International Journal of Educational Studies in Mathematics, 2019, 6(2), 68 - 78

International Journal of Educational Studies in Mathematics

IJESIM

EDUGARDEN

Examination of the Achievement Inferring Cross Section of Pre-Service Math Teachers According to the Various Factors

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ABSTRACT

The aim of this study was to examine the achievement inferring cross section of pre service mathematics teachers according to some factors such as gender, class level, academic achievement, taking Analytic Geometry courses, note taking during Analytic Geometry courses. This study was carried out by the participation of 145 pre-service mathematics teachers in Faculty of Education of a state university in the region of Aegean of Turkey. Santa Barbara Solids Test was administered to the participants. The results obtained from the analysis of survey data have shown that there is a significant difference between the achievement inferring cross section of 3rd grade students and 1st or 2nd grade students, but there is not a significant difference between the achievement inferring cross section of 3rd grade students and 4st grade students. Moreover, there is not a significant difference the achievement inferring cross section of pre-service mathematics teachers according to both academic achievements and genders. Furthermore, there is not a significant difference the achievement inferring cross section of pre service mathematics teacher who taken Analytic geometry courses according to genders, academic achievements and note-taking during the course.

ARTICLE INFO

Article History:
Received: 22.10.2018
Received in revised form: 05.02.2019
Accepted: 10.04.2019
Available online: 08.05.2019

Article Type: Standard Paper

Keywords: Santa Barbara Solid Test, The Achievement Inferring Cross Sections, Elementary Mathematics Pre-Service Teachers

1. Introduction

The first research on spatial ability was conducted by Francis Galton in 1880. Psychometric studies were carried out until the 1940s when the spatial ability was a separate capacity from general intelligence. In the 1970s, studies on spatial ability in the field of education examined how spatial ability develops from childhood to adulthood and the reasons for individual differences (Mohler, 2008).

Spatial ability is defined as the ability to move an object and its components in one's mind in one or more parts in three-dimensional space (Turgut, 2007).

It is thought that there are two important reasons for investigating spatial ability. The first of these is the spatial ability has a favourable and market relationship with the positive science branches and geometry success. The second is that for an individual living around the world surrounded by three-dimensional objects, the perception of displacement or restructuring of objects, understanding activities will become more effective by developing the spatial ability, and the individual will find effective solutions to real-life problems by using notations (Turgut, 2007).

Tartre (1990) distinguished spatial abilities two separate components: spatial visualization ability, and spatial orientation ability. The skill of spatial visualization is defined as the ability of an object to move

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mentally in space while the skill of spatial orientation is defined as the ability to move the point of view mentally while the object remains constant in space. Spatial orientation tasks should not require moving an object. Only the perceptual perspective of the person which views the object is changed or moved. The spatial visualization skill is divided into two separate components: rotate in mind skill and mental transformation skill. The skill of rotate in mind defines the ability to imagine returning object in space as a whole, while the mental transformation skill defines the transformation of object-forming parts in the mind. Converting a two dimensional (2D) shape into a three dimensional (3D) shape or visualizing a 2D planar shape with a 3D shape is related to this type of capability. Folding and unfolding of a cube can be given as the examples of these situations, respectively. Similarly, Cohen and Hegarty (2007) noted that some spatial visualization activities require the ability to associate 2D shapes with a 3D shape. Inferring cross sections of geometric objects with planes is such a spatial visualization activity. Namely, the ability to infer cross sections is a type of the spatial visualization skills.

Bishop (1978) divides the developmental stages of spatial skills into three groups as follows:

- At the first stage topological abilities are acquired. Topological abilities are 2-dimensional and are acquired by most children until 3-5 years old. With this ability, children realize the closeness of one object to the other, order within the group and whether it is inside or outside an environment. Children who can complete a jigsaw puzzle usually gain this skill.
- In the second stage of development, children gain projective spatial abilities. This phase includes the visualization of 3D objects, how they look from different viewpoints, what they look like when they are turned in space, or when they are transformed. Most of the children have gained this skill from their experience in daily life with the help of objects they know. If the object is strange or is formed by moving a pattern, high school or even university students will have difficulty at this stage.
- People in the third stage of development can visualize the concepts of space, volume, distance, translation, rotation, reflection. At this stage, one can combine measurement concepts with projective abilities.

