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The Role of Spatial Ability on Architecture Education

Saliha Türkmenoğlu Berkan, Gebze Technical University, Turkey
Saniye Karaman Öztaş, Gebze Technical University, Turkey
Fatma İlknur Kara, Gebze Technical University, Turkey
Ayşegül Engin Vardar, Gebze Technical University, Turkey

Abstract
Spatial ability is one of the most important key points for technical professions such as architects and engineers and is directly related with the success in educational and professional business life. In this regard, "Techniques of Architectural Presentation", a first semester architectural department course at Gebze Technical University, aims to provide these skills through a variety of techniques such as two-dimensional, three-dimensional representations and models. In this study, the contribution of this course on spatial skills were researched considering students' spatial experiences and innate abilities before architectural education. Pre-test and post-test research were applied and analysed with Statistical Packages for Social Science (SPSS) version 18 software. The pre-test and post-test results have concluded that significant progression was seen between spatial visualisation-spatial perception and spatial orientation tests, while no significant progression was seen between mental rotation and spatial relation- mental rotation tests. The evaluation of the data indicates that the mentioned course is highly effective in the development of spatial skills in total and in the context of spatial visualisation and spatial orientation and the skills can be enhanced by training. Therefore, the syllabus of the course needs to be improved in terms of mental rotation and spatial relation.

Keywords
Spatial Ability, Spatial Experiences, Architecture Education, Architectural Presentation, Mental Rotation.

Introduction
As Cross (2006) clearly stated, design is 'the conception and realisation of new things'. Every discipline that incorporates the process of designing new things (architects, engineers, graphic designers, industrial designers etc.) requires a variety of cognitive skills. Spatial ability is one of the most important of these cognitive abilities. Spatial ability, to visualize an object or a space, mental manipulation of the scene, to animate, rotate, and resize an object in space, is considered necessary and important in all STEM (Science, Technology, Engineering and Mathematics) disciplines (Halpern & Collaer 2005; Nagy-Kondor 2014; Stieff & Uttali 2015). Considered in its most basic form, basic spatial abilities are needed in the simplest actions in daily life, such as driving or finding direction. Further spatial abilities are needed in architecture discipline when designing a building or interpreting the technical drawing of the designed building. Sutton and Williams (2011) state that architecture is foremost in its application of spatial abilities, a component of design cognition, to the creation of space, and comments that

spatial ability plays an important role in architectural education and for the learning experiences of architecture students.
From this point of view, in this study, it is aimed to investigate the effects of the students' spatial experiences and innate abilities on developing individual spatial abilities before architectural education, and to examine the contribution of the “Techniques of Architectural Presentation” (ARCH 101) course in the development of spatial abilities of the Gebze Technical University, Department of Architecture first year students.

Spatial Ability

The idea of spatial ability was expressed by Galton in 1879. The investigations of spatial ability continued in the 1880s with his studies on mental imagery. He defined the visualising faculty as spatial ability and, asserted that the visualising faculty is a natural gift and has a tendency to be inherited (Galton, 1880a,1880b). Since that time, researchers have defined spatial ability in various ways, discussed the components of spatial ability, and developed various methods to measure it (Mohler, 2006). Spatial ability has been a significant area of research in educational psychology since the 1920s -30s (Sorby, 1999), as the concept of spatial intelligence was defined within other factors of intelligence. The spatial ability is a complex area in terms of scope and does not have a clear definition or categorisation. McGee (1979) defines spatial ability as the ability to mentally manipulate, rotate, twist or invert pictorially presented stimuli. Linn and Petersen (1985) approach this from a more conceptual perspective and define spatial ability as skill in representing, transforming, generating, and recalling symbolic, non-linguistic information. Sutton and Williams (2011) form an idea of the concept from an architectural perspective and define spatial ability as the mental manipulative skills required to perform mental processes such as the rotation of objects, the understanding of how objects appear in different positions, and the conceptualisation of how objects relate to each other in space. Schneider and McGrew (2012) define spatial ability as the sensory- and motor- linked abilities and indicate that these abilities are hard to define.

Ilıc and Djukic (2017) state that, in educational psychological research, a distinction is often made between "spatial ability" and "spatial skills”: spatial ability identifies an innate ability, whereas spatial skills define the skill acquired by one’s own effort through training. Sorby (1999) interprets that it is impossible to distinguish between spatial abilities and spatial skills for students at the university level as we have no idea of the training; therefore, the researcher prefers to use the terms "spatial ability" and "spatial skills" interchangeably. In this context, Bishop (1978) narrates that, according to Piagetian theory, spatial skills are developed in three stages (as cited in Sorby 1999; Mohler 2008):

1. Topological Space Stage (Level 1): Two-dimensional (2D) skills, that are acquired by the age of 3-5. (making puzzle or playing with construction toys)
2. Projective Space Stage (Level 2): The ability to visualise objects three-dimensionally (3D). Children often develop this skill in adolescence, with the use of everyday objects.
3. The Transition from Projective Space to Euclidean Space Stage (Level 3): The individuals learn to go back and forth between 2D and 3D. The ability to combine measurement concepts with their projective skills, to visualise the concepts of area, volume, distance, translation, rotation, and reflection are acquired.

The researchers do not mention about one type of intelligence but stress the existent of many intelligences to be learned. In this regard, spatial skills, as a learned skill, have many sub-factors as referred to below.

Factors and Tests of Spatial Ability

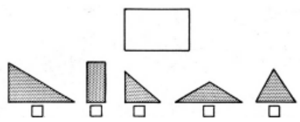
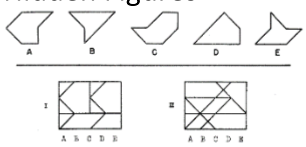
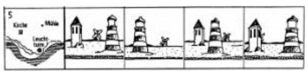
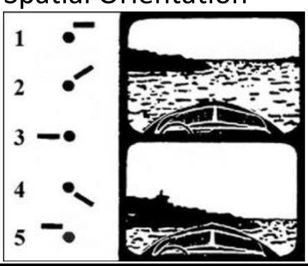
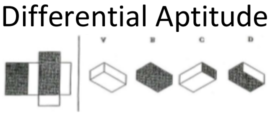
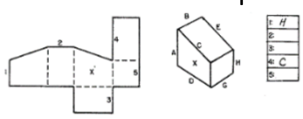
Even though researchers have different approaches in the definition of spatial skills, there is no real consensus about the categorisations of the field. Between 1950 and 1994, during the factorial phase of spatial ability, researchers examined spatial ability more closely and identified the constituent factors of this intelligence (Maresch 2014). Linn and Petersen (1985) had analysed the studies of Carpenter and Just (1986), Cooper and Regan (1982), Guilford (1967), Shepard and Cooper (1982), Thurstone and Thurstone (1941), Cattell (1971) and Vernon (1965) and classified spatial ability under three factors: Spatial Perception, Mental Rotation and Spatial Visualisation. Linn and Petersen (1985) define these factors as: Spatial Perception (SP), Mental Rotation (MR) and Spatial Visualisation (SV). Maier (1994) states that the subject is too complex to be handled under three elements and distinguishes the spatial intelligence under five factors based on several theories of intelligence, meta-analyses and a number of spatial ability studies (as cited in Maier 1996). The five factors of spatial intelligence are:

