service teacher successfully creates the 3D models previously demonstrated. The 3D model (problem) and how to create it (answer) were provided by the instructor. At this stage, the instructor was responsible for showing the construction phases of the 3D models, supporting the pre-service teachers in designing the 3D models within master-apprentice relationship (cognitive apprenticeship), guiding them, encouraging the pre-service teachers to have conversations, supporting cooperation among them, and increasing the motivation of the pre-service teachers.

3. **Learning how to revise 3D models:** This stage involved the process in which students made some revisions (formal changes) on the 3D model that was constructed in the previous stage. The main objective of this stage was to enable each pre-service teacher to successfully make the desired revisions on the 3D models. Knowledge of how to make revisions (answer) was partially provided by the instructor. At this stage, the instructor undertook a similar role to the one at the previous stage.
4. **Learning to reconstruct 3D models:** At this stage, problem-based learning method was used. The stage involved the process of combining (Huang et al., 2019) and reconstructing the 3D modeling tasks performed in the previous lessons and transforming them into complex, advanced and ill-structured modeling problems. Ill-structured problems were explained but their answers were not provided by the instructor. At this stage, pre-service teachers applied their previous 3D modeling knowledge and skills for solving the newly given 3D modeling problems so that their problem-solving skills could be improved, and they could learn effectively. At this stage, the role of the instructor was to give feedback to the pre-service teacher on their performances and to assist them to solve the problems they face in cooperation with their peers. However, the instructor avoided directly showing the solution leading to the answer.
5. **Learning to construct new 3D model**: This stage was closely related to project-based learning method. Towards the end of the semester, the participant pre-service teachers, in addition to the in-class activities, were assigned a project in which they were supposed to model a three-storey architectural structure by using all of the modeling skills and knowledge acquired in class. It helped to make sure that the pre-service teachers applied all the knowledge and skills they learned about 3D modeling to the 3D modeling project, the learning became more permanent, and their innovative thinking skills flourished. At this stage, the role of the instructor was to give feedback to the pre-service teachers on their project performances and to help them solve the problems faced in cooperation with their peers.

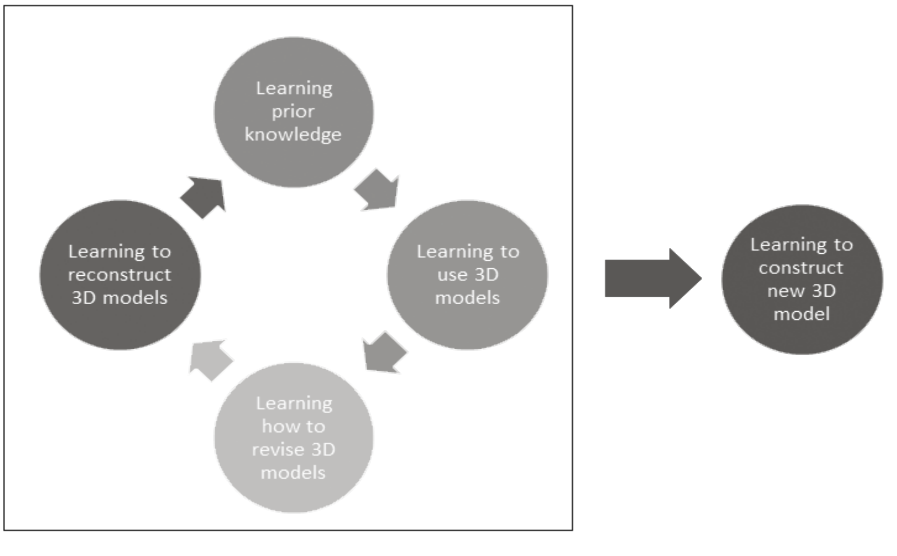

Figure 1. The education framework.

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Most of the time, the first three stages were combined in one week and stage four in the following week or vice versa. As for the last stage, the participants were then instructed to carry out works related to 3D architectural modeling by reverting to all of their modeling skills and knowledge towards the end of the semester, in addition to in-class activities.

Before and after the treatment, the EG was administered the ROT test and AS3DM. However, only the ROT test was administered to the CG. The pre-service teachers were given 10 minutes to solve 20 multiple-choice items in the ROT test in the paper-pencil format. The data collection tools were administered by the same researcher.

