18
Research paper I Оригинални научни рад
DOI 10.7251/STP2215181P
ISSN 2566-4484

Dajana Papaz, University of Banja Luka, dajana.papaz@aggf.unibl.org
Sandra Kosić-Jeremić, University of Banja Luka, sandra.kosic-jeremic@aggf.unibl.org
Maja Ilić, University of Banja Luka, maja.ilic@aggf.unibl.org

IMPACT OF DESCRIPTIVE GEOMETRY ON THE IMPROVEMENT OF SPATIAL ABILITIES OF ARCHITECTURE STUDENTS

Abstract

Spatial intelligence is an important skill for students of technical faculties, especially those fields where the capacity for engineering thinking and creative expression is equally valued. The field of Architecture is emphasized here, and the issue of assessing the spatial abilities of architecture students and their improvement has often been observed. This paper will examine the impact of the course of descriptive geometry on the development of their spatial thinking, and whether there is progress between the initial spatial abilities with which students were enrolled and abilities after completing the first semester of study.

Keywords: spatial abilities, spatial thinking, descriptive geometry, architecture.

УТИЦАЈ НАЦРТНЕ ГЕОМЕТРИЈЕ НА УНАПРЕЂЕЊЕ ПРОСТОРНИХ СПОСОБНОСТИ СТУДЕНАТА АРХИТЕКТУРЕ

Сажетак

Просторна интелигенција представља значајну вјештину за студенте техничких факултета, нарочито оних гдје се подједнако вреднују склоности према инжењерском мишљењу и креативном изражавању. Овдје се посебно истиче архитектонска професија, те је питање процјене просторних способности студената архитектуре и њихово унапрјеђење често испитивано. У раду ће се испитивати утицај курса нацртне геометрије на развој њиховог просторног мишљења, те да ли постоји напредак између иницијалних просторних способности са којима су студенти уписани и способности након одслушаног првог семестра студија.

Кључне ријечи: просторне способности, простоно мишљење, нацртна геометрија, архитектура.

1. INTRODUCTION

Studying architecture requires the ability of students to visualize, analyze, compose and manipulate different spatial elements inside their minds before presenting them by the analog or digital medium. It is highly necessary for them to be aware of the spatial relations in the environment to create new forms and to design different and unique structures. Every segment of a design process should be followed by multistep operations, where students/ architects need to have the capacity to switch between different projections and views [1]. Besides architecture, spatial abilities (SA) appeared to be the common requirement for all STEM fields (Science, Technology, Engineering, and Mathematics) [2].

To become competent and professional engineers, students of architecture are also necessitated to have a great aptitude for understanding and mentally visualizing spatial transformations, differentiating separate parts of the observed subject, and finally interpolating them into a complex system [3]. Therefore, during their studies, they are required to complete various courses that are expectantly going to improve their spatial abilities through different forms of tasks and exercises. Descriptive geometry (DG) is one of them, and it aims to provide essential knowledge and methods for understanding 3D space, presenting it as 2D drawings while being able to create new forms and shapes that are interrelating. An important part of the previous mention is that there is a difference between understanding 2D and 3D drawings, shapes, and objects.

Leopold, in her work, shows that Descriptive Geometry can provide the foundations for creating and understanding 2-D drawings of 3-D objects while it also impacts the development of spatial visualization abilities [4].

Architecture and its tight bond with spatial abilities were also studied by M. Berkowitz and his fellows [5]. The basic assumption of this paper was whether acquiring experience in architecture improves students' spatial abilities. These authors considered the existence of different types of spatial abilities while focusing on finding out whether some aspects of spatial thinking are more probable to be improved by acquired architectural experience. After a series of tests and discussions, it was concluded that architecture does influence spatial abilities, thus they do improve during architecture studies, already at the beginning of the studies [5].

At the Faculty of Košice, there was a study that included pretest and post-test methods by Baranová and Katreničová. Their findings proved that the DG course positively impacts the development of students' spatial skills. However, it seems to be one of the most difficult courses [6].

According to Sorby [7], the majority of spatial skills tests are supposed to evaluate a student's skill levels during the first two development stages. The first stage refers to, essentially, 2D tests that assess the topological spatial skills, but they appeared not to be significantly important for engineering educators. The second stage of development evaluates projective spatial skills, these tests consist of 3D graphics tasks, and they are mostly used by engineering graphics educators. The most used tests such as The Mental Cutting Test (MCT) [8], The Differential Aptitude Test: Space Relations (DAT: SR) [9] The Purdue Spatial Visualization Test: Rotations (PSVT: R) – developed by Bodner and Guay [10] are still a matter of discussion because spatial intelligence tests are yet to be standardized. It is still not a fully developed field of psychology because different researchers claim that different factors influence spatial abilities. Many types of tasks, found in literature, are used to measure various spatial abilities aspects, still, some of them such as The Mental Rotation Test (MRT), The Differential Aptitude Test: Space Relations (DAT: SR), and the Mental Cutting Test (MCT) are the most common [11], [12].

