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CAN SPATIAL ABILITY BE TRAINED – THE ANALYSIS OF PREPARATORY COURSE FOR ENROLMENT AT THE FACULTY OF ARCHITECTURE

Abstract:

Spatial abilities are becoming an increasingly important predictor of success, especially in professions that balance analytical and creative thinking, such as architecture, especially with the increasing presence of digital media and technology, and the importance of the spatial presentation of one's ideas. There are differing opinions as to whether these abilities can be improved, or whether a spatial thinking strategy can be developed. At the Faculty of Architecture and Geodesy in Banja Luka (FACEG), spatial abilities have long been part of the entrance exam, and this paper will address the analysis of preparatory teaching at FACEG in this area and the success of the entrance exam for two groups of candidates - those who attended preparatory classes and those who prepared independently.

Keywords: entrance exam, spatial skills, spatial abilities, training, architecture

МОГУ ЛИ СЕ ПРОСТОРНЕ СПОСОБНОСТИ РАЗВИТИ – АНАЛИЗА ПРИПРЕМНЕ НАСТАВЕ ЗА УПИС НА СТУДИЈ АРХИТЕКТУРЕ

Сажетак:

Просторне способности постају све важнији предиктор успјеха, нарочито у струкама које балансирају између аналитичког и креативног мишљења, као што је архитектура, а нарочито са повећањем присутности дигиталних медија и технологије, те важности просторне презентације замишљених идеја. Постоје различита мишљења да ли се ове способности могу побољшати, односно, да ли се може развити стратегија просторног мишљења. На Архитектонско-грађевинско-геодетском факултету у Бањој Луци (АГГФ) просторне способности су већ дуго дио пријемног испита, те ће се овај рад бавити анализом припремне наставе на АГГФ-у из ове области и успјехом на пријемном испиту за двије групе кандидата – оне који су похађали курс припремне наставе и оне који су се спремали самостално.

Кључне ријечи: пријемни испит, просторне вјештине, просторне способности, тренинг, архитектура

1. INTRODUCTION

1.1. On spatial abilities and their relevance to engineers

In psychology, term *spatial ability* still does not have a clearly accepted definition, and it owes it to the fact that spatial intelligence, as a broader term, includes multiple factors and components. One of the interpretations given by Khine says that spatial ability is *"the capacity to perceive the visual images accurately, construct mental representations and imaginary of visual information, understand and manipulate the spatial relations among objects"*, characterizing it as a "*powerful indicator of personal quality and individual differences"*. [1] It is clear that this ability implies different cognitive operations - from arranging cubes to map reading and spatial orientation, and their influence in particular professions such as medicine, engineering, mathematics, geology, chemistry have been researched in several studies [2]–[6] showing moderate-to-strong correlational relationships with predictive validity of performance.

Spatial abilities are not sufficiently represented in the educational system, in comparison to verbal and quantitative ones, although research shows that spatial abilities are an important predictor for discovering talent and creativity. Wai and colleagues [7] summarize and extend five decades of spatial abilities research examining a sample of 400,000 high school students (grades 9 through 12) tracked via Project TALENT in the 1960s and 1970s along with contemporary GRE data and the Study of Mathematically Precocious Youth [8]. The authors demonstrate mathematical and spatial abilities are the two greatest predictors of STEM career success and degree attainment, and that spatial ability predicts success in STEM fields beyond just mathematical aptitude. [1]

It is possible that the reason for neglecting these abilities in the early educational system lies in the large gender differences, where men show an advantage over women, which dates from childhood and early differentiation in training these abilities through prejudice about toys (girls played with dolls, while boys were more forced to play with dice, cars or other mechanically driven toys). The second reason is the rigid school curriculum, which does not allow to easily change, and which also includes teachers to go through specialized training. [9]

Many of previously conducted studies show that spatial abilities could be developed over time, and that certain types of exercises can improve them [10]–[13]. Because of all the above stated, it is important to continue further research on spatial abilities, its factors, and influences on other scientific fields, and to determine if it is possible to develop them in later ages. If so, what are the right methods to do that, and what influence will they have on other occupations, specifically those concerning engineering.

1.2. Need for students of architecture to understand space

Spatial abilities are of particular importance in the field of architecture. This profession combines creativity, technology and space consumption where the initial architectural idea must be put in the space and materialized. Spatial solving tasks can be a key component of student success in architecture studies. For this reason, entrance exams often include some form of spatial aptitude tests - sometimes they are tested with standardized mental rotation, cross-section or spatial orientation tasks, or through a drawing that should present the applicant's ability to visualize space.

