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THE EFFECTS OF GEOMETRICAL-MECHANICAL INTELLIGENCE GAMES ON THE SPATIAL ABILITIES[1]

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Abstract

In this research, it was intended to determine the effects of geometrical-mechanical intelligence game activities on the spatial abilities of secondary school seventh grade students. The research was designed according to quasi-experimental design with pre-test and post-test control groups and conducted with two experimental and two control groups. The study group of this research included a total of 117 seventh grade students who took and did not take elective intelligence games course in a secondary school located in Turkey. In the study, experimental-I group played intelligence games activities with concrete materials, experimental-II played intelligence games on PC, control-I group played intelligence games that were recommended by the Ministry of National Education and control-II group did not play any of the intelligence games. Before, and after the empirical processes that lasted nine weeks, “Spatial Visualization Test”, “Spatial Relations Test” and “Spatial Orientation Test” were used as data collection tools. Paired samples *t*-test and one-way analysis of variance for independent samples were used in data analysis. The results obtained from the research showed that the spatial visualization and spatial relations skills of students have significantly improved according to the activities recommended by the Ministry of National Education in both concrete materials and computer games.

Keywords: Intelligence games, Geometrical-mechanical game, Spatial ability, Spatial visualization, Spatial relations, Spatial orientation.

INTRODUCTION

Spatial ability is a mental process that establishes the interaction between knowledge and mechanisms included in spatial cognition (Hauptman, 2010). Spatial ability is the ability to mentally represent and manipulate two or three dimensional images (Wang & Carr, 2020). This ability is an important building block of general cognition, as it provides the perception, storage, recalling, reconstruction, regulation and transmission of the spatial images (Osberg, 1997). Spatial ability can be perceived as a unique type of intelligence that can be distinguished from other types of intelligence, such as verbal ability and reasoning ability. It is not a monolithic and static trait, but it consists of sub-skills that are related to each other and that can be developed throughout a person's life (Shamsuddin & Din, 2016). Factor analysis and meta-analysis studies led to the emergence of many spatial ability models, each with different spatial skill classifications (Gilligan, 2019). For example, Lohman (1979) emphasized the existence of three major components of spatial ability as follows: “spatial relations”, “spatial visualization”, and “spatial orientation”. He defined the spatial relations factor as the ability to solve mental rotation problems quickly, defined the spatial orientation factor as the ability to visualize how a stimulus sequence looks from another perspective, and defined the spatial visualization factor as the tasks that are relatively do not require speed and are complicated with respect to other factors. Linn and Petersen (1985), based on their meta-analysis study results, divided the spatial ability into three components as “spatial perception”, “mental rotation” and “spatial visualization”. The researchers defined the spatial perception component as the ability to determine spatial relations in respect to the orientation of one’s own body or in the context of distracting information, defined the mental rotation

[1] This study was developed from the doctoral thesis of Neşe Dokumacı Sütçü.

component as the ability to rotate two and three-dimensional figures quickly and accurately in one's mind, and defined the spatial visualization component as the tasks that involve complex, multi-step manipulations of the information that are presented as spatial. Pittalis and Christou (2010), based on their factor analysis study results, claimed that spatial ability consists of three major spatial ability factors, namely “spatial visualization”, “spatial relations” and “spatial orientation”, and confirmed the spatial ability model Lohman (1979) predicted with the research that they carried out.

As an alternative to factor analysis and meta-analysis studies, spatial ability classification can be derived using theoretical approaches. One such classification is Uttal et al.’s (2013) theoretical, top-down model of spatial skills. This model makes use of two fundamental theoretical distinctions. The first is between intrinsic versus extrinsic information. Intrinsic information is the specification of the parts, and the relationship between the parts, that defines a particular object. In contrast, extrinsic information refers to the relation among objects in a group, relative to each other or to an overall framework. The second distinction is between static versus dynamic tasks. Dynamic tasks require movement such as moving, rotation, combinig, bending, folding or scaling. However, static tasks do not require movement (Uttal et al., 2013). Within this classification, four different categories of spatial ability are defined as intrinsic-static, intrinsic-dynamic, extrinsic-static and extrinsic-dynamic spatial skills. Intrinsic-static skills involve "perceiving objects", intrinsic-dynamic skills involve "assembling small units into larger ones, mentally rotating 2D or 3D objects and visualizing". Extrinsic-static skills involve "understanding abstract spatial concepts" and extrinsic-dynamic skills involve "perspective taking" (Jung et al., 2020). Classifications of spatial skills based on factor analysis and meta-analysis studies can be paired onto Uttal et al.’s (2013) model of spatial skills. For example, Lohman (1979) emphasized the existence of three major components of spatial ability as “spatial visualization”, “spatial relations” and “spatial orientation”. Spatial visualization tasks, which are diverse in their nature, require both intrinsic-static and intrinsic-dynamic spatial skills, while spatial relations and spatial orientation fall intrinsic-dynamic and extrinsic- dynamic sub-domains respectively.

Uttal et al.'s (2013) model provides a useful framework for investigating spatial cognition. However, it is possible that the distinctions suggested by Uttal et al. are over refined and spatial thinking can also be defined using similar and broader categories. Uttal et al.’s (2013) model also aligns with spatial models based on the evolutionary origins of spatial skills (Gilligan, 2019). From an evolutionary perspective, Newcombe (2018) suggested three kinds of spatial cognition as navigation, object manipulation and spatialization. Navigation is a function necessary to a broad array of mobile species and it draws on various subsystems relevant to location and movement tracking, integrating those systems in various ways. These systems require extrinsic coding. Object manipulation involves far more than simply holding objects. Object manipulation involves the mental representation and transformation of the objects, that is, intrinsic coding. Difference between navigation and object manipulation is that navigation concerns the extrinsic spatial relations among objects, whereas object manipulation concerns intrinsic spatial relations that constitute the structure of objects. There is also a third kind of spatial cognition: Spatialization involves many kinds of spatial symbol systems, including language, metaphor, analogy, gesture, sketches, diagrams, graphs, maps, and mental images.

In this study, Lohman (1979) classification has been taken into account, as it was also considered by other certain studies (Pittalis & Christou, 2010; Risma, Van Eerde, Abel, Putri & Ilma, 2013; Ung, Ngowtrakul, Chotpradit & Thavornwong, 2016) related to spatial ability. In that case, Spatial Visualization Test was included as a measure of intrinsic-static and intrinsic-dynamic spatial skills, Spatial Relations Test was included as a measure of intrinsic-dynamic spatial skills and Spatial Orientation Test was included as a measure of extrinsic-dynamic spatial skills.

Spatial ability has a critical status in our everyday life in many activities ranging from simple to complex. For example; we use our spatial skills while assembling a furniture, studying the graphs in newspapers, trying to find our current location, trying to find the direction using the maps (Jirout & Newcombe, 2014). Spatial ability is important for the success in science, technology, engineering and mathematics (STEM) as well as in our daily lives (Gilligan, Flouri & Farran, 2017; Kuhl, Lim, Guerriero, & van Damme, 2019; Liu, Huang, Yu, & Dou, 2020; Lubinski, 2010; Uttal & Cohen, 2012). Indeed, research on the subject has shown that spatial ability is positively related to the achievements in areas such as mathematics and geometry (Atit et al., 2020; Cheng & Mix, 2014; Gilligan, Hodgkiss, Thomas & Farran, 2019; Guay & McDaniel, 1977; Lowrie, Logan & Ramful, 2017; Lowrie, Logan & Hegarty, 2019; Turgut & Yilmaz, 2012), physics (Delialioglu & Askar, 1999, Liner, 2012), chemistry (Coleman & Gotch, 1998; Pribyl & Bodner, 1987), biology (Russell-Gebbett, 1985), science (Tracy, 1990) and engineering (Peters, Chisholm & Laeng, 1995).

Despite its importance in numerous fields, spatial ability is not adequately taught in classrooms (Clements & Sarama, 2011). Piburn et al. (2002) indicated that especially verbal and logical-mathematical skills were taught in schools, and the schools are rarely interested in spatial ability, while it could be taught. The results of the researches conducted by Tekin (2007), and Turgut and Yilmaz (2012) in Turkey show that the activities in the primary and secondary education programs are not enough to develop the spatial skills of the students. Osberg (1997) stated that, in the case of lack of spatial ability, the individual will also have difficulties in the school environment and possibly in everyday life, and therefore the emphasis should be given on how to develop and sustain spatial abilities starting at an early age.