To investigate if the DG has any significant impact on developing students' spatial thinking, there were several types of research conducted during the past years. In an older article written by Gittler and Gluck [13], the main goal of the research was to find the correlation between instruction in DG and pupils' performance on a spatial ability test. The test consisted of a Three-Dimensional Cube Test (3DC) and numerous variations of similar cube-connected tasks. Besides the general score, the gender difference was also taken into consideration. The researchers' results indicated that there was a difference between the first and the second test. It also indicates that the DG school subject has stimulated spatial abilities development and has helped improve pupils' spatial thinking skills [13].

The other researchers [3] have also been focusing on spatial intelligence on different levels with different approaches such as having multiple strategies in order to find the connection between science and spatial cognition. This particular research aimed to find out whether improving spatial skills affects science learning, what's the connection between science and spatial relations, and also if there is a way to spatialize the science curriculum. Spatial thinking proved to be closely connected to science success and also to be malleable. Therefore, it's possible to talk about new and improved strategies that can possibly help students to overcome spatial orientation, visualization, and manipulation problems [3].

Various studies have been conducted in the previous years at the Faculty of Architecture, Civil Engineering, and Geodesy in Banja Luka (ACEG) and the main questions of these studies were usually about the existence of any kind of significant connection between the spatial skills of the students and the Descriptive Geometry course they were attending. Also, it was investigated if there were any differences between students of different departments at the faculty. The test used for those research combines the four most common spatial ability tasks mentioned above: MRT, DAT: SR, and MCT [11], [12].

In these researches, DG was observed as a tool supposed to help students develop their spatial abilities. The first group of students didn't attend the DG course while the other one did, during the same semester. Besides this main question, the other topics following the research were trends in improving spatial abilities, proper tools and teaching approaches that may be used to improve spatial abilities, other influential factors, and the potential improvement in spatial abilities based on gender differences. It was concluded that DG has some impact, and it may stimulate spatial thinking rather than improve spatial abilities directly. By all means, the important tool that DG provides is the capability of developing multiple cognitive processes such as deduction, abstraction, and systematization [11].

The preparatory course for enrollment at the FACEG, aside from Descriptive Geometry, was also considered an important factor that may influence the development of spatial abilities [14]. The reason why the preparatory course was selected instead of the DG course was because of the different types of tasks that are included within the preparatory course. DG has its own methodology and the tasks consisted in it are mostly abstract – with the coordinate systems, points, lines, and planes. The preparatory course, on the other hand, consists of 3D figures and 2D shapes that are more likely to be imagined and mentally manipulated. The results of the entering exam were in favor of those students who took the preparatory course at the faculty. They showed significantly better performance, unlike the students who were preparing for the exam by themselves [14].

This paper focuses also on the DG course and its role in spatial thinking progress, however, the focus group is only architecture students, since the previous studies showed a significant difference in performance between students of different departments, in favor of architecture students. For that matter, the research was redirected to analyzing the results of architecture students exclusively. In this paper, two groups of participants will be examined and compared. The first group consists of the last two generations of architecture students, while the control group consists of three generations of students who did the SA test without attending the DG course during the research period.

This research is going to show if the course of DG helps with developing and improving students' spatial abilities. Also, after analyzing the general results based on the students' scores, the paper will discuss the results of individual tasks in the spatial ability test and compare them between the two research groups.

2. METHODOLOGY AND RESEARCH

2.1. METHODOLOGY OF THE RESEARCH

Teaching methods and materials are constantly changing due to upgrading and reevaluating the knowledge that students are expected to acquire. Nevertheless, teaching experience shows that the best skill students can gain during their studies is divergent thinking [11] and the capacity to manage multiple data, identify the problem, and search for the necessary information. Therefore, spatial abilities could be an essential starting point to evolve this kind of thinking.

DG course is one of the subjects that involve spatial thinking in the process of solving different geometry problems. The semester lasts for 15 weeks, and the DG course takes 4 hours a week (2 hours of theoretical lectures combined with small tasks + 2 hours of drawing assignments). The very beginning of the course tends to introduce students to Monge's projections and basic theoretical information about points, lines, planes, and solids. The first assignments are principally basic, but the tasks are getting more difficult as the study material becomes more complex. All of the tasks are drawn by hand, so the students learn to use drawing tools such as pencils, triangles, rulers, and compass. A significant number of students struggle with the DG course, they consider it as one of the most difficult subjects in the first year of studies [11].