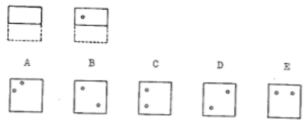
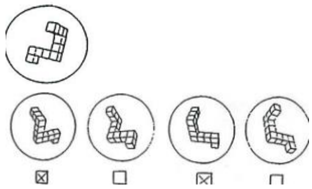
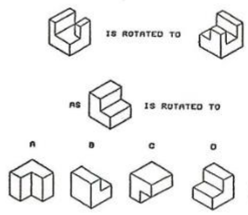
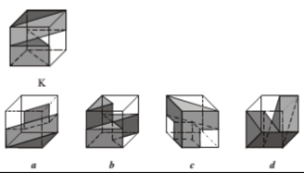
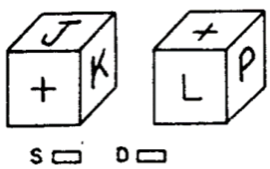
- SP: The ability to identify the horizontal or the vertical location, in spite of distracting information
- SV: The ability to visualise a configuration in which there is movement or displacement among (internal) parts of the configuration.
- SR: the ability to comprehend the spatial configuration of objects or parts of an object and their relation to each other.
- SO: The ability to orient oneself physically or mentally in space.
- MR: The ability to rotate a 2D or 3D figure rapidly and accurately.

Schneider and McGrew (2012) classified spatial ability under eleven factors: Visualisation (VZ), speeded rotation (spatial relations- SR), Closure speed (CS), Flexibility of closure (CF), visual memory (MV), Spatial scanning (SS), Serial perceptual integration (PI), Length estimation (LE), Perceptual illusions (IL), Perceptual alternations (PN) and Imagery (IM) in the Cattell-Horn-Carroll (CHC) theory. Buckley, Seery & Canty (2018) offers 25 factors which are not explicitly represented within the CHC theory and classified spatial ability in two categories as static spatial factors and dynamic spatial factors.

Standardised tools such as spatial ability tests (Mental Cutting Test, Purdue SV Test, etc.) exist to assess spatial ability. In order to present a typology of spatial ability tests, Ilıc and Djukic (2017) grouped 18 spatial ability tests under two categories according to the dimensionality of space (2D or 3D), and subsequently classified the 3D tests into four types based on their complexity, factors that measure, and the execution in architectural studies.

Table 1. Typology of Spatial Ability Tests (Ilic and Djukic 2017).

Group	Type	Number	Task		Factors measured				
					SV	SP	SR	SO	MR
2D		1	Form Board 	Which of the given shapes could be rotated to fit into a given rectangle?	✓		✓		
		2	Card Rotations 	Which shape on the right match to the shape on the left that has been rotated?					✓
		3	Hidden Figures 	Which of the shapes given in the Picture above are contained in complex figures given in the bottom of the drawing?	✓	✓			
3D	Orientation	1	Arial Orientation 	Determine the position of the observer on the left for each view shown on the right.				✓	
		2	Spatial Orientation 	Which of the five offered top views Show the change in orientation of the bow drawn in the pictures?				✓	
3D	Mental Manipulation	1	Differential Aptitude Test 	Which of the solids given right match the unfolded net on the left?					✓
		2	3D Surface Development 	Data is a 3D image of the object and its developed network. Match the letters and					✓

				the numbers to correspond to a given shape and it's developed surface.						
		3	Paper Folding 	Sheet of paper is folded and then drilled as shown in the left picture. Which of the given solutions to the right match to the developed form of paper on the left?						✓
		4	Mental Rotation Test 	Respondents should determine which of the offered rotated solutions below match the given object above.						✓
		5	Purdue Spatial Visualisation Test 	Which of the offered rotated solutions below match the given object in the middle, if the rule of rotation is given in the example on top.						✓
		6	Complement Cube Test 	Which of the solutions given on the right fit to the object on the left to make a cube?				✓		✓
		7	Cube Comparisons Test 	Which of the given pairs of views present the same cube? All the sides of the cube are different.				✓		✓

Significant Factors in the Development of Spatial Skills

Spatial ability, like other types of intelligence, can be an innate ability, or a skill acquired by one's own effort through training or experiences. McKim (1980) states that sketching 3D objects is a significant factor in the development of spatial abilities. Besides, Sorby (1999) remarks the importance of activities that require eye-to-hand coordination to develop these skills and lists these activities as: 1) playing with construction toys as a young child, 2) participating in classes such as shop, drafting or mechanics as a middle school or secondary student, 3) playing 3D computer games, 4) participating in some types of sports, 5) having well developed mathematical skills.

Medina, B. P. Gerson and Sorby (1998) formed a questionnaire in their study to grasp information from the backgrounds of the participants. Questions asked to the participants were related to the types of activities thought to develop spatial skills including: age, handedness, play with construction toys (like Legos® or Lincoln Logs®), previous geometry instruction, work experience, participation in certain sports, their parent's technical instruction, play with video/computer games, previous descriptive geometry instruction, previous art courses, previous technical courses, previous experience with graphics/drafting and project based work experience. The results of the study showed statistical significance in the development of 3-D spatial skills for almost all factors based on the context of the test type.

Baenninger and Newcombe (1989) state that training studies to improve spatial ability can take a number of forms. The simplest type of training is task specific, in which a specific spatial test can be performed to the experimental group. A second type of training is to offer instructions in spatial ability to the experimental group. The third type of training is "spatial experience", in which participants involve experience not directly linked to particular spatial ability. Baenninger and Newcombe (1989) remark that when a PreT and PosT research is used, it can be seen that a spatially rich environment, such as a technical drawing course, increases spatial ability more than task-specific training. Pütz (2000, 2001) states that descriptive geometry courses, the training of 3D imagination, are significant for understanding the various ways of projection for architectural drawings spatial objects in the architect's field of activity.

Uttal, Miller and Newcombe (2013) examined 206 studies using a meta-analysis technique to answer spatial ability can be improved by spatial training. Like playing video games, practicing spatial tests, graphic/design courses improved spatial skills and well designed and intensive training can have lasting benefits. Another finding about their analysis is that children and adults as well as women and men responded equally to training. But more research is necessary to determine difference with each mentioned group. Stieff and Uttal (2015) highlighted that extended training in excess of several months to yield lasting benefits for spatial training interventions may be required, and the impact of such training may not be seen until much later in a student's educational life or developmental trajectory.

Besides the factors that establish direct proportion with the development of spatial skills, there are also factors that have inverse proportion with spatial skills, such as age. Studies in Developmental Research have found that age affects spatial ability; spatial ability improves with age in childhood but declines with age in adulthood (Mohler, 2008). Another factor that does not establish a direct proportion to spatial skills, such as the age factor, is the sex factor. However, there is still a debate about how gender affects spatial skills.