Spatial ability is developed from birth, together with language and other specialized abilities, through interactions between inherited capabilities and experiences (Mathewson, 1999). Although there are numerous theories on why some individuals develop spatial skills and others lack the ability to develop these skills (Sorby, 1999), there are a number of studies that suggest that this ability can be improved with appropriate tools and activities (Uttal et al., 2013). For example, De Lisi and Wolford (2002) stated that computer-based educational activities could be used to improve the spatial skills of students in schools. You, Chuang and Chen (2008) stated that playing digital games can be a solution for improving the spatial skills of the students, when the game is designed and applied appropriately. Boakes (2009) stated that origami can be used as an important tool for the development of spatial skills. Jirout and Newcombe (2015) stated that the experiences with spatial toys, such as blocks and puzzles have an important influence on the development of spatial skills. Alexe, Alexe, Voica and Voica (2015) have stated that spatial learning tools for development of spatial ability and current approaches for the development of educational programs are the use of real or virtual manipulations, and the games such as Jigsaw Puzzles, LEGO, Rubik’s cube, Tetris, chess, and origami. Renavitasari and Supianto (2018) stated that educational game tangram puzzle activities could be used to improve the spatial ability. Alexiou and Schippers (2018) stated that digital games facilitate the development of cognitive skills such as spatial skills; enhanced mental rotation abilities. According to Kuhl et al. (2019) play with spatial toys in early education and home settings offers a promising and underutilised avenue for supporting spatial skills. According to Toub, Verdine, Golinkoff, and Hirsh-Pasek (2019) an initial step towards providing early spatial education is ensuring access to toys like shape sorters, blocks, puzzles and origami that lend themselves to spatial play. According to the Ministry of National Education [MoNE] (2013), geometrical-mechanical intelligence games can be used effectively as the means of improving the spatial skills of the students.

Geometrical-mechanical intelligence games are games which can be played single, mutual or as a team. While playing these games, the player make use of geometrical thinking methods, spatial thinking skills, hand-eye coordination or motor skills. Pre-established game materials and digital environments can be used in most of the games. The examples of these games include tangram, polyomino, cube counting, making shape, maze games, node games, Rubik's cube, mikado, jenga and puzzles (MoNE, 2013).

In this research, by using geometrical-mechanical intelligence games for the development of spatial ability, the tasks in the games were presented to students in two different physical forms as concrete materials and in computer environment (virtual environment). Computer manipulatives are often similar to concrete manipulatives (Bouck ve Falnagan, 2010). A major difference between concrete and computer manipulatives is their physical nature (Gibson, 1962). Concrete manipulatives can be touched, held, and rearranged physically. Computer manipulatives are available via computer and closely resemble concrete manipulatives but can only be manipulated and moved on the screen (Spencer, 2008). The computer manipulatives are more interactive than a picture or video, but provides less sense stimuli than a concrete manpulatives. In other words, concrete manipulatives give children tactile experiences unlike computer manipulatives (Olkun, 2003). Active touch is an excellent channel of spatial information in that the arrangement of surfaces is readily picked up (Gibson, 1962). On the other hand intensive training in computer environment may create deeper spatial understanding than concrete manipulatives because of the opportunity to encourage students to think about spatial problems, manipulate objects directly, and navigate around in virtual environments (Osberg, 1997). In the studies about the subject, the games such as LEGO, block, jigsaw, Tetris, Tangram, and pentomino that are used in the development of spatial ability were discussed under the title of geometrical-mechanical intelligence games as stated by MoNE (2013), and the literature was examined within this scope.

In the literature, studies that examine whether or not using concrete materials as geometrical-mechanical intelligence games have any effect on students' spatial abilities have shown that these games are not related to the students’ spatial abilities (Caldera et al., 1999; Grimshaw, Sitarenios & Finegan, 1995; Newcombe, 1993), while other research results (Brosnan, 1998; Cockburn, 1995; Connor & Serbin, 1977; Jirout & Newcombe, 2015; Levine, Ratliff, Huttenlocher & Cannon, 2012; Newman, Hansen & Gutierrez, 2016) have generally shown that these games are effective in the development of spatial abilities. The results of the researches examining the effects of geometrical-mechanical intelligence games played in virtual environment on the development of spatial ability (Alexiou & Schippers, 2018; Corradini, 2011; David, 2012; De Lisi & Wolford, 2002; Lin & Chen, 2016; Liu, Huang, Yu & Dou, 2020; Martin-Dorta et al., 2014; Masendorf, 1995; Moreau, 2013, Okagaki & Frensch, 1994; Osberg, 1997; Yang & Chen, 2010; You, Chuang & Chen, 2008) show that such games are effective in the development of spatial ability. When the researches that compare the effects on the development of spatial ability of geometrical-mechanical intelligence games played in the form of concrete materials and virtual environments (Olkun, 2003; Spencer, 2008; Thompson, 2016) are analyzed, it is seen that different results have been reached. In a research conducted by Olkun (2003), the effects of tangram game which was played in computer environment and as a concrete material, on the spatial visualization skills of primary school students in two-dimensional geometry were compared and after the application, although significant increases were determined in the spatial visualization skills of both groups, it was revealed that this increase was a bit more in experimental group where Tangram game was played in computer environment, but this difference was not statistically significant. In Spencer’s (2008) research, the effects of concrete material and digital tangram games on the two-dimensional visualization skills of primary school teacher candidates were researched and as a result of the study, it was observed that significant improvements took place in the two-dimensional visualization skills of teacher candidates. In Thompson’s (2016) study, the effects of concrete, virtual and multimodal tangram usages on the spatial skills of primary school students were examined. In the research, it was revealed that there was a statistically significant difference between the spatial skill pre and post test scores of virtual tangram group, however, there wasn’t a statistically significant difference between the pre and post test scores of concrete and multimodal tangram groups. In addition to this, in the research the post test scores of the groups were compared with each other and it was determined that there wasn’t a statistically significant difference between them.

A recent meta-analysis of spatial training interventions by Uttal et al. (2013) clearly indicate that spatial skills are malleable. According to this even a small amount of training can improve spatial reasoning in both males and females, and children and adults. Uttal et al. (2013) clearly demonstrated gains in spatial thinking ability through the use of various interventions ranging from the formal training through the study of technical graphic, to informal experiences that used virtual reality and/or video games. The results of the meta-analysis research conducted by Yang, Liu, Chen, Xu and Lin (2019) suggest that diverse training strategies or programs including hands-on exploration, visual prompts, and gestural spatial training significantly foster young children's spatial skills. According to Hawes, Tepylo & Moss (2015) construction play affords opportunities to develop spatial reasoning through physical and visual experiences involving the composition and decomposition of 3D structures, perspective taking, symmetry, and transformations. Ha and Fang (2018) determined that the use of a technological tool called interactive virtual and physical manipulatives improves the spatial abilities of middle school students.

In the literature, it was revealed that the geometrical-mechanical intelligence games, which are played in the form of concrete materials or in virtual environments, usually have a positive effect on the development of spatial ability. The results of the studies comparing the effectiveness of geometrical-mechanical intelligence games played with concrete materials and virtual environments are very limited and the results of these studies are differ. In these studies, it was observed that the Tangram game was applied to primary school students and preservice teachers. In this research, the effects of Katamino, Q.bitz Extreme, Architecto and Soma Cube games, which are geometrical-mechanical intelligence games, are examined on the spatial skills of secondary school students by using in both physical form. According to Piaget, in the development the spatial abilities that require abstract thinking skills secondary school period is very important, due to the fact that this is the period that students' abstract thinking skill start to be formed (Senemoglu, 2012). On the other hand, the Intelligence Games Course has been taught in secondary schools as an elective course in our country within the body of the MoNE since the 2012-2013 academic year. The Intelligence Games Course Curriculum is designed as a flexible framework program that needs to be structured by teachers rather than a standard program. Research conducted on the Intelligence Games Course (Adalar & Yüksel, 2017; Aslan, 2019; Sargın & Taşdemir, 2020) revealed that teachers had difficulties in practicing intelligence games. Therefore, the training was designed to guide teachers for the geometric-mechanical intelligence games unit of the program. According to the MoNE (2013), pre-built game tools and digital environments can be used in most of the games. On the other hand, Gecu-Parmaksiz and Delialioglu (2019) state that both physical and virtual manipulatives are the supportive teaching tools used in teaching. Therefore, the activities are designed in two different physical forms with concrete materials and in the computer environment. In the teaching design, activity plans and worksheets of the geometric-mechanical intelligence games Katamino, Q.bitz Extreme, Architecto and Soma Cube were developed. Three applications were performed including experiment-I and experiment-II in order to compare the effectiveness of the activities carried out with concrete materials and in the computer environment, and the control-I where the activities performed depending on the initiative of the teacher in line with the MoNE (2013) in order to determine the effects of the activities carried out with concrete materials and in the computer environment. For these reasons, in this research, it was aimed to compare the spatial abilities of seventh graders in which environment they are more effective and useful. For this purpose, the answers for the following questions are sought.