2. How to Measure Spatial Abilities?

There are delelopped many tests to determine which person's spatial ability belongs to the stage of development classified by Bishop.

Most of these tests mentioned in the rest of the article measures the person's projective spatial ability level

The Differential Aptitude Test has been developed by Bennett and his colleagues. It consists of 50 items. In each question, the student is asked to choose among four objects given a 3D object, which is a fold of a given 2D pattern.

Various tests have been developed to measure the person's rotate in mind ability. The details of these tests are as follows:

Purdue Spatial Visualization Test (Rotation) has been developed by Guay and consists of 30 items. In this test, an object is shown to the students, and then the image of its rotation in space is shown. Then a second object is given. It is necessary to determine how the image of this object is rotated as the first object in space.

The Mental Rotation Test (MRT) has been developed by Vandenberg and Kuse and consists of 20 items. Each problem consists of a main form, which contains two correct and two wrong. Students are asked to determine which two shapes have been rotated.

The 3D Cube (3DC) test has been developed by Gittler, consists of 17 items. In each question, a cube depicting a different pattern is given on 3 faces. Students are told that there is a different pattern on the each 6 main figure. Students are asked to choose which of the 6 different cubes which matches with the main shape rotated in space. In addition, each question has two additional options. These are "I do not know the answer" and "none of the cubes is right". The response time of this test is determined by the respondent, time is not limited, because limited time may lead to the mixing of the measurement speed of the spatial skill levels with the measurement power. Students usually take 15 to 40 minutes to complete the test.

The Mental Cutting Test (MCT) has been developed for the student selection system in the United States. MCT assesses the spatial visualization abilities which contain the ability to infer cross sections and MCT consists of 25 items. Each problem of this test is about determining the shape of a 3-dimensional object with a plane. The student has to choose the right one from the five alternative options.

Santa Barbara Solids Test (SBST) developed by Cohen and Hegarty measures the ability to infer cross sections level. The questions of the Santa Barbara Solids Test were produced to measure the cross-sections of three types of solids, which are composed of two objects, consisting of two inserted objects and composed of a single object, which are cut by horizontal, vertical and oblique planes. A participant is given a plane intersecting a body and is asked to select the right intersection from four different options. The test consists of 30 items. The first 10 items in the test were created to contain only one of solid objects such as cones, cubes, cylinders, prisms and pyramids. The other 10 items were created by adding these objects to each other. The last 10 items were created by inserting one of these objects into the other.

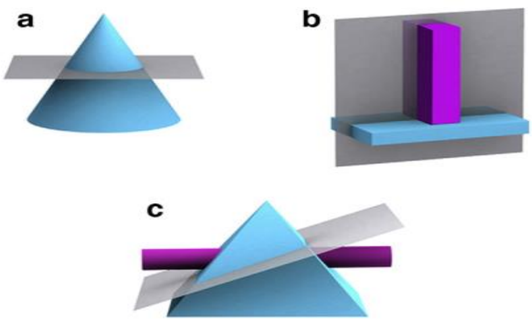

Figure 1. Types of solids and cutting planes in SBST, a) A simple figure with a horizontal cutting plane b) A joined figure with a vertical cutting plane, c) An embedded figure with an obligue cutting plane

In all the questions, each solid is shown with a different color. In addition, half of the questions measure the ability to infer cross sections of objects with the horizontal or vertical planes, while the other half measure the ability to infer cross sections with the oblique planes.

