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Effect of Modeling-Based Activities Developed Using Virtual Environments and Concrete Objects on Spatial Thinking and Mental Rotation Skills*

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Abstract

In this study, the effect of modeling based activities using virtual environments and concrete objects on spatial thinking and mental rotation skills was investigated. The study was designed as a pretest-posttest model with a control group, which is one of the experimental research models. The study was carried out on sixth grade students attending Mareşal Mustafa Kemal Primary School in Konya's city center during the 2010–2011 academic year. The study group is composed of a total of 87 students in two experimental and one control group. In the activities applied for 9 weeks in the experimental groups, a total of 18 different models were developed. As a result of the study, it was found that the spatial thinking skills of Experimental Group, 1 in which concrete objects were used to develop models, were significantly higher compared to those in Experimental Group 2 and the Control group. The mental rotation skills of Experimental Group 2, in which a virtual environment was used to develop mental rotation was significantly higher compared to Experimental Group 1 and the Control Group. The result of the study suggests that using virtual environments and concrete objects together would be more effective in developing spatial skills.

Key Words

Research in Educational Sciences, Measurement Instrument, and Design Errors.

Spatial skill is a significant issue that is related with many areas. Spatial skills are used in science, geometry, engineering, architecture and in many other fields hence there are excessive numbers of studies in this issue. Studies carried out so far have revealed that spatial skill is related with success in painting, physics, chemistry and mathematics (Battista, Wheatley, & Talsma, 1982; Clements & Battista, 1992; McClurg, Lee, Shavalier, & Jacobsen, 1997; Pribyl & Bodner, 1987).

When the literature is reviewed, it is seen that the concept of spatial skill and spatial ability are used reciprocally. According to Sorby (1999) spatial ability and spatial skill are different concepts. While spatial ability is an innate capacity, spatial skill is an ability that can be learnt, reached and developed with training. According to Lohman (1993) spatial skill is rather significant in learning science and mathematics. Lohman defined as a skill to construct, convert, and remember well-constructed visuals in the mind (p. 14 cited in Bayrak, 2008). According to Tarte (1990, p. 216) spatial skill can be regarded as combination of "skills of understanding, grasping, organizing, interpreting visual relations". As for Carroll (1993), spatial skill is the skill to imagine, perceive, interpret, and grasp visual relations between objects or figures (p. 14 cited in Bayrak, 2008). Stockdale and Possin (1998) made a detailed study of spatial skill and defined it as individual's ability to establish spatial relations bet-

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ween himself and his environment. It is stated that spatial relations coves such characteristics as size, distance, volume, order and time. The settlement of objects on a table, the distance between the objects, the order of letters in a word, the length of an hour, and the kinesthetic activities and digits of a simple division operation are given as examples for spatial relations. According to Olkun (2003a, s. 8), spatial skill is to be able to mentally manipulate objects in a two or three dimensional space. Some researchers studied spatial skills by categorizing them into various sub categories (Carroll, 1993; Kimura, 1999; Linn & Petersen, 1985).

Spatial skill has become an indispensable part of modern the human profile. We use our spatial skills when parking our car, putting dishes into the dishwasher, ordering objects in our room, playing bowling, walking on the street, trying to find our way on the map of a city new. In short, spatial skill is a tool people need and use in their daily life. Spatial skill is professionally used in such fields a graphic design, topographical engineering, architecture and Radiology. These occupational groups need such spatial skills as converting dimensions mentally, spatial visualization, spatial thinking and spatial orientation. Many studies have been carried out to develop spatial skills of trainees in these occupational groups. However, recent studies have revealed that spatial skill is related with many important fields of study. After this finding, a number of studies have been carried out in many different fields to assess and develop this skill (Ben-Chaim, Lappan, & Houang, 1988; Boyraz, 2008; Delialioğlu & Aşkar, 1999; Field, 1994; Guay & McDaniel, 1977; Kakmacı, 2009; Kayhan, 2005; McClurg & Chaille, 1987; McClurg et al., 1997; Olkun, 2003a; Pribyl & Bodner, 1987; Rafi, Samsudin, & Ismail, 2006; Rauscher, Shaw, & Ky, 1993; Tarte, 1990; Tsutsumi, 2005; Yıldız, 2009; Yolcu, 2008;). When relevant studies are examined, it is seen that the number of studies comparing the effects of virtual environments and concrete objects on developing spatial skill is scarce. There is a need for comparative studies to find out which manipulatives (visual environment, concrete objects etc.) are more effective and beneficial in developing skills like spatial visualization, spatial thinking, spatial orientation and mental rotation. This study aims to discuss strengths and limitations of manipulatives used for the development of spatial skills with a comparative approach.