- Is there a statistically significant difference between the mean of the pre and post test scores of experimental and control group students' spatial visualization test?
- Is there a statistically significant difference between the mean scores of experimental and control group students' spatial visualization test differences?

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- Is there a statistically significant difference between the mean of the pre and post test scores of experimental and control group students' spatial relation test?
- Is there a statistically significant difference between the mean scores of experimental and control group students' spatial relations test differences?
- Is there a statistically significant difference between the mean of the pre and post test scores of experimental and control group students' spatial orientation test?
- Is there a statistically significant difference between the mean scores of experimental and control group students' spatial orientation test differences?

METHODS

Research Model

In a study, experimental patterns are used to measure variables and to reveal cause-effect relationships between these variables (Çepni, 2014). It is possible to find different classifications of experimental patterns in the literature. A classification widely accepted in the literature and applications is as follows; real experimental designs, quasi-experimental designs and weak experimental designs (Büyüköztürk, 2014). Since the classes were previously established by the school administration, researchers did not have the opportunity to create classes through random assignment. For this reason, unpaired pre-test and post-test control group pattern, among the quasi-experimental designs, was preferred in the research. In these designs, one or multiple experimental and control groups are selected. Random distribution is not used in the formation of groups and no effort is spent for random assignment (Çepni, 2014). In accordance with the purpose of the study, two experimentals, and two control groups were randomly selected from the available classes.

Study Group

The study group of this research included a total of 117 seventh grade students who took and did not take elective intelligence games courses in a secondary school located in Turkey during the academic year of 2016-2017. 61 of the students were male and 56 were female. Students' ages ranged from 12 to 13 years old. The study group was selected by considering the developmental characteristics of the students. Since the fifth and sixth grade students are at the beginning of the transition from abstract thinking to concrete thinking, the seventh grade students, who were in the process of abstract thinking, were selected as the study group, in order to develop their spatial skills, which required abstract thinking skills. As a result of the research, three classes, who took the intelligence games course from the same teacher to minimize the situations that may arise from the teacher differences, were chosen as the study groups. Of these three classes, experimental and control groups were chosen randomly as experimental-I, experimental-II and control-I groups. A randomly selected class among the classes that do not choose this course was also selected as control-II group. In the study, experimental-I group played intelligence games activities with concrete materials, experimental-II played intelligence games on PC, control-I group played intelligence games that were recommended by the MoNE (2013) and control-II group did not play any of the intelligence games.

The purpose of using experimental-I and experimental-II groups in this study was to compare the effectiveness of the activities that are performed using the concrete materials and in the computer environment designed by the researchers. The reason for choosing the control-I group is to determine the effects of the activities carried out by using the concrete materials and in the computer environment, by the experimental-I and experimental-II groups. The reason for the selection of the control-II group is to control the situation, in which the progresses that may occur due to any reason such as maturation of the students during the nine-week experimental practice and may affect the results of the research.

Data Collection Tools and their Development

Spatial visualization is defined as the tasks that include complex and multi-step manipulations of information that are presented as spatial (Linn & Petersen, 1985). When the items in standard tests that measure this skill are examined, it is observed that it includes mental activities such as mental folding, mental integration and transforming from two-dimension to three-dimension (Pellegrino et al., 1984). Spatial relations are the ability to conduct the conversion or rotation processes of an object in the mind quickly and correctly. In standard tests which are used to measure this skill, it is required from students to decide which of the object is the rotated version of the two or three-dimensional object that were given to students on paper. These tests consist of questions such as two-dimensional mental rotation, three-dimensional mental rotation and cube comparison (Pellegrino et al., 1984). Spatial orientation is the ability to visualize the image of an object from a different perspective in the mind (Contero, Naya, Company, Saorin & Conesa, 2005). When the tests that are used to measure this skill are examined, it was observed that they require the visualization of how an object is seen from a different perspective and to decide from this aforethought perspective (Pittalis & Christou, 2010).

In the literature there are tests that were developed by different researchers for the purpose of applying on different samples in order to measure spatial visualization, relations and orientation. Among the tests in the literature, there weren't any tests that are appropriate for seventh grade students (12-13 years old) and measure many of the two and three-dimensional spatial skills in the same test. For example, two or three-dimensional spatial skills such as folding paper, forming cube, mental degradation, mental integration which were included in spatial visualization test that were developed by the researchers, were measured with different spatial visualization tests and appropriate for different grades. In addition to this, Minessota Paper Form Board Test (Likert & Quasha, 1941), Differential Aptitude Test: Spatial Relations (Bennett, Seashore & Wesman, 1974), Purdue Spatial Visualization Test (PSVT): Visualizations (Guay, 1976), Spatial Visualization Test (Alias, Black & Gray, 2002), French Reference Kit (FRT) Paper Folding and Surface Development Test (Ekstrom, French & Harman, 1976) which are intended to measure the spatial visualization skills in the literature are appropriate for high-school and college students. Middle Grades Mathematics Project Spatial Visualization Test was developed by Winter, Lappan, Philips and Fitzgerald in 1986 for middle-school students. However, as a result of pilot scheme that was conducted on seventh grade students, it was observed that students could not answer the questions. As stated by Robichaux (2000), since most of the shapes in the questions are complex, it was not found suitable to include it in this research. Thurstone's Primary Mental Abilities Test (Thurstone, 1938), Mental Rotation Test (Vandenberg & Kuse, 1978); PSVT: Rotations (Guay, 1976), FRT Card Rotation and Cube Comparison Test (Ekstrom, et al., 1976) which are tests that are intended to measure the spatial skills are appropriate for high-school and college students. Similarly, Object Perspective/Spatial Orientation Test (Kozhenikov & Hegarty, 2001), PSVT: Views (Guay, 1976) which are tests intended to measure the spatial orientation skills of students are appropriate for high-school and college students. For this reason, in spatial visualization, relations and orientation tests which were developed by the researchers, questions that measure two and three-dimensional spatial skills and were appropriate for seventh grade students were included together and comprehensive multiple-choice tests were developed in which different question types are included.

Using the relevant literature spatial visualization test (SVT), spatial relations test (SRT) and spatial orientation test (SOT) were developed by taking into account the relationship between the geometrical-mechanical intelligence games presented in Table 1 and the spatial skills considered to be developed with these games. The selection of geometrical-mechanical intelligence games and the relationship between the selected games and the skills related to the spatial ability are designed by researchers together with the opinions of seven faculty members in the field of mathematics education and two mathematics teachers. The reason for these games to be chosen is that they are in the category of geometrical-mechanical intelligence games and require the use of spatial skills. Table 1 is shown below.

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Table 1. Relationship between geometrical-mechanical intelligence games and the components of spatial ability

Geometrical-Mechanical Intelligence Game	Spatial Ability												
	Spatial Visualization								Spatial Relations			Spatial Orientation	
	2D Spatial Visualization			3D Spatial Visualization					2D Spatial Relations	3D Spatial Relations		2D ↕ 3D	
	Mental Integration	Mental Separations	Paper Folding	Mental Integration	Mental separations	Cube Consisting	Cube Counting	Surface Development	Mental Rotation	Mental Rotation	Cube Comparison	Perspective	Construction Plan
Katamino	X	X	X						X				
Q.Bitz Extreme	X	X						X	X		X		
Architecto				X	X					X		X	
Soma Cube				X	X	X	X			X		X	X
Number	6	6	4	4	4	2	2	4	12	8	4	8	4
Total				32						24		12	

In the first stage, SVT consisted of a total of 38 items, SRT consisted of a total of 30 items and SOT consisted of a total of 12 items. The tests were submitted to the opinions of nine faculty members, eight of whom work in the field of mathematics education and one in the field of measurement and evaluation, and two secondary school teachers, for the validity of the content. Master and doctoral dissertation of a lecturer in the field of mathematics education are about spatial skill and has many researchers in this field. In accordance with the feedbacks obtained from the faculty members and teachers, six items were removed from SVT and SRT on the grounds that the number of items in SVT and SRT were high and necessary corrections were made on the remaining items. In addition, the tests were applied to three students in order to determine whether the items in the tests were understandable for students, and necessary corrections were made in places where the items were not understood.