Figure 1 shows the cutting of 3 different types of objects with a plane. In (a), cutting a single object with a horizontal plane, in (b) cutting of the two objects added with a vertical plane, (c) shows the cutting of two interlocking objects with an oblique plane. Test response choices are designed to determine different types of error.

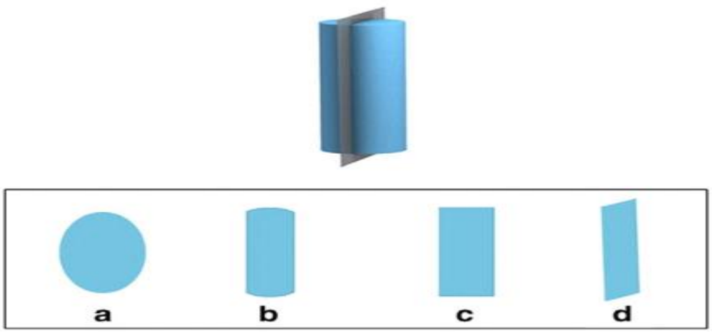

Figure 2. A question in SBST

In figure 2, the cross section of a simple figure (cylinder) with a vertical cutting plane is questioned. The correct answer of this question is shown in figure (c). (d) is an auto-centric parser that represents the way one participant can imagine when he can not change his view direction relative to the plane of the cut. (b) is a joining separator that combines the two possible fragments into a single hybrid shape. (a) is an alternative splitter that shows another possible shape of the shape.

Scientists working in fields such as Engineering, Biology, Medicine and Mathematics frequently encounter intersections of 3D objects with planes. It is used to predict the internal structures of geological formations in engineering. In biology, it is used to create mental representations of cross-sectional shapes of anatomical structures. In Medical science, it is used to imagine such as x-ray and magnetic resonance images of part of human anatomy (Cohen and Hegarty, 2007). It is well known that the ability to infer cross sections, a type of spatial visualization skill, is very important in calculating the areas, volumes, surface areas of intersecting surfaces and geometry lessons. Guay and McDaniel (1977) have stated that relationship between spatial visualization skills and mathematical skills is logically evident. But, Fennema (1974) has stated that the relation between spatial skills and both mathematical and geometric ability is unclear. Moreover, she has noted that there is not a significant difference between the spatial ability and academic performance factor. Therefore, it is important to examine whether the academic achievement level of students are a factor affecting the ability to infer cross sections in the department of mathematics

It has been observed that the spatial skills of men are better than those of women (Hier and Crowley, 1982), (Cohen, Hegarty, 2012) . Some theories about the causes of these differences have been developed. First theory is that spatial skills are transferred as a recessive feature in the X chromosome (Stafford, 1972). According to the second theory, environmental factors are the main cause of female-male differences in spatial skill levels (Fennema and Sherman, 1977). All cognitive abilities, including spatial visualization, can develop through physical interactions with the environment. Children's play activities are compatible with their sexual identity. Man’s interaction with the environment tends to involve more spatial activity than that of the women (Sorby, 1999). The accuracy of this information in the literature will be re-investigated for the ability to infer cross sections.

When the current elementary mathematics curriculum is examined, there is no any acquisition related to the intersections of the solids with the plane. it was included in the 8th grade program with the acquisition of "Identifying and constructing a cross-section of a solids with a plane " in 2005, but it was excluded in curriculum since it was not in accordance with the middle school level in 2013.

When the mathematics curriculum of Faculty of Education is examined in 2017-2018 academic year, solids have been considered 1st grade in the programme of Geometry, the cross sections of a cone with planes have been considered 3rd grade in the programme of Analytical Geometry I, the cross sections of spheres, ellipsoids, cylinders, cones, hyperboloids with planes have been considered 3rd Grade in the programme of Analytic Geometry II. Pre-service mathematics teachers meet cross sections of the solids with the planes at the level of 3rd grade for the first time.