In this, as in the previous studies, the same SA tests were used. This test contained 8 tasks sorted into 4 types, each with 2 levels of difficulty based on the most common SA tasks mentioned above (MRT, DAT: SR, and MCT). The first group of 4 tasks is less complex than the second group of 4 tasks. Every task was valued by max. 1 point, so the maximum score on each test was 8 points. The tests' content and complexity levels are already thoroughly presented and explained in [11], [12], [15].

The test was given to the students at the beginning and at the end of the semester. These two tests are not identical, but the structure, task types, and difficulty are the same. It is a multiple-choice test.

The differences between the two groups of students are compared in relation to attending the DG course between the two tests.

Since the FACEG was formed, the DG course was held during the first semester of the Civil Engineering and Geodesy study curriculum, while the Architecture students attended the DG course in the second semester, thus the architecture students were considered as the control group in the previous studies concerning spatial abilities. The study curriculum at the Architecture department changed in 2020, and since then the DG course was held during the first semester of Architecture. The other courses remained essentially the same, some of them were combined into one course, but the teaching material hasn't fundamentally changed.

This research put its focus only on students of architecture because they have usually shown better performance on the SA test in comparison to the other two departments at FACEG [11], so comparing them mutually should give more relevant results.

The first group consists of 121 students in the following school academic years: 2017/18, 2018/19, and 2019/20. The second group consists of 108 students attending the same semester during the 2020/21 and 2021/22 academic years. Both genders were represented in both groups.

For each generation of the students, the tests were conducted in the classrooms, during the teaching period, hence the students were taking tests right before or after the lessons. The duration of the tests was approximately 25 minutes.

The students were not paid for participating in the study, it wasn't conditioned by any matter.

For the statistical study, the SPSS v.20 was used as the analytical-statistical software package. Descriptive statistics were used for presenting and summarizing data. Also, the Paired Samples t-Test, non-parametric Mann-Whitney U test, $\chi 2$ square test, and the Spearman's rank correlation coefficient were used. No normal distribution was noticed by the variables that were observed [16].

2.2. RESEARCH QUESTIONS

The leading questions concerning this specific paper were:

RQ1. Does the DG course influence the performance of architecture students at the SA test, that is, does it improve their spatial thinking?

Students were tested twice during the research period, at the beginning and at the end of the semester, as stated above. To determine if the DG had an influence on students' spatial thinking, we used a control group of students that did not attend the DG course between the first and the second test. The comparison between the results showed the difference in the performance of the two groups. In this case, we compared the difference in success on both tests between these two groups.

In the second phase, the analysis was extended to the assessment of the student's performance on the different tasks' complexity.

RQ2. Does the DG course have an impact on improving any specific spatial thinking factor or complexity of spatial skills?

In order to discover if DG provided any valuable assets for architecture students, we also compared their performance on different types and complexity of tasks. For example, the performance and the achieved results on the first test's low-complexity tasks were compared to the same complexity level tasks in the second test. The same comparison was performed with the high-complexity tasks.

The analysis is going to show if the progress was partially developed depending on the task complexity or the type of the tasks.

3. RESULTS AND DISCUSSION

Out of 318 architecture students in the first year of the Faculty of Architecture, Civil Engineering and Geodesy at the University of Banja Luka enrolled in 2017/18, 2018/19, 2019/20, 2020/21, and 2021/22 academic years, a total of 229 students were tested. The first group (Group 1) consists of students of 2017/18, 2018/19, and 2019/20 generations, who were not attending the DG course between the two tests, and the second group (Group 2) consists of the 2020/21 and 2021/22 generations, who took the DG course between the two SA tests. All students were observed and tested in the first semester of the year they were enrolled in. Students took the first (initial) spatial ability test – TEST 1 at the beginning of the first semester and the second (control) spatial ability test – TEST 2 at the end of the first semester. The tests were not only a tool used to estimate students' abilities, but they could also be a way to gain experience and training in spatial thinking [15].

Table 1. The number of students by years of enrollment

			Total	Having DG course during the high school	NOT having DG course during the high school
Group 1	2017_18_19	Count	121	41	80
		% of Total	52,8 %	17.9%	34.9%
Group 2	2020_21	Count	108	34	74
		% of Total	47,2 %	14.8%	32.3%
Total	2017_18_19_20_21	Count	229	75	154
		% of Total	100 %	32.8%	67.2%

Table 1 presents the total number of the observed students along with the percentage, 100% (229). Also, it is shown how many students were included in both Group 1, 52.8 % (121), and Group 2, 47.2% (108). The distribution of the students is adequate and nearly equal.