As shown in Table 1, there are 32 questions in the Spatial Visualization Test, 24 in the Spatial Relations Test, and 12 in the Spatial Orientation Test, which were to be applied to the students for validity and reliability studies after getting the opinions of the experts. The questions in the tests were prepared in such a way that there would be at least two questions for each skill, using the SketchUp drawing program and the NCTM ILLUMINATIONS online isometric drawing tool (https://illuminations.nctm.org/activity.aspx?id=4182). KR-20 internal consistency coefficient was calculated as .78 for SVT, .74 for SRT and .71 for SOT.

Spatial Visualization Test (SVT)

After having received the expert opinions, at first the EFA was performed to determine the factor structures of the 32 item test. As a result of the EFA, a two-factor structure "Two-Dimensional Spatial Visualization" consisting of 15 items and "Three-Dimensional Spatial Visualization" consisting of 16 items were obtained by excluding the 6th item from the test. With the exclusion of the 6th item from the analysis, it was observed that the factor loadings of the remaining items varied between .43 and .72 for the first factor and between .44 and .68 for the second factor. Furthermore, it was seen that the explained variance ratios were 20.80 % for the first factor, 15.42 % for the second factor, and total variance was 36.22 % for both factors. In order to determine whether the two-factor structure that was obtained from the result of the EFA was verified as a model, the items (11 and 20) that were proposed to be connected with more than one item, which were theoretically close to each other, were extracted

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from the test, and the modifications were made on the items (15 and 16, 24 and 25, 30 and 32) close to each other theoretically. After the 11th and 20th items had been removed from the test and after the modifications had been performed, it was seen that the two-factor structure obtained consisting of the remaining 29 items had sufficient fit index (χ^2/sd:1.26, RMSEA:.029, GFI:.96, AGFI:.95, SRMR:.074, NNFI:.92, CFI:.93). Item analysis was performed for the remaining 29 items; the test, which consisted of items with different difficulty levels, was found to be moderately difficult and highly distinguishing. The KR-20 internal consistency coefficient was calculated to be .78 for the first factor that consist of 14 items, and .78 for the second factor that consist of 15 items. The KR-20 internal consistency coefficient belonging to the entire test was calculated as .78.

Spatial Relations Test (SRT)

After having received the expert opinions, at first the EFA was performed to determine the factor structures of the 24 item test. As a result of the EFA, a two-factor structure involving "Two-Dimensional Spatial Relations" consisting of 11 items and "Three-Dimensional Spatial Relations" consisting of 11 items were obtained by excluding the 8th and 18th items from the test. With the exclusion of the 8th and 18th items from the analysis, it was observed that the factor loadings of the remaining items varied between .36 and .85 for the first factor and between .44 and .73 for the second factor. Furthermore, it was seen that the explained variance ratios were 23.37% for the first factor, 18.54% for the second factor, and total variance was 41.91% for both factors. As a result of the CFA which was made to determine whether the two-factor structure obtained from the result of the EFA was confirmed as a model, since the factor loading of the 11th item was less than .30 and the error variance was greater than .90, the 11th item was extracted from the test and it was seen that the two-factor structure had sufficient fit index (χ^2/sd:1.38, RMSEA: .035, GFI: .97, AGFI: .96, SRMR: .073, NNFI: .91, CFI: .92). Item analysis was performed for the remaining 21 items; the test, which consisted of items with different difficulty levels, was found to be moderately difficult and highly distinguishing. The KR-20 internal consistency coefficient was calculated as .79 for the first factor that consist of 10 items, and as .73 for the second factor that consist of 11 items. The KR-20 internal consistency coefficient belonging to the entire test was calculated as .74.

Spatial Orientation Test (SOT)

After having received the expert opinions, at first the EFA was performed to determine the factor structures of the 12 item test. As a result of the EFA, a one-factor structure was obtained. It was observed that the factor loadings of the items varied between .47 and .81. Furthermore, it was seen that the explained total variance is 43.98 %. In order to determine whether the one-factor structure that was obtained from the result of the EFA is verified as a model, the items (4 and 10) that were proposed to be connected with more than one item, which were theoretically close to each other were extracted from the test, and the modifications were made on the items (2 and 5, 9 and 11) that were close to each other theoretically. After the 4th and 10th items were removed from the test and after the modifications were performed, 10 items had sufficient fit indexes (χ^2/ sd: 2.14, RMSEA: .062, GFI: .98, AGFI: .97, SRMR: .056, NNFI: .90 and CFI: .92). Item analysis was performed for the remaining 10 items; the test, which consists of items with different difficulty levels, was found to be moderately difficult and highly distinguishing. The KR-20 internal consistency coefficient belonging to the test was calculated as .71.

Preparation of Activity Plans

In the first week of the application, there was a PowerPoint presentation prepared for both experimental groups on what the geometrical-mechanical intelligence games are, commonly known geometrical-mechanical intelligence games and the basic rules of these games. In the subsequent weeks of the application, four activity plans were prepared for each game for two weeks. The activity plans were designed by the researchers by taking in the account the rules assigned by the MoNE (2013) and the rules of each game. The tasks in the activity plans were presented at three levels as beginner, intermediate and advanced, from easy to difficult, in accordance with the step-by-step teaching approach. Then, two faculty members and two mathematics teachers were asked to examine the activity plans for each game. In line with the feedbacks, necessary adjustments were made to the activity plans.

Preparation of Worksheets

Considering the relationship between geometrical-mechanical intelligence games and spatial skills which were aimed to be developed, four in the total, one for each game, worksheets were prepared by the researchers. Two faculty members and two mathematics teachers from the field of mathematics education, were asked to review the draft worksheets. On the feedbacks, necessary corrections were made and the worksheets were finalized. The worksheets were applied to the students individually after each game.

Development of Games in the Computer Environment

Katamino, Q.bitz Extreme, Architecto and Soma Cube games, which are sold in the market were purchased as concrete materials with the support of Dicle University Scientific Research Projects Coordinator's Office. It was investigated whether there are versions of these games that can be played on the computer. It was seen that only the Soma Cube game has the Android app which was developed by Martin Florek in 2016. Using the BlueStacks program, which is a free Android simulator for playing Android games on the computer, it was possible for students to play this game on their computers. Thus, there was no need to develop the Soma Cube game. Katamino, Q.bitz Extreme and Architecto games to be used in this study were developed by the cooperation of the researchers and a computer engineer, in the way that they would be the same games in the market. For the development of games, Blender, Paint.Net, Unity 3D 5.3. 1f1 version, C# and Microsoft Visual Studio programs were used. The following is the brief information on the development process of the games.

- Blender, which is a free three-dimensional modeling and animation program for tissue dressing, was used.
- Paint.Net, which is a free image and photo editing program for user interfaces and design, was used.
- After all the modeling and designs were prepared, they were transferred to version 5.3.1f1 of Unity 3D, which is a free gaming engine, and part and UI (User Interface) designs were made on Unity 3D.
- In Visual Studio environment, games were coded with C #.
- The compilation of the game was made to be played on the computer.

Implementation Process

The application, which was two hours per week, lasted nine weeks in total during the first semester of the 2016-2017 academic year. Before the application, SVT, SRT and SOT were applied as pre-test on the experimental and control groups. In the first week of the practice, PowerPoint presentations on geometrical-mechanical intelligence games were performed to both experimental groups on the smart board. In the following weeks, Katamino, Q.bitz Extreme, Architecto and Soma Cube games and worksheets related to each game were applied for two weeks for each game in both groups. The applications performed in the experimental study process were the same for experimental-I and experimental-II group. The only difference between them was that the tasks assigned to the experimental-I group are presented to the students with concrete materials and the tasks assigned to the experimental-II group were presented on the computer environment. Implementation process is given Table 2.

Table 2. Implementation process

		Experimental-I Group	Experimental-II Group
	Pre-test	SVT, SRT, SOT	SVT, SRT, SOT
NOVEMBER 2016	1.Week	PowerPoint presentation on geometrical-mechanical intelligence games	PowerPoint presentation on geometrical-mechanical intelligence games
NOVEMBER 2016	2. Week 3. Week	Katamino activities with concrete materials + Katamino worksheet	Katamino activities in computer environment + Katamino worksheet
NOVEMBER 2016 / DECEMBER 2016	4. Week 5. Week	Q.bitz Extreme activities with concrete materials + Q.bitz Extreme worksheet	Q.bitz Extreme activities in computer environment + Q.bitz Extreme worksheet
DECEMBER 2016	6. Week 7. Week	Architecto activities with concrete materials + Architecto worksheet	Architecto activities in computer environment + Architecto worksheet
DECEMBER 2016	8. Week 9. Week	Soma Cube activities with concrete materials + Soma Cube worksheet	Soma cube activities in computer environment + Soma Cube worksheet
	Post-test	SVT, SRT, SOT	SVT, SRT, SOT

In the experimental-I group consisting of 30 students, intelligence game activities took place on Fridays in 4th and 5th class hours in Technology and Design Class. In experimental-II group consisting of 29 students, intelligence game activities took place in computer environment on Friday 6th and 7th class hours, at the Information Technologies Class. The installation of the games except for the Soma Cube game was quite simple, thus no other program was required to be installed on the computer. However, for the Soma Cube game, the BlueStacks program was first installed on the computers. During both applications, students played all games individually. After the application, the same tests were applied to the experimental and control groups as the post-test.