At the Faculty of Architecture, Civil Engineering and Geodesy in Banja Luka, the spatial aptitude test is an important part of assessing the competency of candidates for this study program. Since spatial abilities are generally not addressed during secondary and elementary school education, prior to enrollment, the candidate's spatial skills are at a basic level. Before enrollment, the faculty offers a preparatory course that aims to provide candidates with basic training during the two-week course and instruct them on strategies that can help them address spatial tasks.

Solving these kinds of problems, or spatial intelligence, in general, comes down to two components - flexible strategy choice between constructing and transforming mental images and more analytic thinking. Hegarty has demonstrated that even relatively simple spatial tasks included in psychometric tests of spatial ability include analytic thinking, although people also report mental imagery as the dominant strategy by which they perform these tasks. With more complex forms of thinking involved in mechanical reasoning and scientific thinking, it appears to be even more important to supplement mental imagery with more analytical forms of thinking. The second component of spatial intelligence that Hagerty identified includes the ability to choose the optimal external representation for a task, and to use novel external representations, such as interactive visualizations, effectively [14]. This means that the success of solving spatial tasks depends on the strategies adopted (analytical or spatial) and the tasks themselves and their representation.

1.3. Spatial tests and spatial factors

The issue of standardized spatial tests is still an open topic in the field of psychology, most often because of the lack of researchers' consensus on factors that assess spatial abilities. There are many types of tasks that are used for assessing spatial abilities in literature, and the most common are: The Mental Rotation Test (MRT), The Differential Aptitude Test: Space Relations (DAT: SR) and the Mental Cutting Test (MCT).

In an attempt to address these issues, some authors have defined the categories of spatial ability, assuming that there is no single, all-encompassing definition of spatial visualization ability. Maier [15] and Maresch [16] have proposed the following five components that form the spatial ability of a person:

- spatial visualization – ability to see the shape in whole, presented by its rotated parts. Guilford describes this factor as "an ability to think of changes in objects - changes in position, orientation, or internal relationship". This component often includes subcomponent of spatial relations and spatial perception
- spatial relations – ability to make a relation of pieces in order to form a given shape
- spatial perception – includes the ability for identifying the horizontal and vertical directions, wherein the orientation of one's body plays an important role in relation to other
- spatial orientation
- mental rotation

Within these broad categories there is some overlap. For example, there are certain activities that could be classified in the category of spatial relations and in the category of spatial orientation, depending on the task type. An overview of the classification of the most common task types are given in [17].

1.4. Entrance exams at the Faculty of Architecture, Civil Engineering and Geodesy in Banja Luka

In addition to the tests in mathematics and free-hand drawing, tests of spatial ability are also used in assessing the competence of prospective students at the Faculty of Architecture, Civil Engineering and Geodesy in Banja Luka (FACEG). The content of these tests varied from year to year. Table 1 shows an overview of the spatial ability tasks used in the entrance exam for architectural studies in the past 15 years. Data were collected from student office and archives at the Faculty of Architecture, Civil Engineering and Geodesy in Banja Luka.

Table 1. *Implementation of classified spatial tasks in architectural studies entrance exams*

Group	Type	Number	Task	Year														
				2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
2D		1	Form Board															
		2	Card Rotations													•		
		3	Hidden Figures				•											
3D	1	1	Arial Orientation	•													•	•
		2	Guilford– Zimmerman Spatial Orientation			•												
	2	1	Differential Aptitude Test: SR (DAT:SR)		•													
		2	3D Surface Development						•							•	•	
		3	Paper folding test													•		
		4	Shepard-Metzler Mental Rotation Test	••	•	•	•	•	•			•		••	•		•	•
		5	Purdue Spatial Visualization Test: Rotations (PSVT:R)	••		•					•			•		•		
		6	Complement Cube Test		•													
		7	Cube Comparisons Test							••	•							
	3	1	Spatial relation															•
		2	Tube figures		•				•									
		3	Snake in a cube*		•	••	••	•	•	••	•	•		••	•		•	••
		4	Lappan Test															
	4	1	Mental Cutting Test MCT					•	•					••	•		•	•
		2	Surface of water in a vessel															

	Total number of tasks in the test	5	5	5	5	6	5	5	4	4	N/A	8	5	6	6	9
	Number of tasks with multiple choice	0	3	2	0	1	2	2	0	1	N/A	5	3	2	3	3
	Number of tasks that require candidate's solution	5	2	3	5	5	3	3	4	3	N/A	3	2	4	3	6
	Number of unclassified tasks				1	3		1	2	2	N/A	2	2	2	1	3

