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The effects of web-based interactive virtual tours on the development of prospective mathematics teachers' spatial skills

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A R T I C L E I N F O

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A B S T R A C T

The aim of this study was to investigate the effects of web-based interactive virtual tours on the development of prospective mathematics teachers' spatial skills. The study was designed based on experimental method. The "one-group pre-test post-test design" of this method was taken as the research model. The study was conducted with 3rd year students of department of mathematics teaching for primary schools in a state university, who had taken computer courses for two terms but hadn't been involved in a web-based interactive virtual tour before. A total of 60 teacher candidates were included in the study. The Purdue Spatial Visualization Test (PSVT) was administered as the pre-test and the post-test. This test was developed so as to consist of 36 multiple choice items and include the skills of mental visualization of objects based on their surface developments, mental rotation of objects and mental visualization of rotated views of objects. In conclusion, according to the findings, the greatest increase occurred in developments part of prospective primary school mathematics teachers' spatial skills. Secondly, there was an increase in the rotations part. Next, the lowest increase was found in the views part.

1. Introduction

Spatial ability has been recognized as an important human skill set to evaluate the effectiveness in learning, training, working, and even playing. While it is often overlooked as a curriculum goal, spatial ability is of importance to the complete learning of many concepts and skills, especially those in science and mathematics (Crano & Johnson, 1991; Lord, 1990; Pribyl & Bodner, 1987). That's why researchers investigate spatial ability by examining its distinct components. McGee (1979) suggest that spatial ability consists of two components: "spatial visualization" and "spatial orientation". While spatial visualization deals with the skills of mental controlling, rotating, rotating objects in space, spatial orientation involves mental visualization of rotated views of an object. Lohman (1988), on the other hand, adds "speeded rotation" component to the factors suggested by McGee (1979) and claims that this skill involves mental visualization of the rotation of shapes on a plane and therefore differentiates from spatial visualization. Linn and Petersen (1985) examine spatial ability under three dimensions and define it as "spatial visualization", "mental rotation" and "spatial perception". Also, Maier (1998, pp. 69–81) defines components of spatial ability under five headings as mental rotation, spatial perception, spatial orientation, spatial relations and visualization. On the other hand, this study is based on "spatial visualization", "spatial relations" and "spatial orientation" factors of spatial ability. While spatial visualization is defined in parallel to the definitions made by McGee (1979) and Lohman (1988), spatial relations involve the skills to understand the relations of shapes with their fragments and with each other. Spatial orientation, on the other hand, involves imagining oneself mentally oriented toward another point in space (Maier, 1998, pp. 69–81).

Spatial skills are important in teaching many subjects of mathematics, especially in teaching geometry. Smith (1998) emphasizes the importance of these skills saying, "Without spatial skills it would be difficult to exist in the world as one would not be able to communicate about position and relationships between objects, give and receive directions and imagine changes taking place in the position or size of shapes". Learning about space and development of spatial skills (e.g. drawing, producing models, changing models and arranging the environment) basically originate from geometric thinking. It is required that students perceive space and improve their spatial skills. The core reason for this is that "spatial understandings are necessary for interpreting, understanding, and appreciating our inherently geometric world" (NCTM, 2000).

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The primary goal of geometry can be summarized as learning about the properties of objects on plane and in three-dimensional space, identifying the relations among them, identifying geometric position, explaining and expressing rotations and proving geometric proposals (Baki, 2006). In other words, aims such as learning about and knowing geometric objects, discovering the relations among these objects and proving geometric proposals are the main objective in both two-dimensional and three-dimensional geometry. Altun (2004) states that there are many reasons why geometry should be included in school programs. Firstly, objects and beings around us mostly exist in geometric shapes and objects. Also, people make use of geometric shapes and objects in their daily lives or jobs. Efficient use of these units depends on understanding the relationship between the shape and function of objects. Solution of many simple problems in daily life which people have to sort out (making a frame, putting wallpaper, painting and building a store) is only possible by using basic geometric skills. Geometry is closely related to students' spatial skills. Spatial thinking is strongly and positively associated with mathematical thinking (Battista, 1990). NCTM (2000) suggests that geometry teaching involves three-dimensional tasks and provides students with opportunities to use their spatial skills in solving problems. Although curriculums cover three-dimensional space geometry in their backgrounds to improve spatial skills, the emphasis tends to be on two-dimensional plane geometry. Space geometry calculations emphasize the use of visual-spatial skills because they cover three-dimensional geometry activities. Therefore, three-dimensional space geometry is a more convenient area for using and improving spatial skills due to these properties.