The main aim of this study is to determine the effects of modeling based activities in a 6^{th} grade math course in which virtual environment and concrete objects are used on spatial thinking and mental rotation skills. The problem statement for this aim is "Is the development of models using a virtual environment (Cubix Editor) and concrete objects (linking cubes) effective in developing students' spatial thinking and mental rotation skills?" the problem is composed of two sub-problems;

Sub Problem 1: Is there a significant difference between the spatial thinking post-test mean scores of Experimental Group 1, Experimental Group 2 and the Control Group?

Sub-problem 2: Is there a significant difference between card rotation post-test mean scores of Experimental Group 1 and Experimental Group 2 and the Control Group?

Method

The study was designed and conducted as a pre-test post-test with a control group experimental design to determine the effectiveness of model development using virtual environments (Cubix Editor) and concrete objects (linking cubes) in increasing students' spatial thinking and mental rotation skills. In the study, the dependent variables are students' spatial thinking and mental rotation skills and the independent variables are the activities carried out using virtual environments and concrete objects to develop these skills.

Research Group

The study group is composed of 6^{th} grade students attending the 6A, 6F and 6İ sections of the Konya Meram Mareşal Mustafa Kemal Primary School in the second term of 2010-2011 academic year. The experimental and control groups are determined with a random assignment method. 6A (14 girls, 15 boys) is assigned as the control, 6İ (15 girls, 14 boys) and 6F (15 girls, 14 boys) are assigned as the experimental groups. Section 6F was Experimental Group 1 in which modeling based activities are done with concrete objects (linking cubes) and section 6İ was Experimental Group 2 in which modeling based activities are realized using a virtual environment (Cubix Editor). In the section 6A, the activities in the 6^{th} grade math education program are realized. There were a total of 87 students in the study group, each group having 29 students.

According to Piaget, the period when spatial thinking starts and develops fast coincides with the second level in the primary school (Kakmacı, 2009, p. 7). It can be argued that the application of modeling based activities is important for the development of the students in this period. When development characteristics of sixth grade students are closely examined, it is seen that they are at the beginning of a period when they pass from concrete thinking to abstract thinking (Senemoğlu, 2007). Therefore, it is important to employ activities that allow for developmental characteristics of the students in this period for the acquisition of skills like spatial skills, based on abstract thinking.

The following criteria were observed to equalize the experimental and control group: scores from the Spatial Thinking and the Card Rotation pre-test, scores from the Visual Spatial Intelligence sub-scale and the students' socio-economic levels. Studies carried out so far indicated that the parents' socio-economic level is an influential factor in school success (Fennema & Sherman, 1977; Kılınçarslan, 2008). In order to determine if the study group in equal in terms of the criteria set, the means of scores from the "Spatial Thinking Test", the "Card Rotation Test", the "Self-Assessment Scale in Multiple Intelligence Areas" and the parents' income levels were compared. Before the analysis was conducted, we determined if the mean scores from the tests show a normal distribution and if there was a difference between the distributions of the scores' variances. According to the findings, to test if the difference between means is significant one-way factor analysis was used. One-way factor analysis is applied to test if the difference between two or more irrelevant samples is significantly different from zero (Büyüköztürk, 2011, pp. 39-48). As a result of the analysis, it was found out that spatial thinking and mental rotation skills, visual spatial intelligence scores and socio-economic levels of the groups are equal before the experimental procedure.

Measures

Three different data sets were collected to realize the aim of the study. These are:

1. Students' spatial thinking skills,
2. Students' mental rotation skills
3. Students' visual-spatial intelligence levels.