According to the mentioned classification, the tasks are divided into two basic groups (two-dimensional and three-dimensional), and then the three-dimensional are divided into 4 types:

- TYPE 1: Tasks of orientation where the subject is moved, transformed or rotated in relation to an object
- TYPE 2: Tasks of spatial manipulation with objects. This type requires an ability of mental rotation and spatial relations.
- TYPE 3: Tasks that require visualization of objects given with its projection.
- TYPE 4: Tasks that require visualization of intersecting elements.

Which tasks develop which spatial factor is difficult to define, as individual tasks require multiple cognitive operations to be solved. Some solutions can be driven analytically, while others require a higher level of native spatial ability.

The tasks found in these entrance exams are more complex than the standardized tasks found in the literature. The table is sorted by type, and complexity depends on the task itself, and on whether the task has multiple choice answers offered or the candidate has to sketch the solution himself. From the table, it is evident that in about 30% of the tasks, the multiple-choice is offered, while in the others the candidate offers his solution. For architecture students, this is important because it tests the candidate's ability to draw and represent three-dimensional shapes in two dimensions. Table 1 further shows that there are many tasks that are not classified. These tasks include more complex processes that require minimal knowledge of perspective drawing, some "out-of-the-box" thinking tasks that require creative thinking, and solid intersection tasks.

Table 1 shows that types 2, 3, and 4 are most commonly represented, specifically the tasks of mental rotation (2.4), spatial visualization (3.3) and mental cutting (4.1).

According to this analysis, the preparatory course at FACEG contained training by tasks and spatial factors, and its structure will be presented in more detail in the following pages. The main objective of this paper is to determine whether this type of training improves spatial abilities, and the broader context of this topic will imply the question of whether such tests can assess the performance of candidates in further studies.

2. RESEARCH QUESTIONS AND METHODOLOGY

The 20-hour long preparatory course at the FACEG in Banja Luka has been held for the past two years (2018 and 2019) shortly before the entrance exam. 129 candidates took to the entrance exam in total, of which 61 candidates attended the preparatory course. At the beginning of the enrollment period, the faculty publishes the Bulletin for the entrance exams, which contains the examples of tasks from the previous entrance exams with the correct answers, but without the steps for solving them. This means that part of the candidates was preparing on their own, while those who went to the preparatory course received appropriate training where they learned about various analytical strategies for solving such tasks.

At the beginning and at the end of the course, the candidates took a test similar to the entrance exam. Comparison of these results may give us insight into whether the course contributed to the improvement of spatial abilities of the candidates while comparing the results of the entrance exam between the candidates who attended the course and those who did not should provide an answer as to whether this course had an impact on the performance at the entrance exam as well.

The basic research questions that will be addressed are:

RQ1: Did the preparatory course improve the candidates' spatial competencies for the entrance examination? Here, the results of the first and second tests that candidates took at the beginning and end of the course will be compared.

RQ2: Were these candidates more successful than those who did not attend the preparatory course? Here, the results of the entrance exam of candidates who have attended the preparatory course and those who have not will be compared.

For the statistical analysis, we used the SPSS v.20 analytical-statistical software package, using descriptive statistics for presenting and summarizing data, the Paired Samples t-Test, nonparametric Mann-Whitney U test, and Spearman's rank correlation coefficient. The variables observed in this study did not have a normal distribution.

Table 1 shows that the number of tasks in the entrance exam varied every year. The reason for this is the change of the entrance exam structure in recent years, where the representation of the spatial ability assessment in the entire entrance exam has varied from 40% -100%. Therefore, the data and scoring during the data analysis were considered as a percentage, that is, the percentage of success in solving certain types of tasks.