Data Analysis

In the ROT test, each correct answer was given 1 point, but wrong and blank answers were given 0 point. The highest and the lowest test scores were 20 and 0, respectively. The AS3DM was a Likert-type scale which ranked positive items from 5 to 1, while negative items were scored from 1 to 5. In this research, collected data were analyzed by using SPSS. In order to determine the statistical methods to be used, pre-test and post-test data were tested for normal distribution. In this scope, the Shapiro-Wilk normality test results were examined. It was found out that all the test scores except the AS3DM pre-test scores (p <.05) showed normal distribution (p >.05). The ROT test scores with normal distribution were analyzed with the paired samples t-test and the independent samples t-test among parametric tests; whereas non-normally distributed the AS3DM pre-test scores were analyzed with non-parametric Wilcoxon signed rank test.

Research Results

In this section, the ROT and AS3DM scores obtained by the pre-service teachers are presented to put forward the change in their spatial ability and attitudes before and after the treatment. Table 2 presents the mean and standard deviation values of the EG and CG scores obtained from the ROT pre-test and the independent samples t-test results.

Table 2. Results of descriptive statistics and paired samples *t*-test for ROT pre-test scores of EG and CG.

Group	*N*	*M*	*SD*	*df*	*t*	*p*
EG	27	9.33	3.56	53	.199	.843
CG	28	9.14	3.52			

Table 2 shows that the EG had a mean score of M=9.33 and the CG had M=9.14 in the spatial ability test administered at the beginning of the research. As also seen in Table 2, the independent samples t-test yielded no significant difference between the EG and CG based on the ROT pre-test scores [t (53) = .199, p > .05]. It can be said that both groups were equivalent in the spatial ability test before the treatment.

Table 3 shows the results of the dependent samples t-test, which was administered to calculate the mean scores of the EG in the ROT before and after the treatment, the standard deviation values, and the statistically significant difference, if any, between the mean scores.

Table 3. Results of descriptive statistics and paired samples *t*-test for ROT pre-post test scores of the EG.

Test	*N*	*M*	*SD*	*df*	*t*	*p*
ROT Pre-test	27	9.33	3.56	26	-4.256	.0001
ROT Post-test	27	12.07	3.63			

It is seen in Table 3 that the ROT pre-test mean score of the EG was M=9.33. After the treatment, the ROT was re-administered as post-test where the pre-service teachers' mean score increased to M=12.07. A statistically significant difference was noted between the ROT pre-test and ROT post-test scores of the EG in the paired samples t-test [t(26) = -4.256, p <.01]. This result implies that computer-aided 3D modeling activities proved influential on pre-service teachers' spatial abilities in a positive way.

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Table 4 shows the results of the paired samples *t*-test, which was administered to calculate the mean scores of the CG in the ROT before and after the treatment, the standard deviation values, and the statistically significant difference, if any, between the scores.

Table 4. Results of descriptive statistics and paired samples *t*-test for ROT pre-post test scores of the CG.

Test	*N*	*M*	*SD*	*df*	*t*	*p*
ROT Pre-test	28	9.14	3.52	27	-.316	.754
ROT Post-test	28	9.36	3.87			

It is seen in Table 4 that the ROT pre-test mean score of the CG was *M*=9.14. At the end of the treatment, the ROT was re-administered as post-test. In this test, the pre-service teachers recorded a slightly higher mean score, being *M*=9.36. A statistically significant difference was not found between the ROT pre-test and ROT post-test scores of the CG in the paired samples *t*-test [t (27) = - .316, p >.05]. It can be inferred that the pre-service teachers who had not been taught through 3D modeling activities did not experience a significant increase in their spatial abilities.

Table 5 shows the mean and standard deviation values of the EG and CG scores obtained from the ROT post-test, and the independent samples *t*-test results.

Table 5. Results of descriptive statistics and independent samples *t*-test for ROT post-test scores of the EG and CG.