A significant part of spatial skills literature focuses on sex differences. According to researchers in psychology and the social sciences, males and females differ in spatial ability. Masters and Sanders (1993) state that sex differences have remained at approximately 0.9 standard deviation units for almost two decades. Voyer, Voyer and Bryden's (1995) meta-analysis supports the idea that sex differences are not generally declining and depends on the test used. Halpern and Collaer (2005) state that there has been much interest in the possibility that sex differences in cognitive abilities, in general, and in spatial abilities, are decreasing.

The Role of Spatial Ability in Architecture

The spatial ability which is effective on architecture profession also has been emphasised by the researchers. In the study of Ilıc and Djukic (2017), it was stated that spatial skills are very important for technical professions and are required when enrolling in technical studies, especially in the studies of architecture. Williams and Sutton (2011) also indicated that spatial ability should therefore be considered a fundamental skill in design-based disciplines, but its importance is not always understood or given the attention it deserves. Karlins, Schuerhoff and Kaplan (1969) investigated architectural creativity for 17 undergraduate architectural students. It was concluded that architectural creativity may be related to "visualisation" as a spatial ability. Sutton and Williams (2011) conducted a research project focusing on the relation of spatial ability and course performance of first year architecture design studio students. As a result of the research, it was determined that spatial skills developed more in the freehand study period (first half of the school year), than in the CAD study period (second half of the school year). The researchers did not observe any difference between the spatial ability of females and did not find a significant relationship between the ability of university entrance exam scores and spatial skills.

In order to identify the relationships among spatial ability, creativity and studio performance, Cho (2012a) conducted an exploratory study with 21 freshman architecture students. The results of the study indicate that studio performances cannot be used to explain students' creativity or spatial ability levels.

At Gebze Technical University, technical drawing education is given as a separate course entitled ARCH 101 Techniques of Architectural Presentation. The aim of the course is to provide students with a variety of techniques such as 2D representations (plans, sections and elevations of a project) and 3D representations (physical or computer-generated models and perspectives) to formulate each stage of the architectural design process. The ability to read, interpret, and visualise 2D to 3D in the scope of this course is known as spatial ability (Cho 2012b).

This course is given for six hours a week in the fall term of the first year in the Department of Architecture in Gebze Technical University. It is a two-hour theoretical and four-hour applied course. The course for undergraduate students who are new to architecture education plays an important role in transferring the design ideas they think about mentally to drawings and developing architectural expression techniques.

In this course, each subject was taught theoretically face to face in two drawing ateliers or the computer laboratory for two hours per week. After the theoretical lecture, relevant practices for problem-solving about that subject were provided under the guidance of instructors and supported by hand/computer drawings and models. Extracurricular individual studies were requested to be completed as assignments at the end of each lesson. The assignments were checked by the instructors and the assignments in which the mistakes were marked given back to the students. The assignments that could not be completed by most students were repeated with different practices. The syllabus and assignments of the course for 2018-2019 fall term and spatial abilities expected to be acquired by students are given below (Table 2).

Table 2. The syllabus and assignments of the course and related spatial abilities.

Weeks	Teaching activity/ Syllabus	Assignment No	Definition	Spatial Ability				
				SV	SP	SR	SO	MR
1	outdoor freehand sketching, usage of architectural drawing tools with samples (2D)	No Assignment			✓	✓		
2	technical drawing, drawing types, hatching techniques (2D)	A1	Lines		✓	✓		
		A2	Shapes					
		A3	Alphabet					
3		A4	Hatches		✓	✓		
		A5	Pavement Plan and Section					
		A6	Stair Sections					
		A7	Free Hand Drawings					
4	projection drawings, isometric projection (projection planes), computer aided design geometry - (2D and 3D)	No Assignment		✓	✓	✓	✓	✓
5		A8	Model (Projection Plans)	✓	✓	✓	✓	✓
6	scale and measurement concepts (2D)	A9	Projection Drawings		✓	✓		
7	projection drawings (projection drawings of geometrical object compositions by scaling, plan, section, elevation) scale and measurement concepts with simple plan drawings and computer aided projection drawings (2D and 3D)	A10	Plan of geometrical objects	✓	✓	✓	✓	✓
		A11	Sections of geometrical objects					
		A12	Elevations of geometrical objects					
		A13	Elevations of geometrical objects					
8		No Assignment		✓	✓	✓	✓	✓
9	Mid Term Exam							
10		No Assignment		✓	✓	✓	✓	✓

11	drawing a sample project (masonry building, reinforced concrete building) (2D and 3D)	A14	1/100 plan	✓	✓	✓	✓	✓
		A15	1/100 section					
		A16	1/100 elevation					
12		A17	1/50 plan	✓	✓	✓	✓	✓
		A18	1/50 section					
		A19	1/50 elevation					
13	perspectives drawings, types of perspectives, isometric, diametric, trimetric perspectives, one-point and two-point perspectives (2D and 3D)	A20	One-point perspectives	✓	✓	✓	✓	✓
		A21	Two-point perspectives					
14		No Assignment		✓	✓	✓	✓	✓

Some of the assignments during the course are detailed below (Figure 1, 2).