2.1. Preparatory course - dynamic and structure

The preparatory course for the entrance exam (called *Spatial perception and presentation course)*, which serves also to assess the spatial abilities of the candidates, was held in the previous two years in the month of June two weeks before the entrance exam at the FACEG and lasted 10 days (2 hours/day). At the beginning and at the end of the course, the candidates took a test (two similar, but not identical tests with the same task types) that contained the types of spatial tasks that had appeared in the entrance exams in the past few years. The course is taught according to the spatial factors and task typology defined in Table 1, as follows:

0. Planar geometry and spatial relations - shapes and their rotation within the plane (this part of the course is an introductory, the most common example of such tasks are the so-called "tangram" tasks and problems of dividing the shape into equal parts - Figure 1)

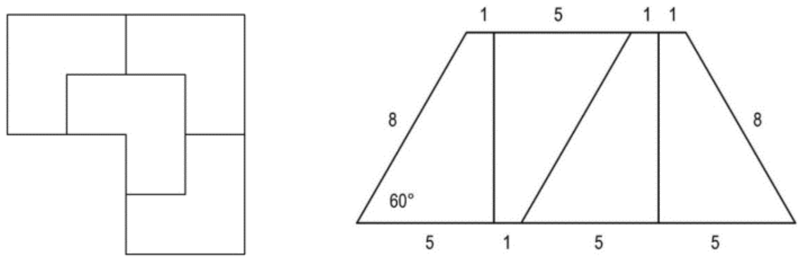

Figure 1. *Task example (divide given areas into 4 equal parts)*

A. Mental rotation (A1) and surface development (A2) - here are the tasks of mental rotation, the more complex tasks of developing a solid surface, as well as a combination of those two subtypes (Figure 2.)

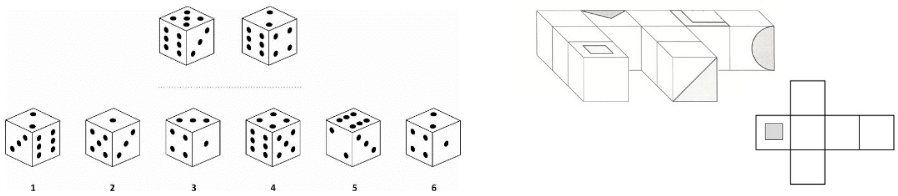

Figure 2. *Examples of A-type tasks (left: mark the answer that shows a cube given above cube, presented in other position (rotated), right: if the cube tumbles across the floor and takes the positions given in the left picture, draw the net of the cube with the signs on its sides)*

B. Planar (B1) and spatial intersection (B2) - these are tasks that fall into the types of mental cutting tasks (two-dimensional and three-dimensional) (Figure 3).

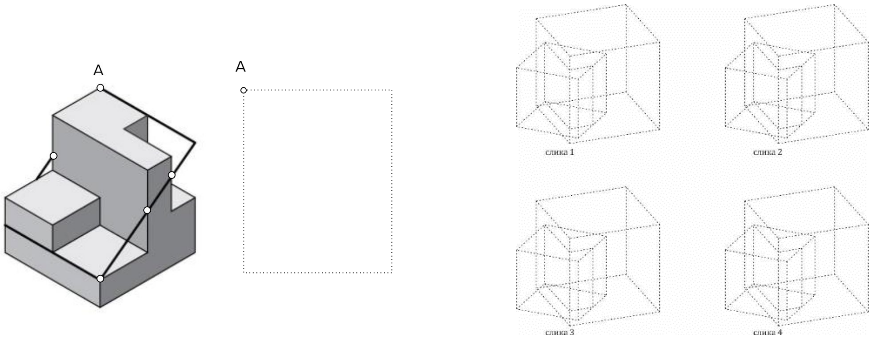

Figure 3. *Mental cutting tasks examples (left: draw a section of a plane with a given solid, right: draw what the two solids would look like if they would a) join, b) intersect c,d) subtracted one from another)*

C. Proportions and Projections - Tasks that are specific to the architectural profession and address the ability to draw the orthogonal views of an object based on a given three-dimensional view, and vice versa - draw a three-dimensional view based on given projections. Task complexity varies with of the shape of the object - full solids or wire models (Figure 4.)

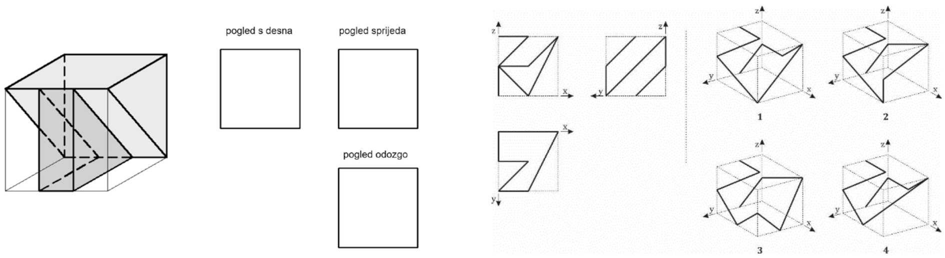

Figure 4. *Examples of object projection tasks (left: draw the orthogonal views of the given object, right: mark the answer that shows the wire given on the left picture with its orthogonal projections*