The "Spatial Thinking Test" which was developed by the researcher is used to collect data in the first item. As for the collection of data in the second item, the "Card Rotation Test" developed by Ekstrom (1976) et al was used and the "Scale for Self-Assessment in Multiple Intelligence Domains" developed by Seber (2001) was used to collect data mentioned in the third item.

The Spatial Thinking Test includes 16 questions related with unit cubes. In the scale, a student receives one point for each correct answer and zero point for each wrong answer. The validity of the scale was achieved with an explanatory factor analysis. To achieve this, this scale was administrated to 211 primary school students. Results of factor analysis revealed that the scale has one dimension. The reliability of the scale was calculated with Cronbach Alpha inner reliability coefficient. According to the results from 211 students to whom the scale was administrated, the reliability coefficient of the scale was found to be 0,92. Accordingly, it can be said that the reliability of the scale is very high (Tavşancıl, 2005). While high scores received from the scale indicate that spatial thinking skill is high, low scores indicate low spatial thinking skill.

In the study, to measure students' mental rotation skills, the "Card Rotation Test" which was developed by Ekstrom et al. (1976) and adapted into Turkish by Delialioğlu (1996) was used. There are a total of 160 questions in the scale. A student receives one point for each correct answer and negative one point for each wrong answer. The administration period of the scales is six minutes. Researchers calculated the reliability coefficient of the scale to be 0,80 (Delialioğlu; Tekin, 2007). While high scores from the scale indicate high mental rotation skill, low scores indicated low mental rotation skill.

In the beginning of the experimental process, in order to make sure that the visual-spatial intelligence levels of the students are equal, the Scale for Self-Assessment in Multiple Intelligence Domains developed by Seber (2001) was used. The items in the sub-scales of the scale are as follows: Verbal Linguistic Intelligence, Mathematical/ Logical Intelligence, Visual Spatial Intelligence, Bodily/ Sensory/ kinesthetic Intelligence, Musical / Rhythmic Intelligence, Interpersonal Intelligence / Social Intelligence, Intrapersonal Intelligence, Naturalistic Intelligence. In the scale, three respond options are provided: "No", "Partially", "Yes" for each item and the highest score to be obtained from each item is 2 and the lowest score is 0. In the development process of the scale, for the content validity of the scale, twelve experts were applied for their views, and construct validity factor analysis was applied. As a result of the factor analysis, it was determined that the scale is composed of a total of 64 items in eight dimensions with each dimension having 8 items. For the reliability of the scale, a test re-test test method was used. The reliability coefficients were 0.86 for Verbal/ Linguistic, 0.97 for Mathematical domain, 0.85

for Visual Spatial field, 0.95 for Bodily/Kinesthetic domain, 0.9 for Musical Rhythmic domain, 0.77 for Interpersonal/Social domain, 0.2 for Intrapersonal/Internal domain and 0.96 for Naturalistic domain.

Procedures

Following from related literature, two different tools were used to realize modeling-based activities. The first one is a virtual environment (Cubix Editor), the other is a concrete object (linking cubes). Two experimental groups were formed in which these tools would be used. In Experimental Group 1, linking cubes were used to form models and in Experimental Group 2 Cubix Editor was used to develop models. In Experimental Group 2, activities were carried out in a computer laboratory, and in Experimental Group 1, activities were realized in a classroom environment. In both experimental groups, 18 different models were developed in 1 hour in 9 weeks. In the activities, students were asked to construct a three-dimensional appearance of models whose two-dimensional views are given. In the process of the models' construction, students are expected to combine two-dimensional appearances in their mind and think three-dimensionally, and in this way they are expected to form models by placing cubes in the correct positions in a three-dimensional space. The models in the activities are presented to the students from easy to difficult. In the control group, the course book recommended in the instruction program and guidebook were used in the courses. The homework, activities and applications in the program were used. The activities were carried out in the classroom and took 9 weeks. At the end of the 9th week, the Spatial Thinking and Card Rotation tests were applied to students for the last time.