The school courses are an important factor in the development of spatial skills (Sorby, 1999). The significant difference in the achievement inferring cross section according to the class level will show which the school course has an impact on the ability to infer cross sections.

There are a lot of theories related to the factors that cause the development of spatial abilities. One of these factors is the sketching 3-dimensional objects and the other is the activities that require eye-to-hand coordination both in and out of school (Sorby, 1999). Taking a lecture notes during the geometry courses is one of the activities that require eye to hand coordination. Therefore, taking a lecture notes during the geometry courses is an important factor, which is thought to influence the achievement inferring cross section.

In this study, we are examine the levels of the ability to infer cross sections of pre service mathematics teachers according to some factors such as gender, class level, academic achievement, taking Analytic

Geometry courses, note taking during Analytic Geometry courses. The answers to the following questions have been sought for this purpose.

- Does the achievement inferring cross section of pre-service mathematics teachers differ according to sex?
- Does the achievement inferring cross section of pre-service mathematics teachers differ according to class level?
- Does the achievement inferring cross section of pre-service mathematics teachers differ according to academic achievement?
- Does the achievement inferring cross section of pre-service mathematics teachers differ according to take Analytical Geometry courses?
- Does the achievement inferring cross section of pre-service mathematics teachers taking the Analytical Geometry Courses differ according to the sex?
- Does the achievement inferring cross section of pre-service mathematics teachers taking the Analytical Geometry Courses differ according to take a lecture note?
- Does the achievement inferring cross section of pre-service mathematics teachers taking the Analytical Geometry Courses differ according to their academic achievements?

3. Method

In this study, which is examined the achievement inferring cross section of pre-service mathematics teachers is used survey research of quantitative research method. Survey research is defined as "the collection of information from a sample of individuals through their responses to questions (Karasar, 2009), (Check and Schutt, 2012).

3.1. Study Group

This study is conducted by the department of elementary mathematics educations of a state university in 2017-2018 academic year. This study is held with 145 pre-service teachers that are 36 (25%) are 1st class level, 33 (23%) are 2nd class level, 51 (35%) are 3rd class level, 25 (17%) 4th class level. Although there are more students enrolled in the department, 145 of all pre-service mathematics teachers are being volunteer. 110 of pre-service math teacher who participate to the study (76%) are female and 35 (24%) are male. The general information about the study group is given in the Table I and II;

Table 1. General information about pre service teachers participating to this research

Participants			n	%
Pre- Service Teacher	1st Class	Woman	28	19%
		Male	8	6%
	2nd Class	Woman	26	18%
		Male	7	5%
	3rd Class	Woman	41	28%
		Male	10	7%
	4th Class	Woman	15	10%
		Male	10	7%
Lecture note		take	100	69 %
		does not take	45	31 %
Academic Achievement		2 to 2.49	16	11%
		2.5 to 2.99	41	28%
		3 to 3.49	72	50%
		3.5 to 3.99	16	%11

As can be seen from Table 1, 100 (69%) of pre-service math teachers participating in the research hold a lecture note while 45 (31%) do not hold a lecture note. Besides, it is seen that the academic achievement of pre-service mathematics teachers is between 3 and 3.49.

Table 2. General information about pre-service teachers taking Analytic Geometry courses

Participants			n	%
Pre-Service Teacher	3rd Class	Woman	38	70%
		Male	10	19%
	4rd Class	Woman	4	7%
		Male	2	4%
Lecture note		take	36	67%
		does not take	18	33%
Academic Achievement		2 to 2.49	7	12%
		2.5 to 2.99	22	38%
		3 to 3.49	23	40%
		3.5 to 3.99	6	10%

When the general information in Table 2 is examined, it is seen that 42 (77%) of pre-service mathematics teachers taking the analytic geometry courses are female and 12 (23%) are male. Pre-service teachers taking the analytic geometry courses tend to take a lecture note in the analytical geometry courses. When their academic achievements are examined, it is understood that the average of academic achievements is between 2,5 and 3,49.