D. Orientation - spatial orientation tasks (Figure 5).

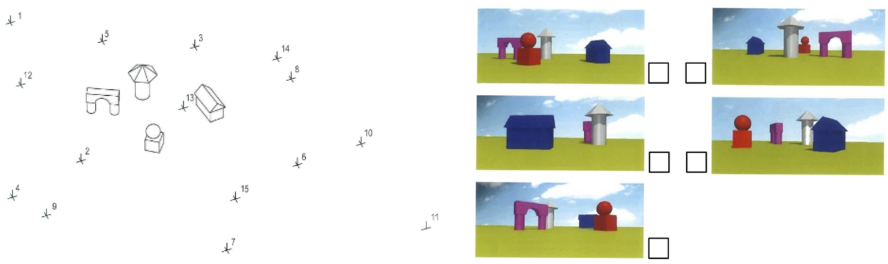

Figure 5. *Example of spatial orientation tasks (write in the boxes next to the pictures on the right number of the viewer's position given on the left)*

E. Symmetry and mirroring - these are the tasks that are very similar to mental rotation and they consist of drawing the object in different positions relative to the given position, as well as paper-folding tasks (Figure 6).

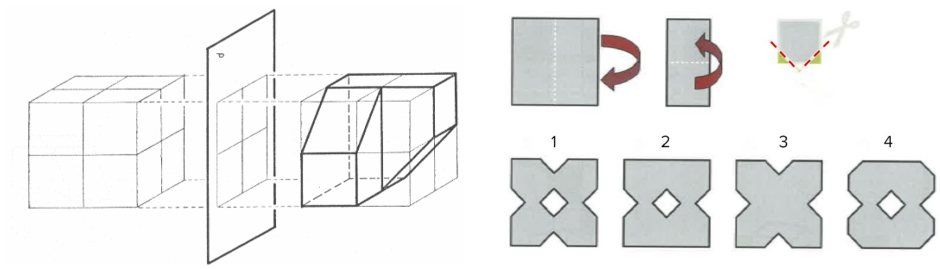

Figure 6. *Symmetry task example (left: draw an object viewed in the mirror, right: mark the answer that shows what a piece of paper would look like when folded and cut as shown in the picture above)*

F. Perspective - the tasks of constructing a perspective drawing based on the given ground scheme (Figure 7)

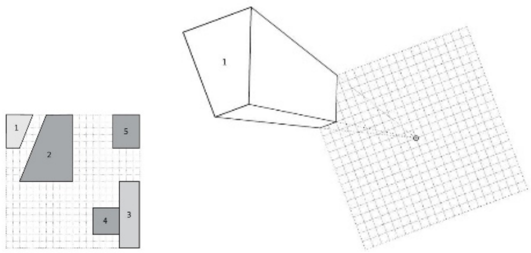

Figure 7. *Example of perspective drawing task*

Classes were conducted in such a way that the candidates solved some of the tasks presented on the board in the group, that is, they discussed and tried to explain the strategies they used in solving them. Individual tasks were given in the paper form, which they solved on paper independently, and then the lecturer explained for each type of task a possible analytical strategy for solving if the solution was not reached intuitively. In addition to paper assignments, during the breaks, candidates also had at their disposal didactic material in the form of wooden cubes or other solids, paper and scissors, or possible physical models on which they could practice their spatial skills.

The initial and the control test is taken at the beginning and at the end of the course consisted of 5 tasks from 5 selected spatial factor groups. In the following section, a comparative analysis of the results that the course participants achieved in both tests in the total and individually by tasks will be presented.

2.2. Entrance exam

The entrance exam at the FACEG has undergone several transformations in the past decade. However, the assessment of spatial abilities has always been an essential part of the entrance exam. In 2018, the percentage of the Spatial perception and presentation section of the entrance exam was 40%, while in 2019 it was 100%. The tasks are similar to the tasks shown in section 2.1 of the paper, and some of them were also used during the course. The structure of the entrance exam varies in the number and complexity of the tasks, so for the purposes of the research, the percentage of the performance of individual spatial factors was analyzed so that the results could be compared across two generations, as well as with the results achieved by the candidates in the preparatory course.