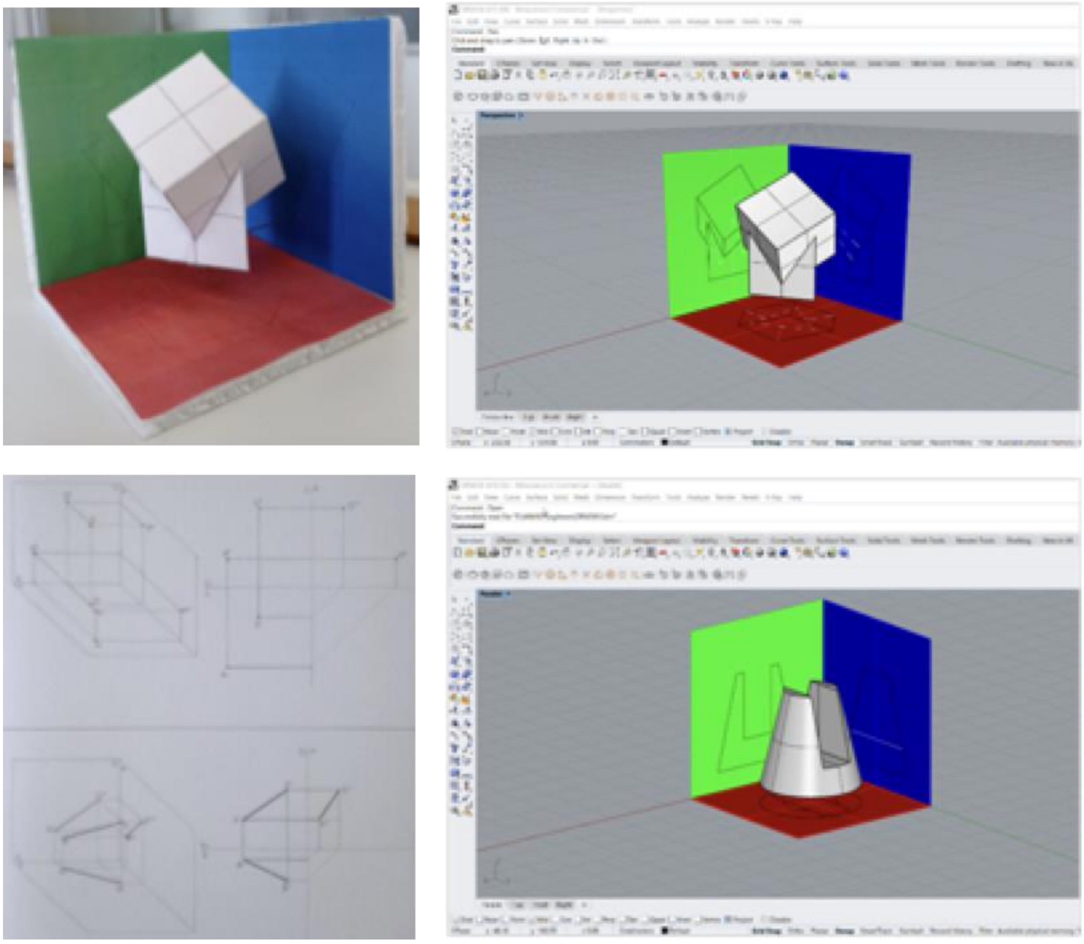


Figure 1. The example of projection drawings and model assignment (A8).

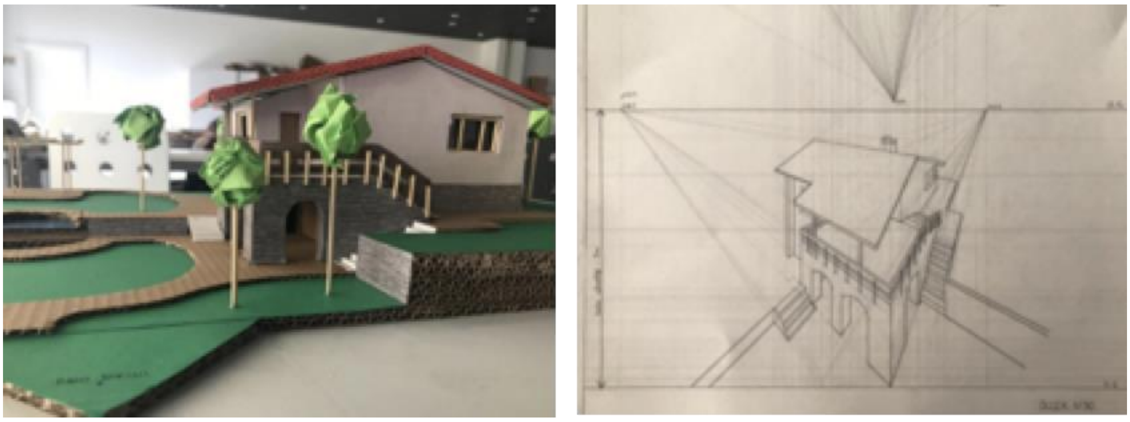


Figure 2. The example of two-point perspective assignment (A21).

Research Aim and Methodology

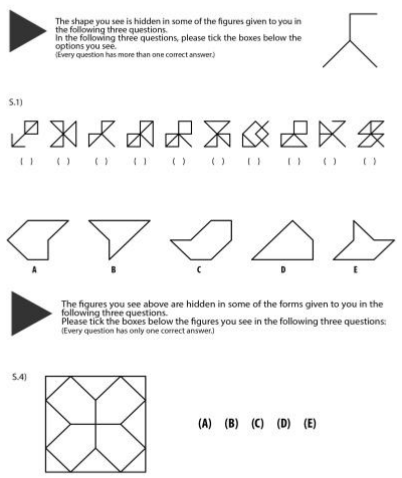
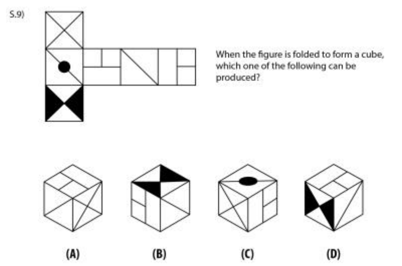
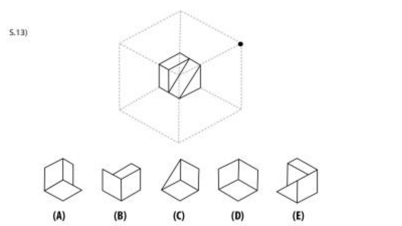
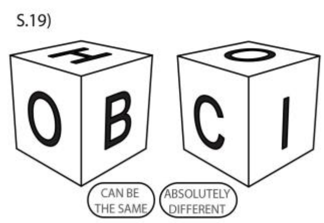
Williams and Sutton (2011) emphasised that spatial ability in the past was considered an innate ability, but recent research has created an awareness that this may not be the case in all situations. In this viewpoint, the aim of this study is:

- to investigate the effects of the students' spatial experiences and innate abilities on developing their spatial skills before architectural education
- to examine the contribution of ARCH 101 course in the development of spatial skills of the architecture students.

For these two research objectives, Pre-test (PreT) and Post-test (PostT) research were applied for the architecture students. The significant limitation of this study was the number of first year architecture students taking the course. The scores of 96 students were evaluated responding to the first and second tests among 124 architecture students. A questionnaire was done before the first test that contains the information about the students considering the factors affecting the spatial skills emphasised in the literature. Age, mother and father profession, gender, university admission score, active used hand, sketching experiences, work experiences, whether computer games have been played, whether geometry and art lessons have been taken before, whether sports have been participated in, whether puzzle and/or construction toys have been played were questioned in this part of the test. In the description part for some questions in the questionnaire, the students were asked to indicate how long experience they had in sketching, working, playing computer games, and taking lessons, etc. Long-term experiences were taken into account in the evaluations.

Design of the test questions: In order to evaluate the student's development between PreT and PostT in terms of spatial ability, the same question types with the same difficulty were prepared for each test. The PreT and PostT were formed by subtests of 24 questions to investigate the students' spatial skills. Detailed contents of the tests can be seen at Table 3.

Table 3. Contents of the PreT and PostT.

Number of Questions	Spatial Ability Test	Spatial Ability Factor	Question Examples
6	Hidden Figures and Hidden Patterns Tests Questions 1-6 (Ekstrom, French, Harman, and Dermen, 1976)	SV+SP	
6	Differential Aptitude Test Questions 7-8 (Kösa, 2011) Questions 9-10 (Carter and Russell, 2007) Questions 11-12 (URL 1)	MR	
6	Arial Orientation Test Questions 13-18 (Kösa, 2011)	SO	
6	Cube Comparison Test Questions 19-24 (Ekstrom, French, Harman, and Dermen, 1976)	SR+MR	

Test was formed based on Maier's spatial ability factors differentiation. Six questions were asked for every spatial ability factor (SV, SR, SP, MR, SO). The pilot study of the test was done, and the test time was determined to be one hour given in total for all subtests of 24 questions to focus the students on the test.