Before enrolling in the faculty, students attended different high schools, where some of them attended the DG course for one or two years. Table 1 shows that, out of the total number of students, 32.8% of them were engaged in the DG course during high school, and 67.2% of them were not.

Out of the total number of the observed students, 175 (76.4%) are female and 54 (23.6%) are male.

3.1. PROGRESS CONCERNING GROUPS AND TESTS (TEST 1 AND TEST 2)

Table 2. The overall success of the groups in test 1 (initial test) and test 2 (control test)

		N	Mean	Std. Deviation	Median	Minimum	Maximum
TEST1	G1 (2017_18_19)	108	**0.5878**	0.20294	0.6250	0.00	1.00
	G2 (2020_21)	121	**0.5330**	0.19791	0.5313	0.00	0.88
	Total	229	0.5620	0.20201	0.5625	0.00	1.00
TEST2	G1 (2017_18_19)	108	**0.6472**	0.20330	0.6250	0.25	1.00
	G2 (2020_21)	121	**0.5799**	0.21597	0.6250	0.06	1.00
	Total	229	0.6154	0.21161	0.6250	0.06	1.00

Table 2 shows the results of both tests that students took. According to the given results, when comparing the success on the **initial** test, Group 1 showed better performance, they achieved 58.78% of the total score, while Group 2 achieved 53.3%. This implies that there could be differences in student performance compared between each generation of the students or possible differences based on the background of the student's previous education.

This can also lead to more discussion about the conditions the test was conducted. Due to the pandemic situation in 2020, some of the students were tested online, or in smaller groups. These changes in testing conditions could influence the student's performance on the test. It also raises another issue —lack of self-confidence can decrease the capacity of the student to perform as well as he/she is actually capable of, which is also an issue when observing any intelligence tests.

However, when analyzing both groups' performance on the control test, it's evident that Group 1 showed better results once again. Group 1 achieved 64.7% of the total score, while Group 2 achieved 58%. This means that both of the groups made significant progress between the first and the second test, but it also means that the DG course may not have influenced the development of their spatial abilities. When comparing the percentage of the progress these students made during the semester, it is obvious that Group 1, besides being better overall, made still greater progress. The score difference between test 1 and test 2 for Group 1 was 6%, and for Group 2 it is 4.7% (Figure 1).

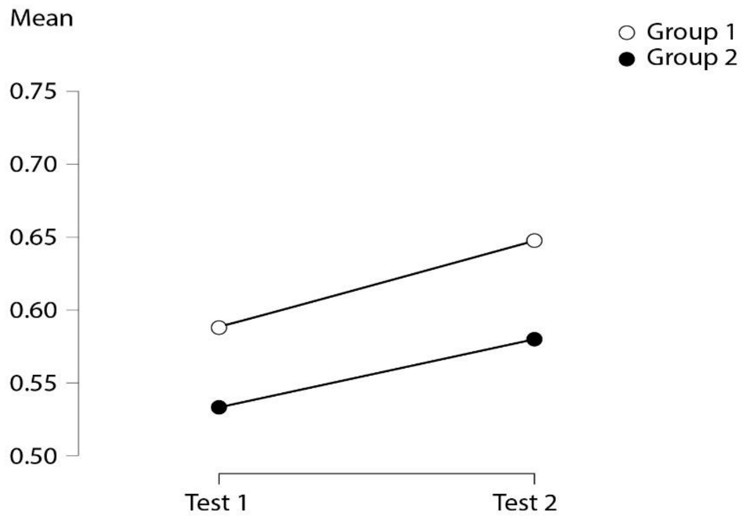

Figure 1. *Progress between test 1 and test 2 for both Group 1 and Group 2*

Table 2 also shows that Group 1 had at least one student who achieved a maximum score on both tests, while Group 2 achieved a maximum score only on test 2.

The Paired Samples t-Test showed a statistically significant difference in success between the first and second spatial ability tests in all students together (t=-3.510, df=228, p=0.001). Students achieved better scores in the second test (Table 2). There is also a mean positive correlation between Test 1 and Test 2 (r_S=0.373, p=0.000).

Analyzing each group separately, the Paired Samples t-Test showed a statistically significant difference in success between the first and second spatial ability tests for Group 1 (t=-2.765, df=120, p=0.007) and for Group 2 (t=-2.165, df=107, p=0.033). There is also a positive correlation between Test 1 and Test 2 for both groups, for Group 1 (r_S=0.315, p=0.000), and for Group 2 (r_S=0.415, p=0.000).

The Mann-Whitney U test did not show a statistically significant difference in success on the Test 1 between students of Group 1 (N = 108, Md = 0.6250) with Group 2 (N = 121, Md = 0.5313), (U = 5635.000, z = -1.810, p = 0.70), but did on the Test 2 (U = 5410.000, z = -2.264, p = 0.024).