3.2. Data Collections

In this study, two data collection tools were used, these are Santa Barbara Solids Test and Personal Information Form. Personal Information Form is developed to determine gender, class level, the average of academic achievement and taking a lecture note during the courses of pre service mathematics teachers by the researchers. SBST measures the ability to infer cross sections that is the sub-step of the individual's spatial visualization ability. Although SBST consists of 30 items, one items of SBST is not used in this study. This question is the third question of SBST and this question is excluded of SBST because it is incorrect by the test makers.

The study was conducted in the last week of the spring semester of the 2017-2018 academic year and each pre-service mathematics teacher answered the question of this test in the classroom with computer technology by the virtual access of to the test. Test response time ranged from 20 to 30 minutes.

Cronbach alpha of SBST is found .86 by Cohen and Hegarty (2007). Cronbach alpha of this test is also found .87.

3.3. Analysis of Data

Data are taken from internet as Microsoft Excel data, and analysed with SPSS 18.0 package program.

The average ($\overline{x}$), independent sample t-test, one-way ANOVA and Pearson correlation's coefficient are used for the analysis of the obtained data

4. Findings of Research

To determine the achievement inferring cross section of elementary school pre-service mathematics teachers according to class levels, descriptive statistical techniques are used and the obtained results are presented in table 3.

When table 3 is examined, it is seen that the means of SBST's scores of the pre-service mathematics teachers have changed between 15.82 and 19.84.

Table 3. The achievement inferring cross section of pre-service mathematics teachers

Class Level	Minimum	Maximum	$\bar{x}$	SD
1st Class	5	24	16	4.80
2nd Class	4	26	15.82	5.52
3rd Class	2	28	19.84	5.96
4th Class	4	25	17:40	6.68

To determine the achievement inferring cross section of elementary school pre-service mathematics teachers according to gender, the independent samples t-test has been used. The following table refers to the results of the t-test.

Table 4. t-test results of SBST's scores of pre-service teachers according to gender

	Gender	N	$\bar{x}$	SD	sd	t	p
Pre-Service Teacher	Woman	110	17.38	5.53	143	- .120	.905
	Male	35	17.93	6.81			

From table 4, the achievement inferring cross section of pre-service mathematics teachers according to gender don't differ (t = -. 120, p> .05). It can be said that the genders of pre-service teachers are not different in terms of the achievement inferring cross section.

To determine the achievement inferring cross section of elementary school pre-service mathematics teachers according to class level, one- way ANOVA is conducted and the findings are presented in table 5.

There is a significant difference (F (1,924) = 4.607, p <.05) among SBST's scores of pre-service teachers according to table 5. According to the results of Scheffe test, which is done to find which classes of the difference between the units, it has been seen the achievement inferring cross section of 3th class level ($\bar{x}$ = 19.84) is higher than 1st class level ($\bar{x}$ = 16) and 2nd class level ($\bar{x}$ = 15.82).

There is no comparison between the fourth class level and the other class levels, since the number of pre-service teachers with fourth class level participating in the study is 25.

Table 5. ANOVA results of SBST scores of pre-service teachers according to class level

	Source of Variance	Sum of squares	sd	Squares Average	F	p
SBST	Between Groups	454.208	3	151.403	4.607	.004
	Inside Groups	4633.654	141	32.463		
	Total	5087.862	144			

To determine the achievement inferring cross section of elementary school pre-service mathematics teachers according to academic achievements, one-way ANOVA are conducted and descriptive statistics of SBST's scores of pre-service teachers are given in Table 6a and ANOVA results are presented in Table 6b.

Table 6a. SBST's scores according to the academic achievement of pre-service teachers

Academic Achievement	N	$\bar{x}$	SD
2 - 2.49	16	15.56	6.429
2.50 - 2.99	41	18.32	6.536
3 - 3.49	72	17.44	5.9
3.50 - 3.99	16	18.06	3.605

As the academic achievement of pre-service teachers increases from 2.50, the standard deviation of SBST's scores decreases.