Sorby (1999) states that most spatial skills tests have been developed to assess a person's skill-level in the first two stages of development. From this point of view, the 2D tests, Form Board, Card Rotation or Hidden Figures, that are mentioned in the list of Ilic and Djukic (2017) assess only topological spatial skills and are not of significant interest for architecture education. On the other hand, these 2D tests indicate students' background spatial experience; therefore, hidden figures and hidden patterns tests were included in the test. Ilic and Djukic's (2017) Typology of Spatial Ability Tests table was taken as reference to compose the other three sections of the test.

Implementation of the test: The PreT intended for investigating the effects of the students' experiences and characteristics on developing their spatial skills was applied in the first week before the first lecture. The second test intended for examining the contribution of ARCH 101 course in the development of spatial skills of the students was applied in the fifteenth week after all lectures. The second test was applied as a final exam to increase the student participation.

Evaluation of the test: The results of the test were evaluated for 96 students responding to the first and second tests. Each question in the test was rated as ten points. The SPSS Statistics 18 programme was used to analyse the results. The complete road map of the research can be seen at Figure 3.

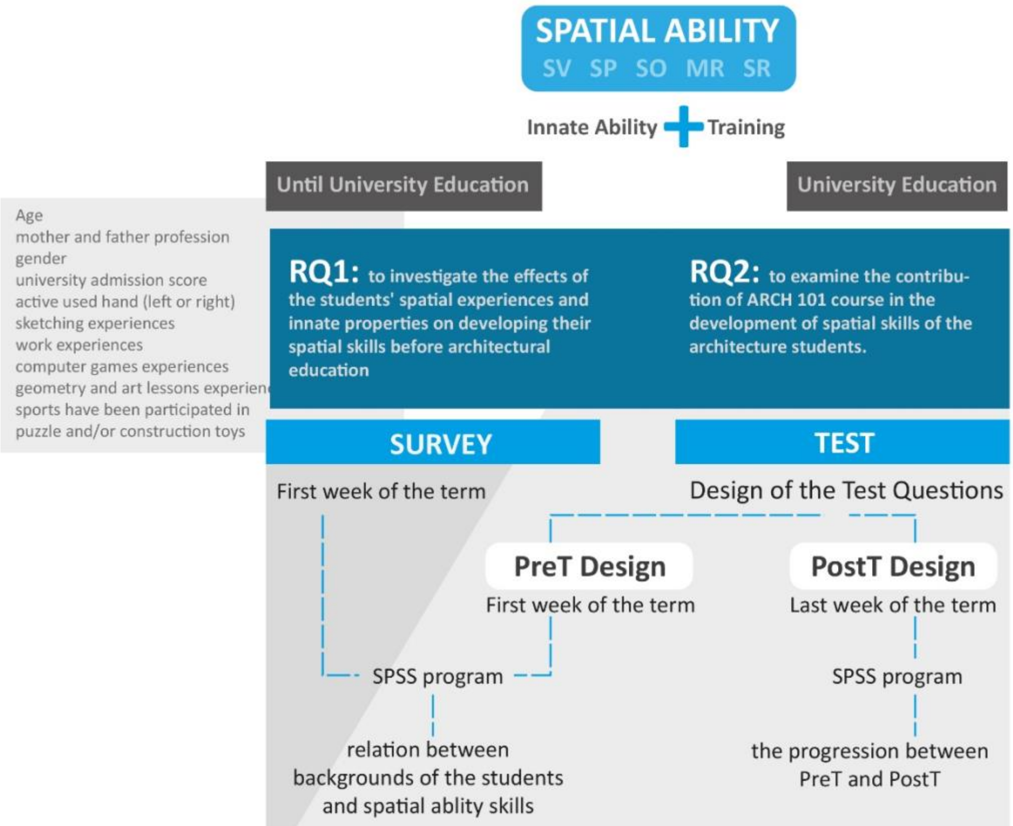


Figure 3. The road map of the research.

Findings of the Research

This study was conducted on all first-year undergraduate students in the Architectural Department at Gebze Technical University. The study group was comprised of 46 (48%) female students and 50 (52%) male students. It was indicated that 79 % of the participants' mothers are housewives, 4% nurses, 3% civil servants, 3% teachers, 2% cooks, 2% workers, 2% retired, 1% architects, 1% self-employed and 1% have other professions.

Regarding the profession of participants' fathers, 20% are self-employed, 9% retired, 9% workers, 8% civil servants, 5% soldiers, 5% other, 4% police, 3% teacher, 3% driver, 3% accountant, 3% lecturer, 2% contractor, 2% construction technician, 2% religious' officer, 1% automation technician, 1% mechanical engineer, 1% mechanical technician, 1 % computer engineer, 1% naval engineer, 1% cook, 1% banker, 1% barber, 1% farmer, and 1% operator. The students' admission scores are between 405 and 438. The questionnaire formed to elicit information from the backgrounds of the students was analysed with the scores of the PreT. Any statistically significant differences between backgrounds and PreT were not found. The graphical presentation of the study group is given in Figure 4.

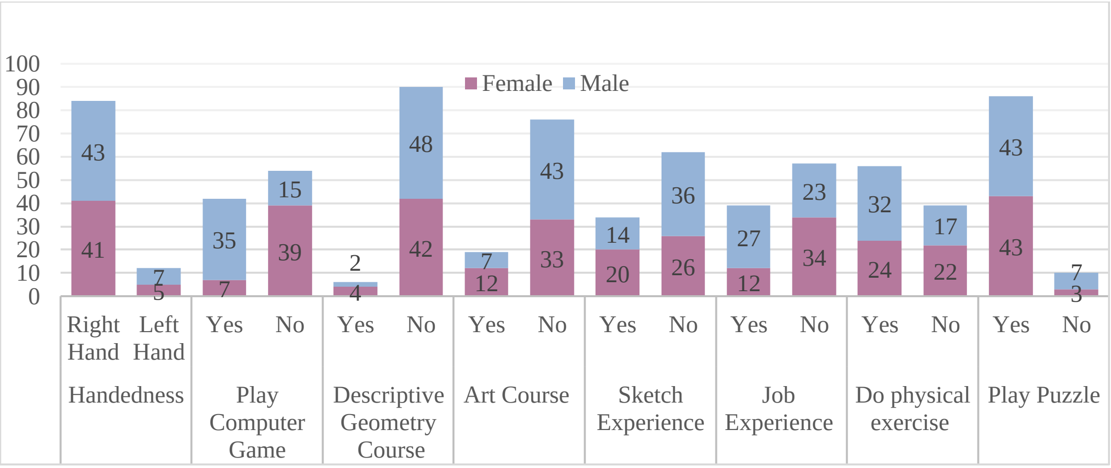


Figure 4. Information from the backgrounds of the study group.

Collected data from PreT and PostT were analysed using the SPSS software. The students' PreT and PostT scores were analysed to determine if there were significant sex differences. Table 4 points out mean, std deviation and std error results of PreTest and PostTest scores according to gender variable. According to the analysis results, the mean values of the PreT and PostT, PreT_SV+SP and PostT_SV+SP, PreT_SO and PostT_SO and PreT_SR+MR and PostT_SR+MR scores increased; mean values of PreT_MR and PostT_MR scores decreased in men and women. There is more difference for men than women in the mean value of PreT and PostT scores (Table 4).