Group	*N*	*M*	*SD*	*df*	*t*	*p*	*d*
EG	27	12.07	3.63	53	2.684	.010	.72
CG	28	9.36	3.87				

In the spatial ability test as post-test, the mean score of the pre-service teachers in the EG was *M*=12.07, while the same value was *M*=9.36 in the CG. When Table 3, Table 4 and Table 5 are considered together, an increase was observed in the ROT post-test scores of the EG. As a result of the computer-aided 3D modeling activities, the EG achieved an increase by 29.4 % in their spatial ability. Conversely, there was no significant improvement in the spatial ability scores of the CG. As seen in Table 5, the independent samples *t*-test delivered a statistically significant difference in favor of the EG in the ROT post-test scores [t (53) = 2.684, p < .05]. It seems that computer-aided 3D modeling activities were influential on improving the pre-service teachers' spatial abilities. The Cohen`s *d* value was calculated to measure the effect size. According to the benchmarks proposed by Cohen (1988) for interpreting the Cohen`s *d* value, .2 indicates a small effect, .5 a medium effect, and .8 a large effect. Given the Cohen`s *d* value for *t*-test (.72), it can be said that the intervention had a medium effect on the spatial ability scores.

Table 6 exhibits the mean scores and standard deviation values from the AS3DM scale administered to the EG before and after the treatment for examining their attitudes towards 3D modeling and the course.

Table 6. Results of descriptive statistics for the AS3DM scores obtained by the EG.

Test	*N*	*M*	*SD*
AS3DM Pre-test	27	3.77	.48
AS3DM Post-test	27	4.09	.54

According to the results shown in Table 6, there was an increase in the AS3DM post-test mean score of the EG. The participants in this group noted the mean score of *M*=3.77 in the AS3DM pre-test. At the end of the research, the scale was re-administered. In the post-test, the pre-service teachers in the EG achieved higher average scores, resulting in *M* = 4.09. Due to the non-normal distribution of AS3DM pre-test scores, the scores obtained from this test were analyzed by using non-parametric Wilcoxon signed-rank test.

Table 7 presents results of the Wilcoxon signed-rank test, which was applied to find out significant differences, if any, between the participants' scores in AS3DM pre-post tests.

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Table 7. Results of Wilcoxon signed-rank test for the AS3DM pre-post test scores of the EG.

Post Test-Pre Test	*N*	Mean Rank	Sum of Ranks	*z*	*p*
Negative ranks	5	15.80	79.00	2.64*	.008
Positive ranks	22	13.59	299.00		
Ties	0				

*Based on negative ranks

As seen in Table 7, Wilcoxon signed-rank test gave away a significant increase in AS3DM post-test taken by the EG (z= 2.64, p < .05). So, it can be said that computer-aided 3D modeling activities carried out in the five-stage education framework based on problem-based learning and project-based learning approaches, have a positive impact on pre-service teachers' attitudes towards 3D modeling and 3D modeling course.

Discussion

In this research, the effect of computer-aided 3D modeling activities on the spatial abilities of pre-service IT teachers and their attitudes towards 3D modeling was examined. The research was planned as an experimental research involving an experimental and a control group. The research data were collected by means of "Purdue Visualization of Rotations Test (ROT)" consisting of 20 questions and "Attitude Scale towards 3D Modeling and 3D Modeling Course" with 30 items. While the EG used both of the instruments at the beginning and at the end of the treatment, the CG was administered only by the ROT test. The intervention lasted for 14 weeks.

The results obtained at the end of the research were summarized under the two main headings below with reference to comparable studies.

The Effect of 3D Modeling Activities on the Spatial Ability

In this research, it was found out that 3D modeling activities significantly improved the spatial abilities of the pre-service teachers in the EG. On the other hand, there was no such increase in the spatial abilities of the CG, who had not gone through the same process of learning. This suggests that 3D modeling activities are effective in developing spatial abilities. However, it was observed that the curriculum courses taken by the CG students throughout the semester were not effective in developing their spatial abilities. This indicates the need that trainings targeting the spatial ability should include goal-oriented, well-planned, and specific activities.

It is possible to divide 3ds Max software interface used for 3D modeling activities divided into several windows that allow simultaneous viewing of 3D objects from different viewpoints such as top, right, left, and perspective. In this way, 3D objects can be viewed from different perspectives and changes on the object can be monitored simultaneously in different windows. Perspectives of objects can be two-dimensional such as from top, front, and left; or they can give three-dimensional views like a perspective view. The boosting effect of 3D modeling activities on the students' spatial abilities could be explained with the fact that the students had to perform the manipulating operations such as rotating, moving, and changing dimensions of 3D objects on the axes x, y, and z through various points of views (viewing windows) for several times before completing the 3D modeling assignments. Most researchers have studied the concept of spatial ability in two parts as spatial visualization and spatial orientation. Spatial visualization is the ability to manipulate, rotate, bend, or invert visual objects in the mind, whereas spatial orientation refers to the ability not to confuse different orientations of visual object(s) or to properly understand the order of such objects given in a specific pattern (McGee, 1979). Spatial orientation tasks require the understanding of the change and representation between two objects, rather than mentally rotating the objects (Tartre, 1990). In view of this classification and definitions, 3D modeling activities performed on 3ds Max seem to present marked opportunities to improve both of the sub- abilities referred above.