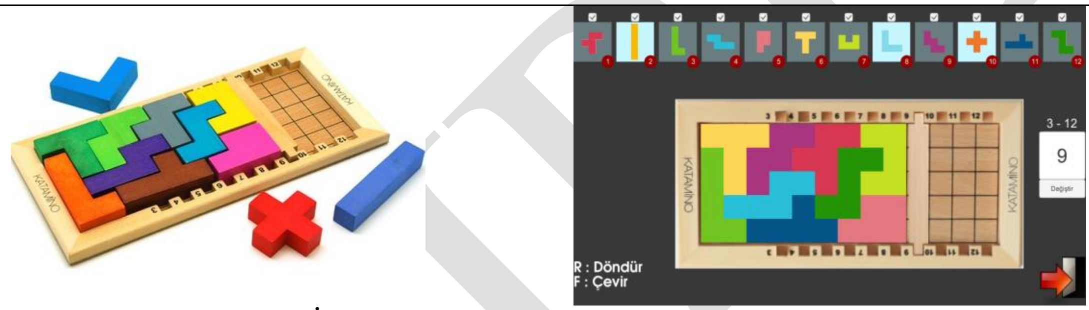
In the intelligence games course, it is appropriate to use a layered curriculum approach since there will be students with different competence levels in the same class (MoNE, 2013). Because the layered curriculum approach, which adopts the student-centered model (Nunley, 2003), considers that pre-learning levels, learning styles, intelligence areas and thinking systems of the students may be different, so it is based on organizing learning experiences in accordance with individual differences. This approach predicts the realization of beginner, intermediate and advanced level activities instead of one-dimensional activities in the intelligence games course (MoNE, 2013). Learners are responsible for fulfilling the activities expected of them at each step. These steps steps follow a path from grasping basic knowledge and skills to high-level thinking skills (Basbay, 2005). The MoNE (2013) describes the levels as follows;

Level 1-Beginner Level: Includes learning the rules of the games, acquiring basic knowledge and skills, playing beginner level games.
Level 2-Intermediate Level: Includes logical deductions, starting from the right place in puzzles, playing intermediate level games.
Level 3-Advanced Level: Includes gaining high-level knowledge and skills and playing advanced level games.

As MoNE (2013) stated, the tasks in the games were presented to the students in the direction of activity plans at beginner, intermediate and advanced levels. Information about games and application process is given below.

In Katamino game, each student was given 12 pentominoes in different colors, 1 playground, 1 separatrix and 1 game booklet. Pentamino is the shape which is created by adjoining five squares which has at least one common edge and penta is the group that consists of pentaminoes which completes a rectangle area that is formed in the location of separatrix. Each pentaminoes occupy a place of five-unit squares in the playground. The purpose in the game is to complete the penta by using pentaminoes. For example, for penta 3, the separatrix is placed between 3 and 4. In the rectangular area which is limited with the separatrix, three pieces of pentamino are placed appropriately.

Katamino game was applied on experimental-I and experimental-II group in three levels. In the beginner level, at first, it was required from students to create free shapes by using pentaminoes in order for them to get used to pentamino pieces and then they were required to create the figures of elephant, kangaroo and camel. In intermediate level, it was required from students to create penta 3 and 4 by using the pentaminoes that were chosen by them and stated in the booklet and in advanced level it was required from students to create penta 5, 6, 7, 8 and 9 by using the pentaminoes that were chosen by them and stated in the booklet. As the number of required penta increases, the number of pentamino that would be used increase as well. Therefore, the difficulty of the task increases equally. Students are expected to create up to penta 9, in accordance with their levels. Figure 1 gives two different physical forms of Katamino as concrete materials and computer environment.



CONCRETE MATERİAL COMPUTER ENVIRONMENT

Figure 1. Two different physical forms of Katamino

In Q.bitz Extreme game, each student was given a table, 16 pieces of cube and game cards. 14 of the cubes are the same and the other 2 cubes are same with one another. In each surface of the cubes there are different shapes. The purpose of the game is to make the same designs on the game cards by using the 16 cubes.

Q.bitz Extreme were applied on experimental-I and experimental-II groups in three levels. In the beginner level, students were required to create significant designs of their own in order to recognize the surface of the cubes and in intermediate level, they were required to make the designs on 15 game cards. In advanced level, students are required to create the design on the randomly chosen game card as much as they remember after examining them in the given period. Figure 2 gives two different physical forms of Q.bitz Extreme as concrete materials and computer environment.

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Figure 2. Two different physical forms of Q.Bitz Extreme

In Architecto game, each student was given 18 building block and 1 booklet. Building blocks are three-dimensional geometrical shapes which are proportional with each other such as cube, cylinder, rectangular prism and bridge. The purpose in the game is to create three-dimensional models with given building blocks for each model in the booklet. The type and number of blocks which would be used in the structuring of each model are shown in a window under each page. There are six difficulty levels, starting from yellow (easy) to red (difficult).

Architecto was applied on experimental-I and experimental-II groups in three levels. Students were required to make a total of 15 model pictures as five pictures for each difficulty level in order for it to be appropriate for the level of the students. In the beginner level, students were required to make free models in order to recognize building blocks and then make the five models in the yellow difficulty level. In intermediate level, students were required to make five models in orange difficulty level and in advanced level they were required to make five models in green difficulty level. Figure 3 gives two different physical forms of Architecto as concrete materials and computer environment.

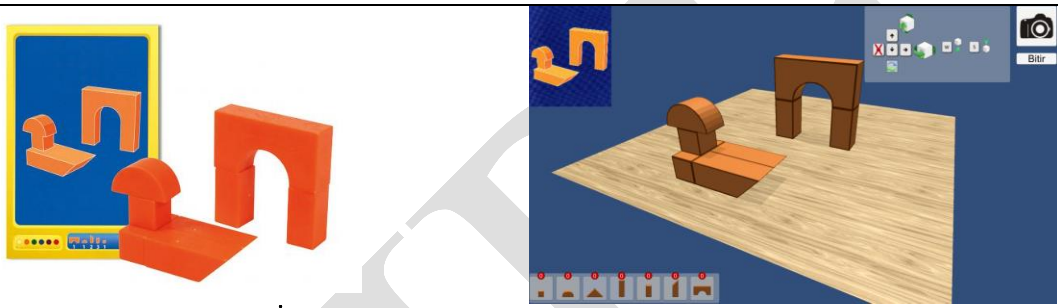

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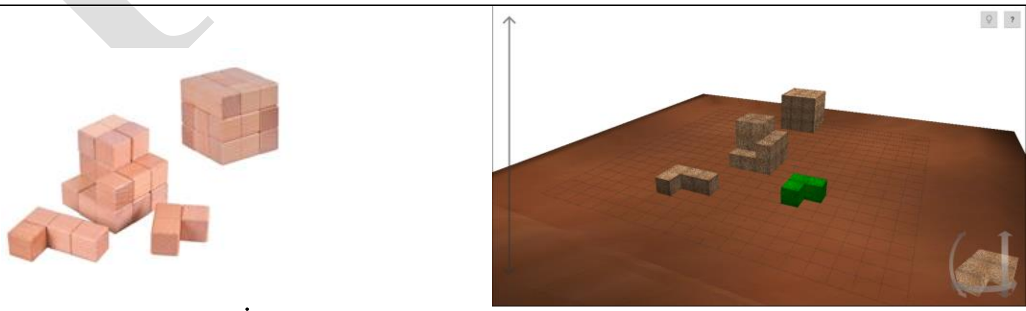
Figure 3. Two different physical forms of Architecto

In Soma Cube game, each student was given a Soma Cube and shape cards. Soma cube was made of 27 small cubes which are equal to each other and consists of one piece that consists of three small cubes and six pieces that consist of four small cubes. The purpose in the game is to create a cube of 3x3x3 by using seven pieces. This cube is called as Soma Cube. Soma cube can be created with many different ways depending upon the array of seven pieces. Furthermore, apart from the cube, with the pieces of Soma Cube many models such as bridge, pyramid, snake etc. can be made.