Table 4. Mean, std deviation and std error results of PreTest and PostTest scores according to gender variable.

Variable		Statistics	PreT	PostT	PreT SV+SP	PostT SV+SP	PreT MR	PostT MR	PreT SO	PostT SO	PreT SR+MR	PreT SR+MR
Sex	Female	Mean	154.29	185.19	7.98	9.59	7.17	6.77	5.46	5.94	5.27	8.55
		Std. Deviation	30.12	25.11	1.78	0.80	1.73	2.28	2.942	2.93	1.57	1.29
		Std. Error	4.44	3.70	0.26	0.118	0.26	0.33	0.43	0.43	0.23	0.19
	Male	Mean	152.66	193.97	7.63	9.42	6.64	6.36	6.06	7.70	5.36	8.83
		Std. Deviation	35.36	25.22	2.22	1.01	1.80	2.01	3.32	2.51	1.97	1.31
		Std. Error	5.00	3.56	0.31	0.14	0.25	0.28	0.47	0.35	0.27	0.18

A Repeated-measures ANOVA test was conducted to examine the effect of gender variable on the progression between PreTest and PostTest. Homogeneity of variance (HOV) was examined using the Levene's test. If the variances are homogeneous, "sphericity assumed" row value was interpreted for a relation between gender and test score values, and the Greenhouse-Geisser row value if the variances are not homogeneous. The variances were found to be homogeneous as a result of the Repeated-measures ANOVA test performed between the PreT and PostT scores in the context of gender in Table 5 (sig> 0.05). Therefore, considering sphericity assumed row in Table 6, it was concluded that gender does not affect the PreT and PostT scores (F = 3.434; sig = 0.067> 0.05). That there is a minor difference between the mean PreT and PostT scores of men and women supports this result.

Table 5. Levene's test of equality of error variance for the progression between PreT and PostT in the context of gender.

	F	df1	df2	Sig.
PreT	2,530	1	94	0.115
PostT	,071	1	94	0.791

Table 6. Test of within subjects effects.

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Test*Gender	Sphericity Assumed	1298.485	1	1298.485	3.434	0.067	0.035
	Greenhouse-Geisser	1298.485	1	1298.485	3.434	0.067	0.035
	Huynh-Feldt	1298.485	1	1298.485	3.434	0.067	0.035
	Lower-bound	1298.485	1	1298.485	3.434	0.067	0.035

Significant results were found in PreT and PostT between sexes in SO but not in MR, SV+SP, SR+MR. The variances were found to be homogeneous as a result of the Repeated-measures ANOVA test considering the progression between the PreT_SO and PostT_SO scores (sig> 0.05) (Table 7). Therefore, considering sphericity assumed row in Table 8, it was concluded that gender affects the PreT_SO and PostT_SO scores (F = 4.309; sig = 0.041< 0.05). Figure 5 shows that males make more progress than females between the PreT_SO and PostT_SO scores.

Table 7. Levene's test of equality of error variance for the progression between PreT+SO and PostT+SO in the context of gender.

	F	df1	df2	Sig.
PreT_SO	2.157	1	94	0.145
PostT_SO	2.157	1	94	0.145

Table 8. Test of within subjects effects.

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Test_SO*Gender	Sphericity Assumed	15.975	1	15.975	4.309	0.041	0.044
	Greenhouse-Geisser	15.975	1	15.975	4.309	0.041	0.044
	Huynh-Feldt	15.975	1	15.975	4.309	0.041	0.044
	Lower-bound	15.975	1	15.975	4.309	0.041	0.044

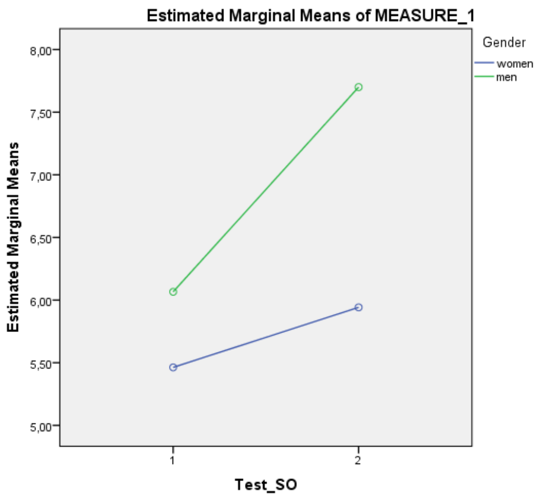


Figure 5. Profile plots of the PreT_SO and PostT_SO scores in the context of gender.

The compliance of the data to the normal distribution was analysed by Kolmogorov-Smirnov test, and the difference values of the PreT and PostT scores were found. It was seen by the normality test that the test result is fit to the normal distribution (Kolmogrov-Smirnov test sig. = 0.096).

Table 9. Paired sample test.

		Correlation	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of The Difference		t	df	Sig.(2-Tailed)
						Lower	Upper			
Pair 1	PreT_SV+SP PostT_SV+SP	0.447	-1.7086	1.8095	0.1846	-2.0753	-1.3420	-9.252	95	0.000
Pair 2	PreT_MR PostT_MR	0.062	.33681	2.71900	0.2775	-.21412	.88773	1.214	95	0.228
Pair 3	PreT_SO PostT_SO	0.577	-1.0804	2.77018	0.2827	-1.6417	-.51916	-3.821	95	0.000
Pair 4	PreT_SR+MR PostT_SR+MR	0.087	-3.375	2.11718	0.2160	-3.8039	-2.9460	-15.61	95	0.000
Pair 5	PreT-PostT	0.567	-36.321	27.8511	2.8425	-41.964	-30.678	-12.77	95	0.000

The sections of the tests were compared separately in order to measure which factors of the spatial ability were supported in the course. There is a significant, positive, and moderate relationship between PreT_SV+SP and PostT_SV+SP (Corr = 0.447). As a result of the test, a statistically significant difference was found between PreT_SV+SP and PostT_SV+SP scores at the beginning and end of the course (sig = 0.000 <0.05). It was concluded that this difference would be between -2.0753 and -1.3420 at the 95 % confidence. When the mean value is considered, it can be interpreted that the course is effective in the development of the students' spatial skills in terms of SV+SP, as the mean value is found negative after the course (Table 9).

No significant relationship was found between PreT_MR and PostT_MR (Corr = 0.062). As a result of the test, no statistically significant difference was found between PreT_MR and PostT_MR scores at the beginning and end of the course (sig = 0.228> 0.05). When the mean value is considered, the mean value after the course is found to be positive and it can be interpreted that the course is not effective in the development of the students' spatial skills in terms of MR (Table 9).

There is a significant, positive, and moderate relationship between PreT_SO and PostT_S0 (Corr = 0.577). As a result of the test, a statistically significant difference was found between PreT_SO and PostT_S0 scores at the beginning and end of the course (sig = 0.000 <0.05). It is concluded that this difference would be between -1.6417 and -.51916 at the 95% confidence interval. When the mean value is considered, it can be interpreted that the course is effective in the development of the students' spatial skills in terms of SO, as the mean value is found negative after the course (Table 9).