The literature lends abundance of studies in compliance with findings of the research in that computer-aided 3D drawing, design, and modeling activities develop students' spatial abilities (e.g. Dere, 2017; Güven & Kösa, 2008; Kösa, 2016; Kösa & Karakuş, 2018; Kösa & Kalay, 2018; Kurtuluş & Uygan, 2010; Martín-Dorta et al., 2008; Šafhalter, Vukman, & Glodež, 2016; Toptaş et al., 2012; Uygan & Kurtuluş, 2016). However, there is also a research (Shavalier, 2004) which could not prove the effect of computer-aided design and modeling activities on the spatial ability.

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The Effect of 3D Modeling Activities on Attitude toward 3D Modeling

In the practical part of this research, it was found out that the five-stage computer-aided 3D modeling education using problem-based and project-based learning approaches led to a meaningful improvement in the attitudes of the pre-service teachers towards 3D modeling and the course. The education was started with the modeling activities which excluded high-level skills and were simple enough for all participants to taste the sense of achievement. Thanks to this choice, the pre-service teachers could not only arouse self-confidence towards 3D modeling and 3D modeling course but also enhance their motivation and upgrade their attitudes towards 3D modeling. Furthermore, the fact that a substantial part of the teaching was fulfilled within the framework of master-apprentice relationship, peer collaboration was promoted, and the participant pre-service teachers were given feedback increasing their motivation and morale might have played a role in improving their attitudes. Last but not least, the desired outcome might be partially accounted for by the five-stage education framework utilizing problem-based and project-based learning approaches as it bestowed an active part to the participants in the modeling activities, engaged them in the process of learning by doing, living, and designing, and motivated them to develop new products with their personal knowledge and experience.

All in all, the findings of this research in the matter of the effects of 3D modeling and design activities on the attitudes of the participants are in conformity with Dere (2017), Halıcı, Turhan, Aksu, and Varinlioğlu (2017), Huang et al. (2019), Martín-Dorta et al. (2008) and Shavalier (2004).

Conclusions

It is thought that 3D design and modeling teaching is likely to pose important opportunities for acquisition of "innovative thinking" skill among the 21st century skills. Also, it might pave the way importantly for development of spatial abilities, which are of critical importance for success in a number of fields such as science, technology, engineering, arts and mathematics.

The International Society for Technology in Education (ISTE) has set standards to support educators to be effective in learning settings using technology. According to ISTE standards for teachers, it is necessary and important for 21st century teachers to have necessary competencies to facilitate learning, improve innovative thinking skills of their students and develop the technology-based activities by using their knowledge of subject matter, pedagogical, and technology (ISTE, 2008). It is considered that spatial ability is an important factor for success in STEM, STEAM and Maker movement trainings and that one main goal of these trainings is to acquire innovative thinking skills to students. IT teachers might undertake major duties on STEM, STEAM, and Maker trainings. Therefore, it seems useful to give pre-service IT teachers trainings to develop the spatial abilities and give them proficiency and positive attitudes regarding 3D modeling. The 3D modeling education can help pre-service teachers to educate students equipped with 21st century skills in their future careers.

Within the scope of the research, it was found that computer-aided 3D modeling activities positively affect the spatial abilities of pre-service IT teachers. Contrarily, there was no significant increase in the spatial abilities of the students who did not attend the 3D modeling classes. Another result reached in this research is that the five-stage computer-aided 3D modeling education using problem-based learning and project-based learning approaches was proven to have a positive effect on pre-service teachers' attitudes towards 3D modeling and 3D modeling course.

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Ali Ihsan Benzer	PhD, Assistant Professor, Hatay Mustafa Kemal University, Department of Management Information Systems, Hatay, Turkey. E-mail: aibenzer@gmail.com
Bunyamin Yildiz	PhD, Professor, Hatay Mustafa Kemal University, Department of Mathematics, Hatay, Turkey. E-mail: byildiz@mku.edu.tr

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