3. RESULTS AND DISCUSSION

A sample of 129 candidates who took the entrance exam at the AGGF in Spatial perception and presentation during the past two years were taken to analyze the research, of which 61 attended preparatory classes and 68 of them prepared on their own (Table 2). It should be emphasized that the candidates were provided with the faculty Bulletin, which contains a collection of tests used in previous years with correct answers, but without instructions for solving them, and a number of candidates decided to prepare themselves independently. It is unknown whether those candidates had any help with the preparation or were able to complete the tasks themselves.

There are also four times more female applicants (105) enrolled in architectural studies than male candidates (24), and a greater percentage of women (almost 50%) choose to attend preparatory classes than men (about 40%).

Table 2. *Number of candidates by age and gender*

Gender			YEAR 2018	YEAR 2019	Total
F	Prep_course	Y	**25**	**29**	**54**
		N	**21**	**30**	**51**
	Total		**46**	**59**	**105**
M	Prep_course	Y	**0**	**7**	**7**
		N	**8**	**9**	**17**
	Total		**8**	**16**	**24**
Total	Prep_course	Y	**25**	**36**	**61**
		N	**29**	**39**	**68**
	Total		**54**	**75**	**129**

Table 3. *Attendance of the preparatory course by type of secondary school*

		high school: Civil Engineering high school	high school: Gymnasium	high school: Other technical schools	high school: Other schools	Total
Prep_course	Y	**19**	**36**	**0**	**6**	**61**
	N	**22**	**35**	**6**	**5**	**68**
Total		**41**	**71**	**6**	**11**	**129**

Candidates also come from different secondary schools where some had a subject of Descriptive Geometry, so the analysis showed that 82 (63.6%) of all candidates did not have a subject of Descriptive Geometry in high school, of which only half attended the preparatory course. Of 47 (36.4%) that had Descriptive Geometry in high school, a total of 19 candidates attended the course. It is expected that two-thirds of the candidates did not have DG in high school, because in the last two years the most candidates applying for enrollment in the architecture program come from Gymnasium - 55% (Table 3).

3.2. Comparison of initial and control test for candidates who have attended the course

The initial test at the course consisted of 5 tasks, classified by types:

- A1 - Mental rotation
- A2 - Surface development
- B1 - Mental cutting (2D)
- B2 - Solid intersection
- C – Proportion and projections

Table 4. *Descriptive statistics by task pairs on the initial and control test*

		Mean	N	Std. Deviation	Std. Error Mean
A1	c_p_u1	**.7111**	**45**	**.27155**	**.04048**
	c_p_i1	**.8556**	**45**	**.22918**	**.03416**
B1	c_p_u2	**.2667**	**45**	**.44721**	**.06667**
	c_p_i2	**.2356**	**45**	**.35939**	**.05357**
C	c_p_u3	**.1978**	**45**	**.31730**	**.04730**
	c_p_i3	**.5267**	**45**	**.42287**	**.06304**
A2	c_p_u4	**.4133**	**45**	**.43096**	**.06424**
	c_p_i4	**.8889**	**45**	**.24884**	**.03709**
B2	c_p_u5	**.1489**	**45**	**.29203**	**.04353**
	c_p_i5	**.4867**	**45**	**.35714**	**.05324**
TOTAL	c_p_utot	**.3476**	**45**	**.18773**	**.02798**
	c_p_itot	**.5987**	**45**	**.20628**	**.03075**

The first task on the initial test was done with 71% success and the first task on the control test with 85% success (Table 4). The first task on the control test was also statistically significantly done with more success with a statistical significance of 0.005 (Paired Samples t-test,t=-3.292, df=44, p=0.002).

The success rate of solving the second task on the initial test was around 27% and on the control test 23.5% (Table 4). On the control test, the candidates had less success as shown by the t-test of paired samples (Paired Samples t-test, t=0.391, df=44, p=0.698).

The success rate of solving the third task on the initial test was around 20% and on the control test 53% (Table 4). On the control test, the third task was statistically significantly better done with a statistical significance of 0.005 (Paired Samples t-test, t=-5.022, df=44, p=0.000).

The success rate of solving the fourth task on the initial test was around 41% and on the control test 89% (Table 4). On the control test, the fourth test was statistically significantly better done with a statistical significance of 0.005 (Paired Samples t-test, t=-7.029, df=44, p=0.000).

The success rate of solving the fifth task on the initial test was around 15% and on the control test 49% (Table 4). On the control test, the fifth task was statistically significantly better done with a statistical significance of 0.005 (Paired Samples t-test, t = -5.893, df = 44 p = 0.000). This task had the lowest success rate of all the tasks in the initial test.