There is a significant, positive, and weak relationship between PreT_SR+MR and PostT_SR+MR (Corr = 0.087). As a result of the test, a statistically significant difference was found between PreT_SR+MR and PostT_SR+MR scores at the beginning and end of the course (sig = 0.000 <0.05). It was concluded that this difference would be between -3.8039 and -2.9460 at the 95% confidence interval. When the mean value is considered, it can be interpreted that the course is effective in the development of the students' spatial skills in terms of SR+MR, as the mean value is found negative after the course (Table 9).

There is a significant, positive, and moderate relationship between PreT and PostT (Corr = 0.567). As a result of the test, a statistically significant difference was found between PreT and PostT scores at the beginning and end of the course (sig = 0.000 <0.05). It was concluded that this difference would be between -41.9644 and -30.678 at the 95% confidence interval. Data about the negative mean value after the course highlight that the course is effective in the development of the students' spatial skills in total (Table 9).

The distribution of spatial ability factors on the syllabus of the course is given in Table 2. The percentages of the factors table have been composed based on the syllabus of the course. As seen in Figure 6, MR, SO and SV factors have low percentages compared to other factors on the syllabus of the course. A statistically significant progression was observed in SV+SP, SO, and SR+MR factors, but no significant difference could be observed in MR factor. Although in Figure 6 the percentage of the MR factor is similar with SO and SV factors, which have statistically significant progression, students could not progress only in the MR test between PreT and PostT scores of this study (Figure 6).

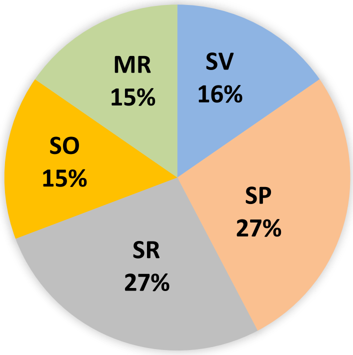


Figure 6. The distribution of spatial ability factors on the syllabus of the course.

Table 10 shows the minimum, maximum, mean, and standard deviation results of the test scores. According to these results, a difference was observed between the mean values of PreT and PostT scores. The PreT values are between 80 and 210, while the PostT values are between 125.72 and 240.00. Standard deviation values generally showed a decreasing trend in PostTests.

Table 10. Descriptive statistics for PreT and PostT scores.

Test Score	n	Min	Max	Mean	Std. Deviation
PreT	96	80.00	210.00	153.449	32.796
PostT	96	125.72	240.00	189.770	25.428
PreT_SV+SP	96	0.81	10.00	7.801	2.0232
PostT_SV+SP	96	6.43	10.00	9.510	0.9211
PreT_MR	96	3.33	10.00	6.899	1.8071
PostT_MR	96	0.00	10.00	6.562	2.1468
PreT_SO	96	0.00	10.00	5.777	3.1481
PostT_SO	96	0.00	10.00	6.857	2.8497
PreT_SR+MR	96	0.00	10.00	5.322	1.7832
PostT_SR+MR	96	3.33	10.00	8.697	1.3068

PreT and PostT scores of the students were compared and the success progression of the students was listed. Among 96 students, 6 students' scores progressed between 80-100%, 6 students progressed between 60-80%, 13 students progressed between 40-60%, 29 students progressed between 20-40%, 34 students progressed between 0-20%, while 8 students could not present an increase of scores. 54 students showed 20-100% progression among PreT and PostT scores.

The research was re-evaluated on the basis of the pre-test in order to observe the progression between the pre-course spatial ability levels and the post-course spatial ability levels. The same five scales were used to examine the students' performances in the PreT. Accordingly, 11 people scored 80% and above, 49 people scored 60-80%, 32 people scored 40-60% and 4 people scored 20-40%. Considering the progression rates of the students' scores in the PostT, it was observed that 80% and above group progressed by 2.78%, 60-80% group progressed by 18.03%, 40-60% group progressed by 43.11% and 20-40% group progressed by 70.18%.

Discussion

The Information from the Backgrounds of the Students

***Gender and age**:* Student PreT and PostT scores were analysed to determine if there were significant sex differences, 0.06 significant was found between the tests. Although Halpern and Collaer (2005) apprise that if the Women's Movement that began in the 1960s provided equivalent learning opportunities for girls and boys, and if cognitive sex differences are primarily social in origin, then these sex differences should diminish and eventually disappear with changes toward a more sex-neutral society, male students succeed better than women students in the research. Besides that, significant difference between man and female was also found at SO progression in PreT and PostT. As per Lawton's (1994) study on gender differences in way-finding strategies, women are more likely to report using a route strategy (attending to instructions on how to get from place to place), whereas men are more likely to report using an orientation strategy (SO - maintaining a sense of their own position in relation to environmental reference points). The average ages of 96 students in the study range between 18 years and 24 years, the average age is 20. 2D and 3D skills can be improved for this age range.

***Mother and father profession**:* 79% of the mother profession of the students to whom the questionnaire was applied is housewife. 46 % of the father's profession of the students is self-employed, retired, workers and civil servants. Although there was no statistically significant relationship between the mother and father profession factor, the findings of the semi-structured face-to-face interviews with the students who achieved a score of 80% or more in the PreT highlight that the family factor (mother, father, uncle, aunt, etc.) was effective in the development of spatial skills (model making with uncle, knitting with mother, etc.). As the sample group was included in the similar socio-cultural group, no significant differences were observed in the results. Different results can be obtained with different sample groups containing socio-cultural group wealth.

***University admission score**:* As the university admission scores of the students were close to each other for the same university, therefore there was no statistically significant result.
Other information from the backgrounds of the students: Referring to Figure 4, experiences such as playing computer games, taking geometry lessons, taking art lessons, and work experiences affecting spatial abilities are mostly absent for the students. Therefore, no

significant result was found between these factors and the PreT result, although it is seen that students have experience in doing sports and especially playing games like puzzle. Medina, B. P. Gerson and Sorby (1998) had found statistical significance in the development of 3-D spatial skills for almost all factors. The existence of this variable may be due to the difference in the years of the research. Medina, B. P. Gerson, and Sorby's research was conducted with 713 students from two universities, in 1997. The socio-cultural changes experienced during this time may have made it possible for students to gain access to factors that provide equal spatial experience.

The Progression in PreT and PostT Scores:

The averages of students' assignment scores during the 14-week course period can be used as indicators for spatial ability progression, besides PreT and PostT scores. Figure 7 presents the assignment performances based on spatial ability factors. Unconditional pass grade of the course is 65 out of 100. It is seen that the average of the assignments per week is over 65.