Soma Cube was applied on experimental-I and experimental-II groups in three levels. In beginner level, students were required to make the shape of a cube by being guided step by step. In intermediate level, students were required to make the models that consist of the combination of few soma cube pieces (2, 3, 4, 5 and 6 pieces) and in advanced level they were required to make the advanced models by using all of the seven pieces. Figure 4 gives two different physical forms of Soma Cube as concrete materials and computer environment.



CONCRETE MATERİAL COMPUTER ENVIRONMENT

Figure 4. Two different physical forms of Soma Cube

The curriculum of the intelligence games courses was designed as a flexible framework program that needs to be structured by the teacher according to the interests and developmental characteristics of the students rather than a standard program. The teacher should design and plan his/her time and activities to be devoted to different units according to student interests, educational environment and materials. In addition to this, for the geometrical-mechanical games unit, MoNE suggested games such as tangram, polyomino, cube counting, making shapes, maze games, node games, Rubik's cube, mikado, jenga and puzzles (MoNE,2013). During the application, the courses of the control-I group was not interfered in any way and the application process of the geometrical-mechanical intelligence games activities suggested by MoNE (2013) was left to the teacher's initiative. Control-II group consists of students who didn't choose the elective course of intelligence games and no activity was performed in the group about intelligence games.

Data Analysis

In the development of spatial ability tests which were used as data collection tools in the study, first the students' responses to the tests were artificially double-categorized into a combinatorial mode as "1" for the correctly answered items, and "0" for the wrongly answered and left blank items. Later, the normal distribution of the scores obtained from the tests was tested by using the "SPSS 21" package program and the normality of the scores obtained from the tests was examined by taking into consideration the histogram, normal Q-Q, box-line charts, the kurtosis and skewness values (Cokluk, Sekercioglu & Büyüköztürk, 2012). Since the responses of the students to the items were artificially transformed into two categories in the form of 1-0, EFA was performed over the tetrachoric correlation matrix to determine the factor structures of the tests (Baykul & Güzeller, 2014). For this, "FACTOR 10.3.01" and "SPSS 21" package program were used. In order to determine whether the factor structures obtained as a result of EFA were validated as a model, CFA was applied. For this, "LISREL 8.54" program was used. In this study, the Asymptotic Covariance Matrix and the Weighted Least Squares Method were used in the CFA because the answers were converted into two categories as 1-0 (Kline, 2011). After EFA and CFA, item analysis was carried out using the "ITEMAN 3" program through the data that were processed as A, B, C, D, in order to present the findings related to difficulty level of items and distinctiveness. The KR-20 (alpha), internal consistency reliability coefficient, was calculated by "ITEMAN 3" program in order to determine the reliability of the test.

The "SPSS 21" package program was used in the analysis of the data which were obtained from the research. The value of 0.05 was taken as the level of significance. One of the analyses that can be used in the comparison of pre-test and post-test score means of experimental and control groups in themselves is paired samples *t*-test. One of the analyses that could be used to test the effect of experimental procedures was one-way analysis of variance (ANOVA) on the difference between the students' pre-test and post-test (gain-access) scores (Büyüköztürk, 2014; Tabannick & Fidell, 2013). In order to use paired samples *t*-test, it is required for the data set which consist of the differences between the pre-test and post-test scores of students, to show normal distribution. In order to use ANOVA over the difference scores, it is required to show the normal distribution feature of the data set which is formed by the differences between the pre-test and post-test scores and the variance of the groups had to be equal. Since the number of students in the group was less than 50, the Shapiro-Wilk test was used to test whether the difference scores obtained showed normal distribution characteristics. In addition, the histogram, normal Q-Q, box-line charts and the kurtosis and skewness values were examined and whether the scores exhibited normal distribution was determined. The Levene's test was used to examine whether the variances of the groups were equal (Büyüköztürk, 2011). For students in the experimental and control groups, the difference scores for each dimension of each data collection tool showed normal distribution characteristics and it was found that the variances of the groups were equal. For this reason, paired sample *t*-test and ANOVA was used in data analysis.

RESULTS

The mean SVT pre-test and post-test scores of the students in experimental and control groups were compared with *t*-test and findings obtained were presented in Table 3.

Table 3. *T*-test result of the mean SVT pre-test and post-test scores of the students in experimental and control groups

SVT			N	Mean	Std Deviation	df	*t*	Sig.
Experimental-I	2D	Pre-test	30	6.97	2.16	29	4.15	.000
		Post-test	30	9.37	3.38			
	3D	Pre-test	30	7.77	2.61	29	4.42	.000
		Post-test	30	10.33	3.06			
Experimental-II	2D	Pre-test	29	6.38	2.80	28	7.06	.000
		Post-test	29	10.41	1.59			
	3D	Pre-test	29	8.03	3.35	28	4.47	.000
		Post-test	29	10.83	2.25			
Control-I	2D	Pre-test	30	7.67	2.97	29	2.02	.053
		Post-test	30	8.57	3.73			
	3D	Pre-test	30	8.77	4.02	29	2.50	.018
		Post-test	30	9.80	3.48			
Control-II	2D	Pre-test	28	6.21	2.60	27	.46	.649
		Post-test	28	6.46	2.85			
	3D	Pre-test	28	7.86	2.21	27	1.24	.226
		Post-test	28	7.29	2.75			

When Table 3 is examined, it was observed that there was a statistically significant difference between the pre-test and post-test score means of spatial visualization dimension of two-dimensional [$t_{(29)}$=4.15, p<.05] and three-dimensional [$t_{(29)}$=4.42, p<.05] of experimental-I group students' SVT and two-dimensional [$t_{(28)}$=7.06, p<.05] and three-dimensional [$t_{(28)}$=4.47, p<.05] of experimental-II group students' SVT. According to this, it can be stated that the intelligence games activities which were performed both with concrete materials and in computer environment, significantly improve the two and three-dimensional spatial visualization skills of students.

In Table 3, it was observed that there wasn't a statistically significant difference between the pre-test and post-test score means of control-I group students' SVT in terms of two-dimensional [$t_{(29)}$=2.02, p>.05] spatial visualization dimension, however, there was a significant difference in terms of three-dimensional [$t_{(29)}$=2.50, p<.05] spatial visualization dimension. According to this, it can be stated that intelligence games activities that are suggested by MoNE, significantly improves the three-dimensional spatial visualization skills of students. In addition to this, there wasn't a statistically significant difference between the pre-test and post-test score means of control-II group students' SVT in terms of two-dimensional [$t_{(27)}$=.46, p>.05] and three-dimensional [$t_{(27)}$=1.24, p>.05] spatial visualization dimension. According to this, it can be stated that there wasn't a significant difference depending upon a different reason in the two and three-dimensional spatial visualization skills of the students of which any activity about the intelligence games are applied throughout the application.

The mean difference scores of the students in the experimental and control groups regarding the SVT were compared using ANOVA, and the findings are presented in Table 4.

As shown in Table 4, it was revealed that there was a statistically significant difference between the means of the difference scores of the students in the experimental and control groups regarding the two-dimensional [$F_{(3,113)}$=9.726, p<.05] and three-dimensional [$F_{(3,113)}$=8.567, p<.05] spatial visualization dimension of SVT. For the two-dimensional spatial visualization, it was determined that the differences were between experimental-I with control-I, experimental-I with control-II, experimental-II with experimental-I, experimental-II with control-I, and experimental-II with control-II. According to these findings, the development of two-dimensional spatial visualization skills of the experimental-I group students was significantly higher than that of the control-I and control-II group students, the development of two-dimensional visualization skills of the experimental-II group students was higher than that of the experimental-I, control-I and control-II group students. For the three-dimensional spatial visualization, it was determined that the differences were between experimental-I with control-I, experimental-I with control-II, experimental-II with control-I, and experimental-II with control-II. According to these findings, the development of three-dimensional spatial visualization skills of the experimental-I group students was significantly higher than that of the control-I and control-II group students, the development of three-dimensional visualization skills of the experimental-II group students was higher than that of the control-I and control-II group students.