Statistically, the results show that DG doesn't have much to do with the development of spatial abilities. The reason for this could be found in the fact that the types of tasks students solve within the DG course are not directly connected with the tasks included in spatial ability tests, but they possibly do stimulate spatial thinking. Another problem could be the strategy students use while solving DG problems. Some of them actually use spatial relations and genuine understanding when passing the course, while the rest of them rely on learning the steps and repetitive procedures without trying to understand the spatial processes behind the procedure.

Both groups did show progress in performance, it is possible to go deeper in observing the difference in the level of complexity and type of the tasks.

3.2. PROGRESS CONCERNING COMPLEXITY LEVEL – LOW AND HIGH-COMPLEXITY TASKS

The Paired Samples t-Test showed a statistically significant difference in success between low-complexity tasks and high-complexity tasks on Test 1 for all the students, (t=15.048, df=228, p=0.000). They generally showed significantly better performance on low-complexity tasks.

The t-test also showed a statistically significant difference between low-complexity tasks and high-complexity tasks by groups, for Group 1 (t=12.037, df=120, p=0.000) and for Group 2 (t=9.278, df=107, p=0.000). Table 4 presents that students in each group showed significantly better performance on low-complexity tasks. The Mann-Whitney U test **did show** statistically significant difference in success at the low-complexity tasks in Test 1 between Group 1 (N = 121, Md = 0.75) and Group 2 (N = 108, Md = 0.75) (U = 5507.500, z = -2.095, p = 0.036), but **not** at high-complexity tasks between Group 1 (N = 121, Md = 0.50) and Group 2 (N = 108, Md = 0.375) (U = 5986.500, z = -1.112, p = 0.266) (Table 3).

Table 3. Overall success in the initial test by task complexity – low and high-complexity

			N	Mean	Std. Deviation	Median	Minimum	Maximum
Low-complexity tasks	TEST1_LL	G1 (2017_18_19)	121	**0.7479**	0.24366	0.75	0.00	1.00
		G2 (2020_21)	108	**0.6759**	0.27077	0.75	0.00	1.00
		Total	229	0.7140	0.25875	0.75	0.00	1.00
	TEST 2_LL	G1 (2017_18_19)	121	0.6374	0.24442	0.75	0.00	1.00
		G2 (2020_21)	108	0.5903	0.26077	0.6250	0.00	1.00
		Total	229	0.6152	0.25281	0.6250	0.00	1.00
High-complexity tasks	TEST 1_HL	G1 (2017_18_19)	121	0.4277	0.25656	0.50	0.00	1.00
		G2 (2020_21)	108	0.3900	0.23724	0.3750	0.00	1.00
		Total	229	0.4099	0.24781	0.3750	0.00	1.00
	TEST2_HL	G1 (2017_18_19)	121	**0.6570**	0.26689	0.75	0.00	1.00
		G2 (2020_21)	108	**0.5694**	0.24667	0.50	0.13	1.00
		Total	229	0.6157	0.26070	0.6250	0.00	1.00

The Paired Samples t-Test **did not** show a statistically significant difference in success between low-complexity level tasks and high-complexity level tasks on Test 2 for all students together ($t=-0.028$, $df=228$, $p=0.977$) nor by groups. For Group 1 ($t=-0.695$, $df=120$, $p=0.489$) and for Group 2 ($t=0.812$, $df=107$, $p=0.419$).
The Mann-Whitney U test **did not** show statistically significant difference in success at the low-complexity level tasks in Test 2 between Group 1 (N = 121, Md = 0.75) and Group 2 (N = 108, Md = 0.625) (U = 5940.000, z = -1.208, p = 0.227), but **did show** at the high-complexity level tasks between Group 1 (N = 121, Md = 0.75) and Group 2 (N = 108, Md = 0.50) (U = 5234.000, z = -2.654, p = 0.008 (table 3). The first group showed better performance at high-complexity level tasks. There is also a positive correlation between TEST1_LL and TEST1_HL for Group 1 ($r_S=0.343$, $p=0.000$) but not for Group 2. There is also a positive correlation between TEST2_LL and TEST2_HL for Group 1 ($r_S=0.265$, $p=0.003$) and for Group 2 ($r_S=0.477$, $p=0.000$).