Table 6b. ANOVA results of SBST's scores of pre-service teachers according to the academic achievement

	Source of Variance	Sum of squares	sd	Squares Average	F	p
SBST	Between Groups	92.331	3	30.777	.869	.459
	Inside Groups	4995.531	141	35.429		
	Total	5087.862	144			

According to Table 6b, the SBST's scores of pre-service teachers do not differ according to academic achievement (F (3.379) = .869, p> .05). it can be said the academic achievement of pre-service teachers is not related to their achievement inferring cross section.

To determine the differentiation of the SBST's scores of elementary mathematics pre-service teachers taking Analytic Geometry 1 and 2 courses according to gender, the independent samples t-test has been used. The following table refers to the results of the t-test.

Table 7. t-test results of SBST's scores of pre-service teachers taking Analytic Geometry courses according to the gender factor

	Gender	N	$\bar{x}$	SD	sd	t	p
Pre-Service Teachers	Woman	42	19.88	5.83	143	-, 018	.986
	Male	12	19.91	6.76			

According to table 7, SBST's scores of pre-service teachers taking Analytic Geometry courses according to gender has no difference (t = -. 018, p> .05). It can be said that SBST's scores of pre service teachers taking Analytic Geometry courses according to their gender is not different.

To determine the differentiation of the SBST's scores of elementary mathematics pre-service teachers taking Analytic Geometry 1 and 2 courses according to take a lecture note, the independent samples t-test has been used. The following table refers to the results of the t-test.

Tablo 8. t-test results of SBST's scores of pre-service teachers taking Analytic Geometry courses according to take a lecture note

In Analytical Geometry Courses,		N	$\bar{x}$	SD	sd	t	p
Lecture note	holds	36	19.25	5.70	52	-1.112	.271
	does not keep	18	21.16	6.48			

According to table 7, SBST's scores of pre-service teachers taking Analytic Geometry courses according to take a lecture note has no difference (t = - 1. 112, p> .05). It can be said that SBST's scores of pre service teachers taking the analytical geometry courses according to take a lecture note don't differ.

To determine the differentiation of the achievement inferring cross section of pre-service teachers according to class level of students taking of analytic geometry courses, independent samples t-test is used. The following table refers to the results of the t-test.

Table 9. t- test results of SBST's scores of pre-service teachers taking of Analytic Geometry courses

Taking Analytic Geometry Courses	Class Level	N	$\bar{x}$	SD	sd	t	p
Pre Service Teachers	3rd Class	51	19.84	5.96	74	1.613	.111
	4th Class	25	17.40	6.68			

When table 9 is examined, SBST's scores of pre service teachers taking analytic geometry courses do not differ according to the class level (t = 1. 613, p> .05). This can be interpreted as there is no difference among SBST's scores of pre-service teachers taking analytic geometry courses according to the class level.

To determine the difference of the achievement inferring cross section of pre-service mathematics teachers taking analytic geometry courses according to academic achievements, one-way ANOVA are conducted and descriptive statistics of SBST's scores of pre-service teachers according to academic achievement are given in Table 10a and ANOVA results are presented in Table 10b.

Table 10a. SBST's scores of pre-service teachers taking Analytic Geometry courses according to their academic achievement

Academic Average	N	x̄	SD
2-2.49	7	15.85	7.646
2.50-2.99	19	21:21	6.187
3-3.49	22	20:36	5.367
3.50-3.99	6	18.6 6	4.273

The standard deviation of SBST's scores decreases as the academic achievements of pre service mathematics teachers taking Analytical Geometry courses increases.