By comparing the overall success on the initial and control test, the paired samples t-test showed a significant improvement on the control test (Paired Samples t-test t = -8.420, df = 44, p = 0.000). The initial test was done with a 35% success rate and the control test with an almost 60% success rate (Table 4). Also, statistics show a mean positive correlation between the initial and control test in the total score, Sperman's rank correlation coefficient is $r_s = 0.394$, p = 0.007.

Improvement in the spatial abilities of candidates is evident in all factors, except for the task with mental cutting, while the candidates showed great improvement in the tasks of the solid intersection.

3.3. Comparison of entrance exam (e_p_tot) and control test (c_p_itot) by task types for candidates that attended the preparatory course

A few days after the preparatory course was completed, the candidates took the faculty entrance exam. A comparison was made between the success on the control test at the course and the entrance exam in total and by tasks. 6 candidates are missing data, as some of the candidates are withdrawn their submissions for the faculty. As entrance exams have varied over the past two years, 4 common task groups for the entrance exam and course tests have been identified: A1 - mental rotation, B1 - mental cutting, C - proportions and projections, B2 – solid intersection.

A statistically significant difference in success on the control test and entrance exam is shown. (p = 0.000). The entrance exam was done statistically significantly better (Paired Samples t-test t = 7.370, df = 38, p = 0.000). The average performance on the control test of candidates was approximately 60%, and on the entrance examination, it was almost 80% (Table 6). There is a high positive correlation between the control test and the entrance exam in the total score, Sprrman's rank correlation coefficient is $r_s = 0.669$, p = 0.000.

Table 5. *Descriptive statistics by task pairs on the course control test and entrance exam*

		Mean	N	Std. Deviation	Std. Error Mean
A1	e_p_A1	**.8908**	**39**	**.19506**	**.03124**
	c_p_i1	**.8462**	**39**	**.23379**	**.03744**
B1	e_p_B1	**.6000**	**39**	**.49630**	**.07947**
	c_p_i2	**.2462**	**39**	**.37406**	**.05990**
C	e_p_C	**.8000**	**39**	**.31119**	**.04983**
	c_p_i3	**.5282**	**39**	**.41228**	**.06602**
B2	e_p_B2	**.7949**	**39**	**.33478**	**.05361**
	c_p_i5	**.4949**	**39**	**.35611**	**.05702**
TOTAL	e_p_tot	**.7885**	**39**	**.18883**	**.03024**
	c_p_itot	**.5974**	**39**	**.20351**	**.03259**

Table 6. *Success rate by task pairs*

	Entrance exam success rate	Control test success rate
e_p_A1 - c_p_i1	89%	85%
e_p_B1 - c_p_i2	60%	25%
e_p_C - c_p_i3	80%	53%
e_p_B2 - c_p_i5	80%	50%
e_p_tot – c_p_tot	79%	60%

Tables 5 and 6 show that candidates performed better on the entrance exam than on the control test for all tasks (grouped by type of task), and on all but the first group of tasks A1 they performed significantly better.

Compared to the results obtained by a comparative analysis of the initial and control test at the course, there is evident progress in the mental cutting task (B1). The candidates had a few more days to prepare for the entrance exam. However, there is a relevant question here as to whether some spatial ability factors require an "incubation" time, that is, a certain time distance for the acquired knowledge to be applied.

3.4. Comparison of entrance exam results between candidates who attended the preparatory course and those who did not

The answer to the question of whether the preparatory course prepared the candidates better than they would have done on their own also speaks of whether innate spatial abilities can be developed.

We compared the results of the entrance exam for candidates who participated in the preparatory course and those who did not in total and by a group of tasks. In addition to the groups mentioned above, a comparison was made here for the group of spatial orientation tasks (D), since this task was found in the entrance exam in both years.

The Mann-Whitney U test showed a statistically significant difference in the score in the entrance test between candidates who took the course ($N = 51$, $Md = 0.8$) and those who did not ($N=31$, $Md=0.6616$) (Table 7) ($U=559.500$, $Z=-2.211$, $p=0.027$)

There was also a statistically significant difference in success between these candidates by type of assignment **A1** ($N = 51$, $Md = 1.00$) (Table 7) ($U=426.500$, $Z=-3.731$, $p=0.000$), and also type **C** between candidates who took the course ($N=51$, $Md=1.00$) and those who did not ($N=31$, $Md=0.67$) (Table 7) ($U=536.000$, $Z=-2.562$, $p=0.010$). **Candidates who attended the course showed better results** (for 47 candidates there are missing data).