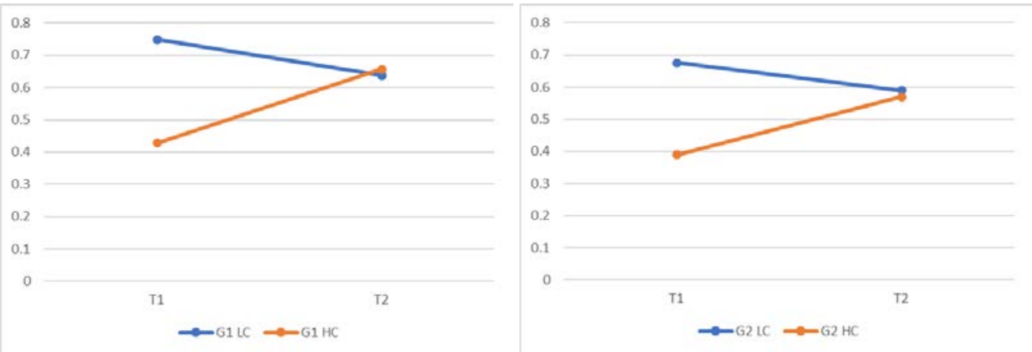

Figure 2. *Difference between success on low and high-complexity tasks for Group 1(left) and Group 2(right) on test 1 and test 2*

Since we found no significant connection between the DG course and the SA test, we will discuss a few observations comparing the progress of each group regarding the tasks' complexity.

Figure 2 shows that both groups decreased in success for low complexity tasks, but also both groups show progress regarding the high complexity tasks between two tests. It is interesting to notice that both groups achieved nearly the same score for both complexity levels in test 2 (Figure 3).

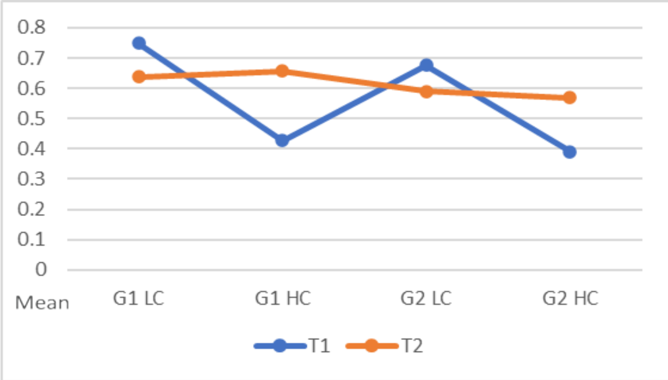

Figure 3. *Score differences between two tests by complexity for both groups*

These results show that low-complexity tasks are generally solved better on test 1 but repeatedly, Group 1 showed better performance. When observed more closely, there is an appreciable difference in the gap between low-complexity and high-complexity tasks' scores. Figure 4 illustrates that even if Group 1 was more successful overall, the gap between scores on high-complexity tasks is significantly smaller than between scores on low-complexity tasks. The difference between the success of Group 1 and Group 2 for low-complexity tasks is 7.2%, but only 3.7% for high-complexity tasks. According to the previous results about evident progress for both of the groups, the question is if Group 2 managed to catch up with Group 2 with at least low-complexity level tasks on test 2?

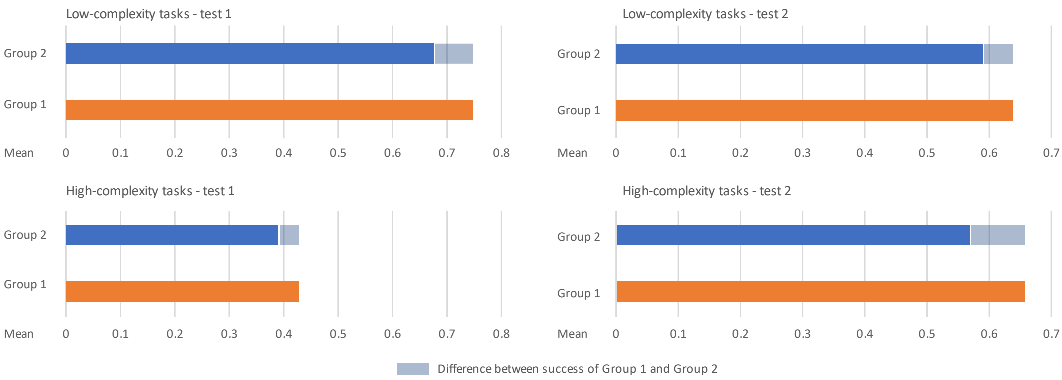

Figure 4. *Success differences between groups on low-complexity tasks and high-complexity tasks on test 1(left) and test 2 (right)*

These data are confirming the general observation – that both groups made similar progress during the first semester. The question from the discussion above, about groups' progress on test 2, may be resolved by analyzing data from Table 3 and Figure 4. As expected, Group 1 achieved better results, but this time it's possible to discuss if the progress Group 1 made between test 1 and test 2 may have been lower than expected. That is, on test 1, low-complexity tasks were solved much better than high-complexity tasks, still, on test 2 that wasn't the case. Both complexity tasks were solved nearly the same, but as noticed, Group 1 improved in solving high-complexity tasks but kept almost the same score as before on low-complexity tasks. Group 2 caught up with Group 1 in solving low-complexity tasks but was left behind with high-complexity tasks. The performance difference between G1 and G2 on low-complexity tasks, on test 2 is 4.7%, and on high-complexity tasks is 8.8%.