In Experimental Group 2, Elica Cubix Editor which was developed by "Elica and DALEST projects" was used as the virtual environment. The program can be downloaded and used without charge from the following link: http://www.elica.net/site/index.html. Elica Cubix Editor was preferred by the researchers as it is easy to use and it has a simple interface. Before using the program, it was piloted on 6th grade primary school students and according to test results, it was concluded that it can be used for research. Besides, permission to use Elica Cubix Editor in the classroom for research was obtained from the administrators of "Elica and DALEST projects". In Experimental Group 2, where Cubix Editor will be used, the program interface was introduced and the necessary buttons for cube addition, cube deletion and choosing appropriate stage etc. were shown. In Experimental Group 1, cubes (linking cubes) were used as concrete objects. Linking cubes are preferred because they were appropriate to the students' level and easy to use. Linking cubes have an unmatched design, key holes on its six faces enables forming desired shapes by establishing multiple connections. In this way, it is considered that students would be able to form desired models easily and with pleasure.

Results

According to results of the analysis, it was determined that there is a significant difference between the groups in terms of their spatial thinking post-test scores. This finding indicates that the activities realized with different manipulatives in the group had different levels of effects in increasing spatial thinking skill. When the means of the groups are considered respectively, it is seen that students in the Experimental Group 1 have the highest spatial thinking skill, followed by students in Experimental 2 and the Control Group. To find the source of the significant difference between the groups, the Mann Whitney U-test was administrated on dual combinations of the groups. Accordingly, it was determined that the spatial thinking skills of the students in Experimental Group 1 were higher compared to the Control Group and Experimental Group 2. Spatial thinking skills of the students in Experimental Group 1 were higher compared to the ones in the Control Group and differences between the groups was significant.

According to the analysis results, it was found out that there is a significant difference between the post-test mean scores of the groups based on the corrected card rotation pre-test results. In other words, the effects of manipulatives (Cubix Editor and Linking Cubes) that were used in modeling-based activities on the development of mental rotation skills are different. According to results of the Bonferroni test administrated on the card rotation post-test mean scores of the group, mental rotation skills of the students in the Experimental Group 2 in which a virtual environment was used were significantly higher compared to mental rotation skills of students in Experimental Group 1 and the Control Group. No significant difference was found between Experimental Group 1 and the Control Group in terms of mental rotation skills.

Discussion

According to the findings from the sub-problem, it was found that the spatial thinking skills of the students in Experimental Group 1 was higher compared to the spatial thinking skills of the students in Experimental Group 2 and the Control group and that the spatial thinking skills of Experimental Group 1 were higher compared to the students in the Control Group. The differences between the groups were significant. According to these results, linking cubes used to develop spatial thinking skills of the students are more effective compared to other manipulatives. Following from this, it can be argued that activities conducted with concrete objects have positive effects on students' spatial thinking skills. This finding is parallel with the findings of the studies in the literature. When the literature is reviewed, it is seen that concrete objects like Tangram, Origami, Tridio and unit cubes were used to develop students' spatial thinking skills (Boakes, 2009; Çakmak; 2009; Spencer, 2008; Yıldız, 2009; Yolcu, 2008). However, in the literature there are also studies that are not parallel with the results of this study (Bakker, 2008; Boakes; Yıldız).

According to the findings with regard to the second sub-problem, it was understood that the mental rotation skills of the students in Experimental Group 2, in which a virtual environment was used, were significantly higher compared to the card rotation skills of the students in Experimental Group 1 and the Control Group. No significant difference was found between Experimental Group 1 and the Control Group. According to these results, Cubix Editor, which was used to develop students' mental rotation skills, is more effective compared to other manipulatives. In other words, it was understood that the activities carried out in a virtual environment had positive effects on students' mental rotation skills. This finding is parallel with the findings of the studies in the literature (Ferla, Olkun, Akkurt, Alibeyoğlu, & Gonulates, 2009; Kaufmann, Steinbügl, Dünser, & Glück, 2005; McClurg et al., 1997; Olkun, 2003b; Olkun, Altun, & Smith; 2005; Rafi et al., 2006). However, in the literature there are also studies that do not show parallelism with the result of this study (Eraso, 2007; Yıldız, 2009).

When the literature and the results of this study are considered together, in general, it is revealed that concrete objects are effective in the development of spatial thinking skill and that virtual environment is effective in the development of mental rotation skill. The results indicate that using virtual environments and concrete objects together will be more effective in the development of spatial skills. However, further comparative studies are to be carried out on the effectiveness of virtual environments and concrete objects in spatial skills.

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