Table 10b. ANOVA results of SBST's scores of pre-service teachers taking Analytic Geometry courses according to their academic achievement

	Source of Variance	Sum of squares	sd	Squares Average	F	p
SBST	Between Groups	160.894	3	53.631	1.544	.215
	Inside Groups	1736.439	50	34.729		
	Total	1897.333	53			

When table 6 is examined, SBST's scores of pre-service teachers taking Analytic Geometry courses do not differ according to their academic achievement ($F(1,133) = 1.544$, $p > .05$). This can be interpreted as there is no difference among SBST's scores of pre-service teachers taking analytic geometry courses according to their academic achievements.

5. Conclusion and Discussion

In this study, we examine the factors affecting the achievement inferring cross sections of the elementary mathematics teacher candidates by using SBST developed by Cohen and Hegarty (2007) and SBST was used by some researchers such as Kösa (2015) and Uygan and Kurtuluş (2016) in Turkey.

SBST, 30-item multiple-choice test, measures individual differences in determining the ability to infer cross section of a 3D object known to be important in Science, Technology, Engineering and Mathematics (STEM) areas.

Data of this research has shown that there is a significant difference between the achievement inferring cross section of 3rd grade students and 1st or 2nd grade students, but there is not a significant difference between the achievement inferring cross section of 3rd grade students and 4st grade students. This consequence is compatible with the study of Sorby (1999). She has stated that school more than any other institution, is responsible for in the development of spatial ability. The purpose of researching the efficiency of this factor is to examine which course affects the achievement inferring cross section.

Elementary Mathematics Teacher candidates meet the course activities inferring cross sections of 3D objects in analysis course taken spring semester of 2nd grade for the first time in all their learning lives. To understand the geometric interpretation of partial derivatives of multivariable functions, teacher candidates use the ability to infer cross sections of surface with planes in this Analyses course. Moreover, pre service mathematics teachers use the ability to infer cross sections to calculate area of cross section region of intersected two surfaces in this course.

However, a conic definition is made in Analytic Geometry I course at fall semester of 3rd grade. Conic is defined as a planar form consisting of the intersection of cone with planes which have different directions. The intersections of 3D objects with planes are considered in Analytical Geometry II at spring semester of 3rd grade. Teacher candidates encounter to cross sections of solids with planes in Analytical Geometry I and II courses of 3rd grade level. Therefore, Analytic Geometry courses are effective in the development of the ability to infer cross sections.

The research has seen that the achievement inferring cross section of prospective teachers who took Analytical Geometry courses and other prospective teachers have not changed according to the variable gender in contrary to some studies in literature such as (Sorby, 1999), (Cohen, Hegarty, 2012). The fact that men's interactions with the environment tend to involve more spatial activity than women is explain that men have higher spatial ability levels than women (Sorby, 1999). So, Cohen and Hegarty (2012) has found that the ability of women to use visual and analytical strategies is lower than that of men. The fact that the number of female and male teacher candidates participating in the research does not have a equal distribution may be a reason. The number of female teacher candidates participating in the study is more than twice the number of men.

Taking a lecture note during the Analytic geometry courses has not positive correlation with the ability to infer cross sections according to the obtained data. Sorby (1999) has stated that sketching of 3-dimensional objects and the activities that require eye-to-hand coordination improve the spatial skills. Taking a lecture notes during the geometry courses is an activity that require eye to hand coordination. The fact that visual images cannot be drawn correctly in the lecture note and the shadowing techniques which is used the visualization of the cross sections are not known can be the reasons explaining this situation. This research has shown that the achievement inferring cross section of prospective teachers who took Analytical Geometry courses and other prospective teachers have not changed according to academic achievement. This consequence is compatible the study of Fennema (1974). She has stated that spatial ability is unrelated to academic performance. This study has verified that the academic achievement is not effective factor on the ability to infer cross sections.

Acknowledgement

We thank the editor and the referee for their careful reading of the original manuscript and their many valuable comments and suggestions that greatly improved the presentation of this work. This work was supported in part by the BAP of Pamukkale University (No. 2018KKP180). It was presented at iecmsa-2018 in Ukraine.

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