Several interrelated studies show that spatial ability is certainly associated with mathematical achievement (Gallagher, 1989; Gimmestad & Sorby, 1996). Researchers argue that students can have a higher level of mathematical achievement provided that they are able to imagine (Battista, Wheatley, & Talsma, 1982; Fennema & Sherman, 1977; McKee, 1983). Students' academic achievement levels are closely associated with their spatial ability. In geometry calculations, for example, spatial ability is needed and possesses an important role (Garcia, Quiros, Santos, Gonzalez, & Fernanz, 2005). Also, spatial ability has a key role in surface and volume calculations of three-dimensional shapes. Moreover, students without proficient spatial skills are reported to have difficulty in calculating surface area of three-dimensional objects given (Liedtke, 1995). Battista et al. (1982) state that there is a statistically significant positive relationship between spatial ability and problem-solving performance. Mitchelmore (1976) reports that those students receiving high scores in spatial visualization test have also high levels of achievement in geometry and the ability of visualization of three-dimensional objects is directly associated with problem-solving skill (quoted in Capraro, 2000). In another study conducted on the relationship between spatial ability and geometric thinking, Naraine (1989) states that there is a significant relationship between students' van Hiele levels of thinking and spatial ability.

A deep understanding of geometry acts as an important factor in teaching spatial ability, but choosing the appropriate tools and methods in teaching geometry in particular also plays a key role in the development of this ability. Computer aided teaching has been used in developing spatial ability recently (Calcaterra, Antonietti, & Underwood, 2005; Smith et al., 2009). Dynamic software applications like Cabri 3D and Google SketchUp, which were developed to design and examine 3D structures in computer, make it possible to move and explore geometric objects that are difficult to examine on plane (Baki, Kösa, & Güven, 2011; Gürsoy, Yıldız, Çekmez, & Güven, 2009; Kurtuluş & Uygan, 2010). The role of various computer aided applications in developing spatial ability has been the focus of many recent studies. For example, in their study investigating the impact of geometry tasks carried out by using Cabri 3D software on prospective primary school mathematics teachers' spatial skills, Güven and Kösa (2008) report that Cabri 3D software both makes it possible to discover geometric relations and concepts easily and helps students develop spatial skills. Comparing the impacts of using dynamic geometry software and concrete materials to teach solid objects on prospective primary school mathematics teachers' spatial skills, Baki et al. (2011) state that spatial skills can be improved with appropriate tools and methods and multimedia and various dynamic software applications can contribute substantially to spatial visualization skills. Cohen and Hegarty (2008) carried out an experimental study on the impact of interactive computer animations prepared in Virtual 3D software and spatial visualization activities using visual geometric objects on the spatial visualization levels of university students with poor spatial skills. In that study they employed tasks designed to visualize and draw interface surfaces emerging as a result of cutting three-dimensional objects with plane and reported that the participant students' skills regarding mental visualization of objects' interface surfaces displayed a significant increase by means of these tasks. Spatial thinking is an inseparable part of real life and evidence suggests that choosing the appropriate tools and methods for teaching space geometry plays a key role in the development of this ability.

Spatial skills are the ability to locate objects in a three-dimensional space. This plays an important role in how people read a map, drive a car or follow building instructions. It is an important skill to develop, as spatial skills help determine how you interact with the world. There are many ways of developing better spatial skills, and one surprising tool for this purpose is video games. Multiple studies show that men typically have better spatial skill development than women (Meeker, 1991; Ogakaki & Frensch, 1994; Terlecki & Newcombe, 2005; Yang & Chen, 2010) but that video games could be used to even out that difference. On the other hand, research shows that differences with women and men on some tasks that require spatial skills are largely eliminated after both groups play a video game for only a few hours. Feng, Spence, and Pratt (2007) suggest that a new approach involving action video games can be used to improve spatial skills that are essential for everyday activities such as reading a map, driving a car or learning advanced math. Rafi, Anuar, Samad, Hayati, and Mahadzir (2005) employed an experiment using a Web-based Virtual Environment (WbVE) to evaluate a group of pre-service teachers' spatial ability after taking the Computer Aided-Design (CAD) course for teaching Engineering Drawing for secondary school subjects. In their study, selected subjects were pre-tested at the beginning of the semester with spatial tests focusing on mental rotation and spatial visualization to provide the baseline measurement. A desktop WbVE, which was employed and tested in the CAD laboratories to improve their spatial ability for five weeks of instructional treatment, was demonstrated. Post-testing of the spatial tests revealed that there was a significant improvement in the participants' overall spatial ability as measured by the test scores. Finally, interactive virtual tours, like action video games and Web-based Virtual Environment, can improve their users' spatial abilities.

A web-based virtual tour is a computer presentation of a place and it shows the geometrical properties of that area. The main item in such a tour is a viewing window that users can control. Users can easily and interactively have a real-like walk around the whole place and zoom in or out wherever they want. This 360-degree panoramic application provides users to look in any direction, see a full circle of the area and walk around by just clicking on the hotspots. Adding links to the images to pass the other images of the place makes possible to use the window as a navigation tool. Providing a floor plan helps users to navigate through the environment. A further step is making this floor plan interactive and integrated with the viewing window. In this way, photos and floor plan can be used together for wandering in the visited place. In today's world, the interactive 3D graphics at the web such as web-based virtual tours are getting more popular and day by day providing such tours is becoming crucial for the websites which present the places with visual importance. People can reach places which