Table 7. *Descriptive statistics for the entrance exam results*

	Preparatory course																	
	Y						N						Total					
	N	Mean	Std. Dev.	Md	Min	Max	N	Mean	Std. Dev.	Median	Min.	Max.	N	Mean	Std. Dev	Md	Min	Max
e_p_tot	51	.77	.19	.80	.24	1.00	31	.66	.20	.67	.21	1.00	82	.73	.20	.75	.21	1.00
A1	51	.86	.21	1.0	.33	1.00	31	.65	.27	.50	.00	1.00	82	.78	.25	.92	.00	1.00
B1	51	.62	.48	1.0	.00	1.30	31	.54	.46	.5000	.00	1.00	82	.59	.47	1.0	.00	1.30
C	51	.77	.33	1.0	.00	1.00	31	.55	.42	.67	.00	1.00	82	.69	.38	.82	.00	1.00
D	51	.89	.24	1.0	.00	1.00	31	.92	.16	1.0	.50	1.00	82	.90	.22	1.0	.00	1.00
B2	51	.71	.38	1.0	.00	1.00	31	.54	.40	.50	.00	1.00	82	.65	.39	.80	.00	1.00

We also analyzed whether the Descripive Geometry course that some candidates had in high school had an impact on their performance in the entrance exam.

Table 8. *Success at the entrance exam of all the candidates in relation to attending the DG course in high school*

DGhs	N	Mean	Std. Deviation	Median	Minimum	Maximum
Y	**33**	**.7227**	**.20749**	**.7500**	**.24**	**1.00**
N	**49**	**.7292**	**.19651**	**.7500**	**.21**	**1.00**
Total	**82**	**.7266**	**.19975**	**.7500**	**.21**	**1.00**

There wasn't a statistically significant difference in success between candidates who had the subject of Descriptive Geometry in highschool ($N = 33$, $Md = 7.50$) (Table 8) and and those who had not have (N = 49, Md = 7.50) (Table 8) by the score in the entrance exam results (Mann-Whitney U test U=803.000, Z=-0.052, p=0.958).

We did the same comparison for candidates who did not attend preparatory courses.

Table 9. *Success at the entrance exam of the candidates that did not attend the preparatory course in relation to havong the DG course in high school*

DGhs	N	Mean	Std. Deviation	Median	Minimum	Maximum
Y	**14**	**.6557**	**.19138**	**.6500**	**.42**	**1.00**
N	**17**	**.6665**	**.21860**	**.6700**	**.21**	**.94**
Total	**31**	**.6616**	**.20344**	**.6700**	**.21**	**1.00**

The Mann-Whitney U test didn't show a statistically significant difference in the score in the entrance exam between candidates who had the subject of Descriptive Geometry in highschool (N = 14, Md = 6.50) (Table 9) and and those who had not have (N = 17, Md = 6.70) (Table 2) (U=108.500, Z=-0.417, p=0.677).

This means that the course of Descriptive geometry in high school did not have a significant impact on performance of the candidates on the entrance exam.

4. CONCLUSION

Spatial abilities are considered as an important predictor of success in the engineering professions, especially those related to creative thinking, such as architecture. The low level of spatial abilities with which candidates approach the entrance exam at the Faculty of Architecture, Civil Engineering and Geodesy is a consequence of the systematic neglect of these skills during lower education. But the question is whether these abilities are innate or can be developed. This paper presents an analysis of preparatory teaching at the FACEG aimed at developing strategies and analytical thinking in solving these tasks, and which should prepare candidates for the entrance exam.

The results show that during the two-week course, students achieved progress in spatial abilities compared to the initial level in 4 assessed spatial ability factors, except for mental cutting factor, and also showed statistically significant progress at the entrance exam compared to candidates who prepared by themselves.

Tha analysis also showed that the course of Descriptive Geometry that some of the candidates had in highschool did not have a significant impact on their performance on entrance exam.

This suggests that strategies for solving spatial problems can be developed and that this topic should be addressed in greater detail in order to increase student performance in further architectural studies. Also, these results show that a more detailed approach to defining the importance of individual factors for assessing spatial abilities and their specificity for other professions, not just engineering, is needed. One of the important issues related to this is the relevance of these competencies to the success in their respective professions, so it is necessary to examine the correlation between these abilities, entrance exams and the faculty success of enrolled candidates in further studies.

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