3.3. PROGRESS CONCERNING TASK TYPE

Besides complexity, tasks are grouped 2 by 2, for example, task 1 and task 5 are the same types but have a different level of complexity. Tasks 1 and 5 are PF type (Paper folding), tasks 2 and 6 are MR (Mental Rotation) type, tasks 3 and 7 are MC type (Mental Cutting) and tasks 5 and 8 are SR (Spatial Relation) type.

Table 4. The success of each group by task types in test 1 and test 2

		N	Mean	Std.Deviation	Median	Minimum	Maximum
TEST 1	G1_1-5	121	0.4711	0.27612	0.50	0.00	1.00
	G2_1-5	108	0.4676	0.27576	0.50	0.00	1.00
	G1_2-6	121	0.5992	0.36297	0.50	0.00	1.00
	G2_2-6	108	0.5556	0.29862	0.50	0.00	1.00
	G1_3-7	121	0.7107	0.30105	0.50	0.00	1.00
	G2_3-7	108	0.5833	0.36494	0.50	0.00	1.00
	G1_4-8	121	0.5702	0.34944	0.50	0.00	1.00
	G2_4-8	108	0.5255	0.36803	0.50	0.00	1.00
TEST 2	G1_1-5	121	0.6364	0.34761	0.50	0.00	1.00
	G2_1-5	108	0.5926	0.36906	0.50	0.00	1.00
	G1_2-6	121	0.8017	0.26987	1.00	0.00	1.00
	G2_2-6	108	0.7014	0.29887	0.75	0.00	1.00
	G1_3-7	121	0.4669	0.33376	0.50	0.00	1.00
	G2_3-7	108	0.4190	0.39392	0.50	0.00	1.00
	G1_4-8	121	0.6839	0.31585	0.50	0.00	1.00
	G2_4-8	108	0.6065	0.34890	0.50	0.00	1.00

Both test 1 and test 2 are analyzed. The $\chi2$ square test showed a statistically significant difference in success between G1 and G2 for tasks T1_2_6 ($\chi2=14.842$, $p=0.005$) in favor of G1, and for T1_4_8 ($\chi2=10.633$, $p=0.005$), also in favor of G1.

$\chi2$ square test showed a statistically significant difference in success between G1 and G2 in favor of G1 for T2_3_7 tasks ($\chi2=10.435$, $p=0.015$).

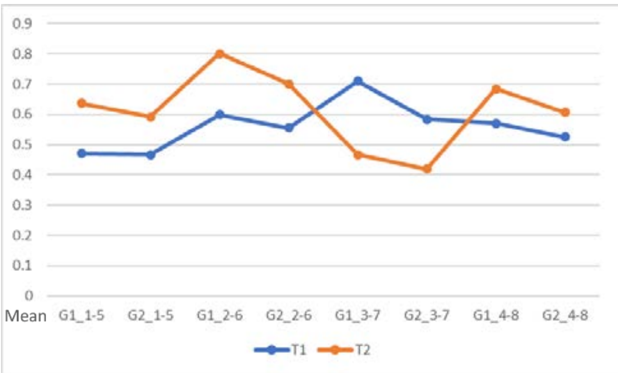

Figure 5. *Success differences between test 1 and test 2 by task types*

Figure 5 shows that both groups' success varied in the same direction on the same task types comparing the two tests. Comparing their performance on test 1 and test 2, they made progress in PF, MR, and SR task types, but their scores noticeably decreased on MC type.

4. CONCLUSION

For many years, much of the research on spatial abilities have been focused on the impact of the DG course on spatial skills between the three departments on FACEG – architecture, civil engineering, and geodesy. Those results have shown obvious inequalities in spatial skills between these students, mostly in favor of architecture students.

They generally performed better at the SA test which may have been due to their preparations for the entry exam in FACEG, when they encountered the spatial abilities training before they enrolled [10]. Because of that, the focus of this research was the improvement of spatial ability skills of architecture students, depending on if they attended the DG course.

The results of the study showed that both groups (with and without DG course) demonstrated a significant increase in spatial thinking during the semester in general, but there was no statistically shown impact of DG. Both groups made progress, G1 by 6% and G2 by 4.7%.

Analyzing tests by task types, the study shows the progress for both groups in all task types, except the Mental Cutting type. Similar results have been shown in previous research [11].