Table 4. ANOVA results on the mean of difference scores of the students in the experimental and control groups regarding the SVT

	Groups	**N**	**Mean**	**Std Deviation**		**Sum of Squares**	**df**	**Mean Square**	***F***	**Sig.**
2D	Experimental-I	30	2.40	3.17	Between Groups	245.850	3	81.950	9.726	.000
	Experimental -II	29	4.03	3.08	Within Groups	952.116	113	8.426		
	Control-I	30	.90	2.44	Total	1197.966	116			
	Control-II	28	.25	2.88						
Significant Differences: Experimental-I and Control-I, Experimental-I and Control-II, Experimental-II and Experimental-I, Experimental-II and Control-I, Experimental-II and Control-II										
3D	Experimental-I	30	2.57	3.18	Between Groups	209.247	3	69.749	8.567	.000
	Experimental -II	29	2.79	3.36	Within Groups	919.949	113	8.141		
	Control-I	30	1.03	2.67	Total	1129.197	116			
	Control-II	28	-.57	2.44						
Significant Differences: Experimental-I and Control-I, Experimental-I and Control-II, Experimental-II and Control-I, Experimental-II and Control-II										

The mean SRT pre-test and post-test scores of the students in experimental and control groups were compared with *t*-test and findings obtained were presented in Table 5.

Table 5. *T*-test result of the mean SRT pre-test and post-test scores of the students in experimental and control groups

SRT			**N**	**Mean**	**Std Deviation**	**df**	***t***	**Sig.**
Experimental-I	2D	Pre-test	30	4.20	3.19	29	4.87	.000
		Post-test	30	6.73	3.51			
	3D	Pre-test	30	4.33	2.93	29	4.09	.000
		Post-test	30	6.40	3.04			
Experimental-II	2D	Pre-test	29	4.59	3.22	28	4.08	.000
		Post-test	29	7.03	2.21			
	3D	Pre-test	29	4.24	2.53	28	6.41	.000
		Post-test	29	6.76	2.67			
Control-I	2D	Pre-test	30	5.03	2.95	29	2.08	.047
		Post-test	30	5.90	3.24			
	3D	Pre-test	30	5.33	3.00	29	2.30	.029
		Post-test	30	6.17	3.18			
Control-II	2D	Pre-test	28	3.21	2.44	27	.44	.665
		Post-test	28	2.96	2.65			
	3D	Pre-test	28	3.14	2.40	27	.54	.592
		Post-test	28	3.32	1.93			

In Table 5, it was observed that there was a statistically significant difference between the pre-test and post-test score means of spatial relations dimension of two-dimensional [$t_{(29)}$=4.87, p<.05] and three-dimensional [$t_{(29)}$=4.09, p<.05] of experimental-I group students' SRT and two-dimensional [$t_{(28)}$=4.08, p<.05] and three-dimensional [$t_{(28)}$=6.41, p<.05] of experimental-II group students' SRT. According to this, it can be stated that the intelligence games activities which were performed both with concrete materials and in computer environment, significantly improve the two and three-dimensional spatial relations skills of students.

When Table 5 is examined, it was observed that there was a statistically significant difference between the pre-test and post-test score means of control-I group students' SRT in terms of two-dimensional [$t_{(29)}$=2.08, p<.05] and three-dimensional [$t_{(29)}$=2.30, p<.05] spatial relations dimension. According to this, it can be stated that intelligence games activities that are suggested by MoNE, significantly improves the two and three-dimensional spatial relations skills of students. In addition to this, there wasn't a statistically significant difference between the pre-test and post-test score means of control-II group students' SRT in terms of two-dimensional [$t_{(27)}$=.44, p>.05] and three-dimensional [$t_{(27)}$=.54, p>.05] spatial relations dimension. According to this, it can be stated that there wasn't a significant difference depending upon a different reason in the two and three-dimensional spatial relations skills of the students of which any activity about the intelligence games are applied throughout the application.

The mean difference scores of the students in the experimental and control groups regarding the SRT were compared using ANOVA, and the findings are presented in Table 6.

Table 6. ANOVA results on the mean of difference scores of the students in the experimental and control groups regarding the SRT

	Groups	N	Mean	Std Deviation		Sum of Squares	df	Mean Square	*F*	Sig.
2D	Experimental-I	30	2.53	2.85	Between Groups	155.123	3	51.708	6.301	.001
	Experimental -II	29	2.45	3.24	Within Groups	927.356	113	8.207		
	Control-I	30	.87	2.29	Total	1082.479	116			
	Control-II	28	-.25	3.03						
Significant Differences: Experimental-I and Control-I, Experimental-I and Control-II, Experimental-II and Control-I, Experimental-II and Control-II										
3D	Experimental-I	30	2.07	2.77	Between Groups	100.926	3	33.642	6.996	.000
	Experimental -II	29	2.52	2.11	Within Groups	543.382	113	4.809		
	Control-I	30	.83	1.98	Total	644.308	116			
	Control-II	28	.18	1.74						
Significant Differences: Experimental-I and Control-I, Experimental-I and Control-II, Experimental-II and Control-I, Experimental-II and Control-II										

As shown in Table 6, it was revealed that there was a statistically significant difference between the means of the difference scores of the students in the experimental and control groups regarding the two-dimensional [$F_{(3,113)}$=6.301, p<.05] and three-dimensional [$F_{(3,113)}$=6.996, p<.05] spatial relations dimension of SRT. For the two-dimensional spatial relation, it was determined that the differences were between experimental-I with control-I, experimental-I with control-II, experimental-II with control-I, and experimental-II with control-II. According to these findings, the development of two-dimensional spatial relations skills of the experimental-I group students was significantly higher than that of the control-I and control-II group students, the development of two-dimensional relations skills of the experimental-II group students was higher than that of the control-I and control-II group

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students. For the three-dimensional spatial relation, it was determined that the differences were between experimental-I with control-I, experimental-I with control-II, experimental-II with control-I, and experimental-II with control-II. According to these findings, the development of three-dimensional spatial relations skills of the experimental-I group students was significantly higher than that of the control-I and control-II group students, the development of three-dimensional relations skills of the experimental-II group students was higher than that of the control-I and control-II group students.

The mean SOT pre-test and post-test scores of the students in experimental and control groups were compared with *t*-test and obtained findings were presented in Table 7.

As shown in Table 7, it was observed that there was a statistically significant difference between the pre-test and post-test score means of experimental-I [$t_{(29)}$=-3.70, p<.05] and experimental-II [$t_{(29)}$=-4.25, p<.05] group students' SOT. According to this, it can be stated that the intelligence games activities which were performed both with concrete materials and in computer environment, significantly improve the spatial orientation skills of students.

Table 7. *T*-test result of the mean SOT pre-test and post-test scores of the students in experimental and control groups

	SOT	**N**	**Mean**	**Std Deviation**	**df**	***t***	**p**
Experimental-I	Pre-test	30	4.83	2.15	29	3.70	.001
	Post-test	30	6.90	2.32			
Experimental -II	Pre-test	29	5.72	2.48	28	4.25	.000
	Post-test	29	7.86	1.48			
Control-I	Pre-test	30	6.30	2.67	29	1.66	.108
	Post-test	30	7.27	2.36			
Control-II	Pre-test	28	5.82	1.96	27	.823	.418
	Post-test	28	6.25	2.30			

In Table 7, it was observed that there wasn't a statistically significant difference between the pre-test and post-test score means of control-I group students' SOT [$t_{(29)}$=1.66, p>.05]. According to this, it can be stated that there wasn't a significant increase in the spatial orientation skills of the students after the intelligence games activities that are suggested by MoNE were applied. In addition to this, there wasn't a statistically significant difference between the pre-test and post-test score means of control-II group students' SOT [$t_{(27)}$=.823, p>.05]. According to this, it can be stated that there wasn't a significant increase, depending upon a different reason in the spatial orientation skills of the students of which any activity about the intelligence games are applied throughout the application.

The mean difference scores of the students in the experimental and control groups regarding the SOT were compared using ANOVA, and the findings are presented in Table 8.

Table 8. ANOVA Results on the Mean of Difference Scores of the Students in the Experimental and Control Groups Regarding the SOT

	Groups	**N**	**Mean**	**Std Deviation**		**Sum of Squares**	**df**	**Mean Square**	***F***	**Sig.**
SOT	Experimental-I	30	2.07	3.06	Between Groups	61.169	3	20.390	2.358	.075
	Experimental-II	29	2.14	2.71	Within Groups	977.139	113	8.647		
	Control-I	30	.97	3.19	Total	1038.308	116			
	Control-II	28	.43	2.75						

When Table 8 was examined, a statistically significant difference between the means of the SOT difference scores of the students in the experimental and control groups [$F_{(3,113)}$=2.358, p>.05] was not observed. This finding can be interpreted as there is no significant difference between the development of spatial orientation skills of students in experimental and control groups.