In Figure 7, it is observed that there is a decrease in the average of the assignments' scores in the weeks 5, 7, 11, 12 and 13, in which SV, SO and MR abilities were integrated. A significant progression was identified on SV+SP, SO, and SR+MR between PreT and PostT results, while no significant progression was found at MR tests. The averages of the assignment scores also support this finding. The reason of the students' having difficulty in making progress in MR ability can be revealed by examining the developmental stages of spatial ability. Level 1 and Level 2 stages of spatial ability develop until adolescence (Bishop, 1978 as cited in Sorby 1999; Mohler 2008), in other words before university education. The Hidden Figures and Hidden Patterns tests that assess SV and SP ability include only Level1 ability (Ilic and Djukic, 2017); therefore, the success of the students in this test group is not surprising. Uttal et al. (2013) state that individuals improve their spatial skills performance by experiencing spatial training from practicing a specific task and taking a drawing class. This study reveals that the ARCH 101, a technical drawing course, contributes to the development of spatial skills in terms of SV+SP, SO, and SR+MR factors.

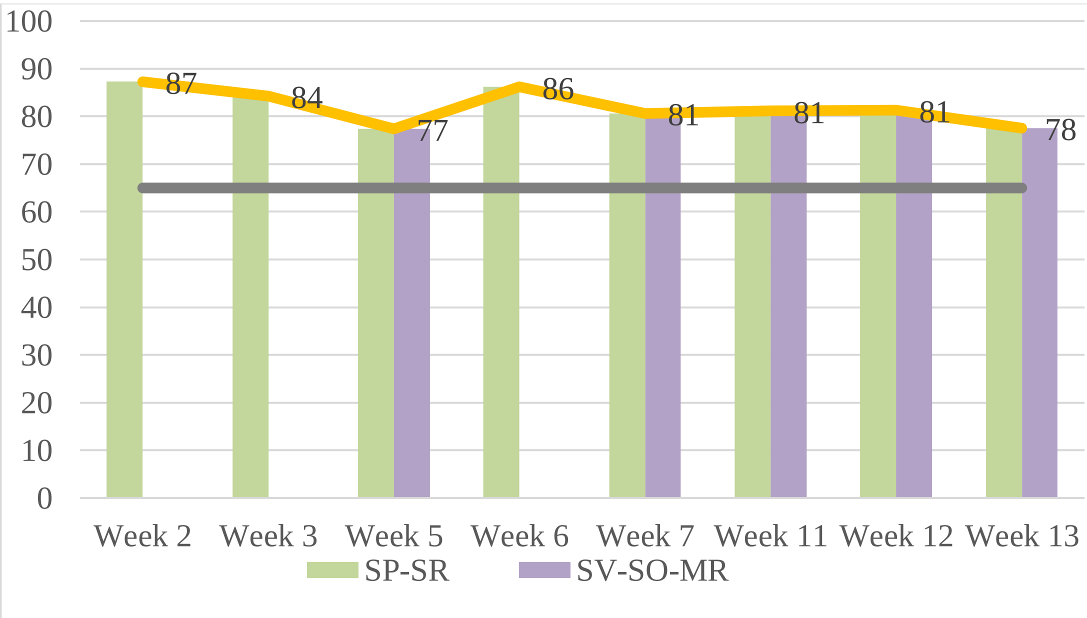


Figure 7. The assignments' average scores in terms of spatial ability progression.

In order to examine the contribution of ARCH 101 course in the development of spatial skills of the architecture students, it is observed that the percentage of the MR factor in the syllabus is similar with SO and SV factors, which have statistically significant progression (Figure 6). No significant difference could be observed in MR factor between the PreT and PostT scores. As a result of research on the investigation of the relation between spatial ability, creativity, and studio performance in architecture education, Cho (2012a) reported that students felt MR the most difficult among the three spatial ability tests (MR, Paper folding and SO).

Baenninger and Newcombe's (1989) research on the role of experience in spatial test performance highlights that the participants who have higher spatial experience use their maximum potential in pre-test so they do not show a higher progression in post-test, on the contrary, the participants who have lower spatial experience have the potential to increase their scores in post-test. In this context, this research was re-evaluated on the basis of pre-test in order to observe the progression between the pre-course spatial ability levels and the post-course spatial ability levels. Almost half of the students (49 out of 96 students) have spatial skills on a 60-80% scale. While the spatial skills of the students with above-average spatial skills progressed at a lower rate, the spatial skills of students with lower spatial skills before the training revealed a higher rate of progression. In this context, it can be said that there is an inverse relationship between PreT scores and skill progression rates. The student groups with low scores in the PreT may not have been sufficiently exposed to the spatial skills experience before the training. Therefore, spatial ability is not only an innate skill, but a skill that can be developed through life-long experiences.

Conclusion

Spatial skill is an important intelligence in architecture as in other STEM disciplines. It is necessary for an architect to visualise, transform, scale, associate and scale a space/design. Architecture students begin their undergraduate education life with spatial skills that have been developed since their childhood. Level 1 and Level 2 spatial skills can be acquired at certain and different levels until university education, and 3rd level spatial skills are taught through various courses within the undergraduate education, especially for professions that need specific spatial skills, such as architecture. ARCH 101 is one of these courses and given in the first semester of its education. In this course, students who are new to university are expected to gain graphic expression and 3D thinking skills, to use appropriate representational media, to develop visual perception and to obtain fundamental design skills. In this study, the contribution of ARCH 101 course to the development of spatial skills of the first semester students is investigated by PreT and PostT research.

Although spatial ability is an innate ability, it is also a skill that can be acquired by learning. Spatial experiences since childhood, such as playing with construction toys or having sketch experiences, can improve spatial skills. Therefore, a questionnaire consisting of factors supporting the development of the spatial skills mentioned in the literature was performed before the research in order to obtain information about the students' spatial experiences. The results of the questionnaire and the scores of the PreT and PostT were examined through SPSS. Statistically progression between PreT and PostT in the context of gender was found as mentioned in the literature. Particularly significant difference between men and female was found at SO progression in PreT and PostT. On the other hand no statistically, significant progression was obtained through the evaluation of PreT in the context of spatial experience backgrounds. In further studies, different results can be obtained by expanding the sample group of the research under different circumstances.

A statistically significant progression was observed in comparison with the PreT and PostT scores. However, this progression differs in the context of student's ability. In the study it is revealed that the students with lower spatial skills before the training acquired a higher rate of progression compared to the students with higher spatial skills before the training. Considering that the architectural students are in the first of the eight-semester education process, the progression of the students in the course in terms of spatial ability is noteworthy. This result confirms the argument that the ARCH 101 course contributes to progression of the students' spatial skills. The progression between pre-tests and post-tests was found significant with SV+SP, SO and SR+MR tests, while no significant progression was found in MR test. It was also observed that the mean of MR ability did not increase between the PreT and PostT. The average of the assignments' scores of the students also supports this finding. When the spatial skill factors are taken into consideration, it is seen that MR was treated equally with SO and SV in the context of course duration. Although there was enough time for MR in the syllabus, it was observed that students had difficulty in this skill. In further studies, developing the MR skill by updating the curricula in order to progress MR skill and the correlation of spatial skills progression with architectural design courses can be examined.

The researchers hoping to extend and improve upon the present study by including first year architecture students from other universities in the study group.

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