Results also show an interesting balance of all scores on the second test for both groups, that is, the scores for both low and high complexity tasks converge to the same value.

This may lead us to the conclusion that studies of architecture all together influence spatial thinking, and the combination of all the courses the students are attending may have an impact on improving their spatial skills. Observing those courses closely and examining their impact on spatial abilities could be the potential base for further research in this subject.

LITERATURE

[1] N. Cross, "DESIGN THINKING UNDERSTANDING HOW DESIGNERS THINK AND WORK."

[2] D. H. Uttal and C. A. Cohen, "Spatial Thinking and STEM Education. When, Why, and How?," in Psychology of Learning and Motivation - Advances in Research and Theory, vol. 57, 2012, pp. 147–181. doi: 10.1016/B978-0-12-394293-7.00004-2.

[3] N. S. Newcombe, "Thinking spatially in the science classroom," Current Opinion in Behavioral Sciences, vol. 10. Elsevier Ltd, pp. 1–6, Aug. 01, 2016. doi: 10.1016/j.cobeha.2016.04.010.

[4] C. Leopold, "Geometry education for developing spatial visualisation abilities of engineering students Some of the authors of this publication are also working on these related projects: Nexus Network Journal: Architecture and Mathematics View project Geometry, Architecture and Music View project," 2005. [Online]. Available: https://www.researchgate.net/publication/228908412

[5] M. Berkowitz, A. Gerber, C. M. Thurn, B. Emo, C. Hoelscher, and E. Stern, "Spatial Abilities for Architecture: Cross Sectional and Longitudinal Assessment With Novel and Existing Spatial Ability Tests," Frontiers in Psychology, vol. 11, Feb. 2021, doi: 10.3389/fpsyg.2020.609363.

[6] L. Baranová and I. Katreničová, "Role of Descriptive geometry course in development of students' spatial visualization skills," Annales Mathematicae et Informaticae, vol. 49, pp. 21–32, Apr. 2018, doi: 10.33039/ami.2018.04.001.

[7] S. A. Sorby, "Developing 3D spatial skills for engineering students," Australasian Journal of Engineering Education, vol. 13, no. 1, pp. 1–11, Jan. 2007, doi: 10.1080/22054952.2007.11463998.

[8] P. Katsioloudis, V. Jovanovic, and M. Jones, "A Comparative analysis of spatial visualization ability and drafting models for industrial and technology education students," Journal of Technology Education, vol. 26, no. 1, pp. 88–101, 2014, doi: 10.21061/jte.v26i1.a.6.

[9] G. Bennett, H. Seashore, and A. Wesman, "Differential aptitude tests.," 1947, Accessed: Mar. 14, 2022. [Online]. Available: https://psycnet.apa.org/record/1948-02421-000

[10] G. M. Bodner and R. B. Guay, "The Purdue Visualization of Rotations Test."

[11] M. Ilić, S. Kosić-Jeremić, and M. Stavrić, "Descriptive geometry and spatial ability-correlation and mutual impact at engineering students," Tehnicki Vjesnik, vol. 27, no. 6, pp. 2001–2007, 2020, doi: 10.17559/TV-20190425181038.

[12] M. Ilic and A. Djukic, "Typology of spatial ability tests and its implementation in architectural study entrance exams," Facta universitatis - series: Architecture and Civil Engineering, vol. 15, no. 1, pp. 1–14, 2017, doi: 10.2298/fuace161113001i.

[13] G. Gittler and J. Glück, "Differential Transfer of Learning: Effects of Instruction in Descriptive Geometry on Spatial Test Performance," 1998.

[14] M. Ilić, S. Kosić-Jeremić, and D. Papaz, "CAN SPATIAL ABILITY BE TRAINED – THE ANALYSIS OF PREPARATORY COURSE FOR ENROLMENT AT THE FACULTY OF ARCHITECTURE," САВРЕМЕНА ТЕОРИЈА И ПРАКСА У ГРАДИТЕЉСТВУ, vol. 14, no. 1, Jun. 2020, doi: 10.7251/stp2014318i.

[15] S. Kosić-Jeremić, "COMPARISON OF PERFORMANCE OF ENGINEERING STUDENTS IN DESCRIPTIVE GEOMETRY IN RELATION TO THEIR STUDY PROGRAM," САВРЕМЕНА ТЕОРИЈА И ПРАКСА У ГРАДИТЕЉСТВУ, vol. 13, no. 1, Jun. 2018, doi: 10.7251/stp1813445i.

[16] L. Preradović and Đajić Vlado, Analitičko-statističke tehnike u savremenim istraživanjima. Banja Luka: Arhitektonsko-građevinski fakultet, 2011.