DISCUSSION and CONCLUSIONS

In the research, it was revealed that intelligence games activities that were performed with concrete materials and in computer environment significantly improve the two-dimensional spatial visualization skills of the students. Demirkaya and Masal (2017) also concluded that activities based on geometric-mechanical games are effective in improving the two-dimensional spatial visualization skills of secondary school students. Also, in this research the development of two-dimensional spatial visualization skills of the groups, where intelligence games activities were conducted both in computer environment and by using the concrete materials, was significantly higher than the groups, of which performed the intelligence games activities suggested by the MoNE and the group in which no activity related to the intelligence games were performed. Moreover, the development of two-dimensional spatial visualization skills of the group in which intelligence games activities were performed in the computer environment was significantly higher than that of the group where intelligence games activities were performed with concrete materials. The reason for this finding might be that students had to think in a relatively abstract way compared to the activities performed with concrete materials, since there was no use of concrete objects in computer-based activities and because students who were forced to think in a more abstract way in computer-based activities may be considered to develop two-dimensional spatial visualization skills that require abstract thinking skills. According to Clements (1999), the reason for this finding might be that computer-based applications can provide a more suitable environment to improve some aspects of two-dimensional geometry because the computer screen is inherently two-dimensional. However, Osberg (1997) stated that "intensive education in virtual environment may create deeper spatial understanding in students because of the opportunity to encourage them to think about spatial problems, manipulate objects directly, and navigate around in virtual environments." Mayer (2018) also stated that the promising cognitive outcome of playing spatial games on the computer is the development of two-dimensional spatial skills. Alexiou and Schippers (2018) stated that dijital game facilitate the development of cognitive skills such as spatial skills, enhanced mental rotation abilities. At this point, it is also observed that Olkun (2003) found similar results as well. Olkun (2003) found in his study that the Tangram game as a concrete material played by the fourth and fifth grade students caused a significant increase in the two-dimensional spatial visualization skills of these students, while this increase was higher with the same game on the computer environment. The findings obtained from this study are supported by the research conducted by Olkun (2003). According to this, it can be said that the intelligence games played in the computer environment improved the two-dimensional spatial visualization skills of the students more than the games that are played with concrete materials.

In the research, it was revealed that intelligence games activities that were performed with concrete materials, in computer environment and were suggested by MoNE, significantly improve the three-dimensional spatial visualization skills of the students. Ha and Fang (2018) determined that the use of a technological tool called interactive virtual and physical manipulatives improves the three-dimensional spatial visualization skills of middle school students. Moreover, in this research the development of three-dimensional spatial visualization skills of the groups where intelligence games activities were performed in both concrete materials and computer environments was significantly higher than that of the group where intelligence games activities proposed by MoNE were performed and the group in which no activity related to intelligence games were performed. After the applications, it was found that the development in three-dimensional spatial visualization skills of the group in which the activities of intelligence games were performed in computer environment was higher than that of the group in which intelligence game activities were performed with concrete materials. However, it was found that the difference between them was not statistically significant, and similar findings were obtained by Drickey's (2000), and Yildiz and Tüzün's (2011) studies. Drickey (2000) investigated the effects of virtual and concrete manipulatives on visualization and spatial reasoning skills of students on the sixth-grade students in primary school in a study. As the result of this research, it was determined that the virtual manipulatives increased students' visualization and spatial reasoning skills compared to the concrete manipulatives, although the difference between them was not statistically significant. In their study which was carried out on fifth grade students, Yildiz and Tüzün (2011), compared the effects of the three-dimensional virtual unit cube simulation in computer environment and concrete unit cubes on three-dimensional spatial visualization skills of the students, and found that the use of three-dimensional virtual unit cubic simulation further improves the spatial visualization skills of the students compared to the use of concrete unit cubes, but the difference between them was not statistically significant. According to Durmus and Karakirik (2006) the reason for these findings is the fact that the virtual manipulatives are the actual models of concrete manipulatives, so that virtual manipulatives provide as much engagement as concrete manipulatives do. Because both physical and virtual manipulatives are one of the supportive instructional tools used in teaching (Gecu-Parmaksiz & Delialioglu, 2019). The findings of this study and the findings obtained from the previous studies are similar. Based on these findings, it can be said that activities in virtual environments can be used interchangeably with concrete materials in the development three-dimensional spatial visualization skills.

In the research, it was revealed that intelligence games activities that were performed with concrete materials, in computer environment and were suggested by MoNE, significantly improve the two-dimensional spatial relations skills of the students. Liu et al. (2000) investigated the effects of video game on two dimensional spatial relations skills of students in a study. As the result of this research, it was determined that video game training led to significant improvements in two dimensional spatial relations skills. Furthermore, in this research, the development of two-dimensional spatial relations skills in the group where intelligence games activities were performed both using the concrete materials and in the computer environment was significantly higher than the group where intelligence games activities proposed by MoNE were performed and the group in which there was no activity related to intelligence games. Although the development of two-dimensional spatial relations skills in the group where intelligence games activities were performed with concrete materials was higher than the group where intelligence games activities were performed in the computer, but the difference between them was not statistically significant. Verhaegh, Resing, Jacobs and Fontijn (2009) linked the fact that the intelligence games activities with concrete materials have a greater impact on the development of two-dimensional spatial relations skills than computer-based activities to concrete materials since they don't degrade the dimensionality to a flat screen, and provide a more visual-spatial freedom than the computer by adding different tactile experiences. In the research carried out by Yurt and Sünbül (2012) with sixth grade students, different results were obtained. According to the research, the two-dimensional spatial relations skills of the students in the group which use computer manipulatives were significantly higher than those in the group which use concrete manipulatives. There are situations where the findings of the study contradict with the findings obtained from the previous studies. Therefore, it seems difficult to reach a certain conclusion about what kind of activities develop the skills in two-dimensional spatial relations.

In the research, it was revealed that intelligence games activities that were performed with concrete materials, in computer environment and were suggested by MoNE, significantly improve the three-dimensional spatial relations skills of the students. VanMeerten et al. (2019) investigated the effects of a mobile puzzle game on three dimensional spatial relations skills of students in a study. As the result of this research, it was determined that a mobile puzzle game training led to significant improvements in three dimensional spatial relations skills. Moreover, in this research the development of the three-dimensional spatial relations skills in the group which use concrete materials and computer games on intelligence games was significantly higher than the group in which the activities of the intelligence games recommended by MoNE were carried out and the group in which any of the activities related to intelligence games were performed. Although the development of the three-dimensional spatial relations skills of the group in which intelligence games activities were performed in computer environment was higher than that of the group in which the activities were performed with concrete materials, the difference between them was not statistically significant. Yildiz and Tüzün (2011) found that the use of concrete unit cubes, the use of three-dimensional virtual unit cubic simulation, improved students' three-dimensional spatial relations skills, although the difference between them was not statistically significant. From these findings, it can be stated that the concrete material and the activities performed in the virtual environment can be used instead of each other in order to develop three-dimensional spatial relations skills.

In the research, it was revealed that intelligence games activities that were performed with concrete materials and in computer environment significantly improve the spatial orientation skills of the students. At this point, it is also observed that Lowrie et al. (2019) found similar results as well. The results of the research conducted by Lowrie et al. (2019) add to evidence that a spatial reasoning enrichment program implemented by teachers in their own classrooms can enhance spatial orientation skills. But in the research, it was found that there was no significant difference in the development of spatial orientation skills of the group, in which the activities were performed computer environment, by using concrete materials and were proposed by MoNE and there was no activity related to intelligence games. This can be due to the fact that intelligence games activities, both in concrete materials and in computer environments, do not require the use of direct spatial orientation skills, because activities require the use of spatial visualization skills, such as associating and parsing direct geometric shapes in the mind, as well as spatial relations skills such as rotating the shapes in the mind to suit the purpose.

Based on the findings, it can be recommended that teachers use both concrete materials and computer-based intelligence gaming activities in the development of spatial abilities of secondary school students. In the development of two-dimensional spatial visualization, especially in the computer environment intelligence games activities can be utilized. Geometric-mechanical intelligence games in both physical forms can be used to teach geometry, which has a positive relationship with spatial ability. Geometric-mechanical intelligence games can be included in the geometry course, especially in subjects such as "Geometric Objects, Transformation Geometry, Appearances of Objects from Different Perspectives", so that middle school students can learn both by having fun and by doing and experiencing. Teachers may be specifically recommended to use Q-Bitz Extreme and Katamino games in teaching the subject of "Transformation Geometry", which includes Reflection, Translation, Image, Symmetry, and Architecto and Soma Cube in teaching the subject of "Appearance of Objects from Different Perspectives". In future studies, researches on the development of different cognitive skills can be carried out for other units of the intelligence games courses. Studies can be carried out to monitor whether the intelligence games activities carried out in computer environment or using concrete materials can be transferred to other courses in the school. Studies comparing the effects of two-and three-dimensional intelligence games individually on spatial ability can be conducted.

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