

THE INFLUENCE OF COMPUTER ANIMATION COURSE ON INCREASING THE LEVEL OF VISUAL-SPATIAL CAPACITY OF STUDENTS

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Abstract

Visual-spatial capacity is an important and basic intellectual activity of people, necessary for different areas of life, starting from the very ability to navigate the living space, to success in various areas of life, e.g. education. This research supports the thesis that attending a computer animation course has a positive outcome with a growing visual-spatial capacity. Students' capacities were assessed using PSVT (Purdue Spatial Visualization Test), applying pre-test, post-test and re-test to the whole group and subgroups (full-time and part-time students). Resurvey related to the impact of previous experiences about attending similar courses with increasing visual-spatial capacity. The results showed that using computer animation, as one of the 3D technologies, can increase visual-spatial capacity, but not the same in all observed groups.

Keywords: visual-spatial capacity, computer animation, mental rotation, PSVT, education

1. Introduction

Visual-spatial capacity (after this VSC) is key to success in various fields of study - it enables the location, selection and separation of important stimuli from the environment; analysis of the observed and manipulation of relevant information. Many authors have studied the relationship of VSC with other sciences.

Thus, Langlois et al., (2020) study the relationship between VSC and technical skills in health care, Saor'n-Perez et al., (2009) investigate the relationship between VSC and engineering sciences, Ashkenazi & Velner (2023), Pui Tam & W. Wai Lan Chan (2022), Stavridou & Kakana (2008) and Ben et al., (1986) study visual-spatial capacity with mathematical, Hartman and Bertoline, (2005) use of VSC in computer graphics learning environments. Some authors believe VSC can be increased by applying to various specialities training or courses (Sorby, 2009; Yang et al., 2003; Martin-Dorta et al., 2008; Eyal & Tendick, 2001; Gerson et al., 2001). However, VSC can also be improved by attending courses related to engineering or computer science (Kösa & Karakuş, 2018; Friess et al., 2016; Blade & Watson, 1955).

Computer animation is a course that is studied at many faculties related to computer science, so for these reasons, the study of the relationship between VSC and learning computer animation (CA) was done. The course CA directly affects VSC capacity, by studying 2D / 3D geometric transformations and procedures for performing mental manipulations with such objects.

The research was conducted from several aspects: - the impact of attending CA on VSC (whether there may be a potential increase in VSC after completing the CA course). Another aspect was to determine whether the prior experience in using 3D software was in correlation with students' levels of VSC possession after taking the CA course. The research included students who took the CA course. The study lasted for two school years (the subject is monitored in the winter semester), and the instrument of choice for assessing students' VSC, was Purdue's Spatial Visual Test (PSVT). At the same time, a further aspect of this study was to evaluate whether the increase in the PSVT test could be the outcome of test repetition. To confirm this, additional research was conducted with students who do not take the CA course.

2. Visual-spatial capacity

Cognitive capacity is skills based on brain activities that are performed as tasks. They are connected to mechanisms related to the way of learning, recall, problem-solving or the way of paying attention. In addition, they affect the ability to remember and perceive, hold attention, logical reason and conclusions, the speed of processing auditory and visual information, and the ability to express themselves verbally. Cognitive capacity is necessary for performing various tasks, even those that involve manual work.

The capacity of spatial visualisation is usually defined as visual-spatial intelligence, which regulates the ability to perceive and distinguish colours, shapes, sizes and mutual distances of objects. Visually and spatially gifted people can recognise and remember patterns, imagine scenes in three dimensions and navigate in open space. During the 1980s, there was a new interpretation of the concept of general intelligence, and spatial visualisation was identified as one of the seven primary mental capacities. With this newer approach, visual-spatial intelligence is described as "the ability to accurately perceive the visual world, perform transformations and modifications according to one's initial understandings" (Gardner, 1983). VSC (visual-spatial capacity) means

the ability to reason spatially, manipulate mental images, recognise visual patterns, think in 3D and construct 3D shapes from 2D information (Zimmerman & Dean, 2011).

Many studies have used various standardised tests to measure VSC, but the most commonly used is The Purdue Spatial Visualization Test (PSVT), developed by Guay, (1976). The PSVT test includes three subsets: views, development, and rotations, and belongs to the group of multiple choices. There are 30 questions in each subset, and for ease of use, they were named: PSVT-V, PSVT-D and PSVT-R, respectively. The test, developed by Guai, had the same three subsets, each with twelve questions, and was later expanded by adding eighteen new questions for each subset. Examples of questions for each subset are shown in Figs. 1, 2, and 3.

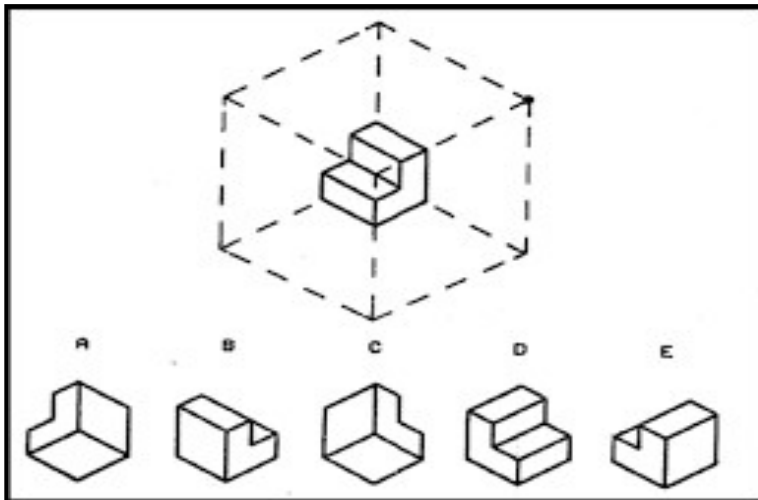


Fig 1. Example problem in the Views section of PSVT

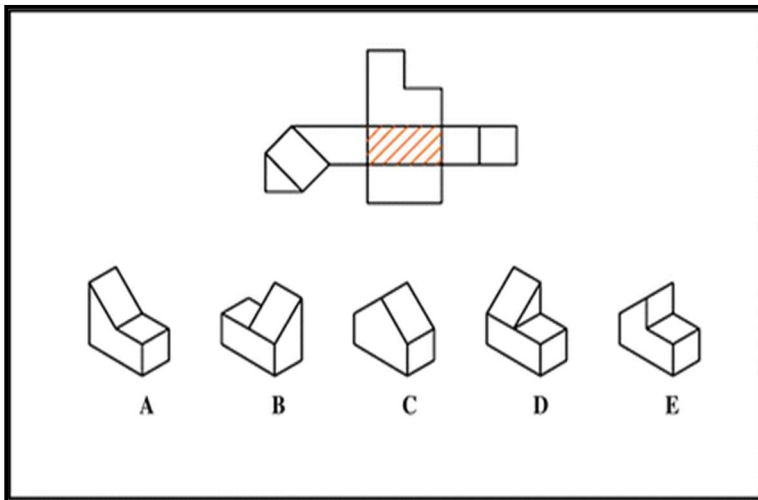


Fig. 2 Example problem in the Development section of PSVT

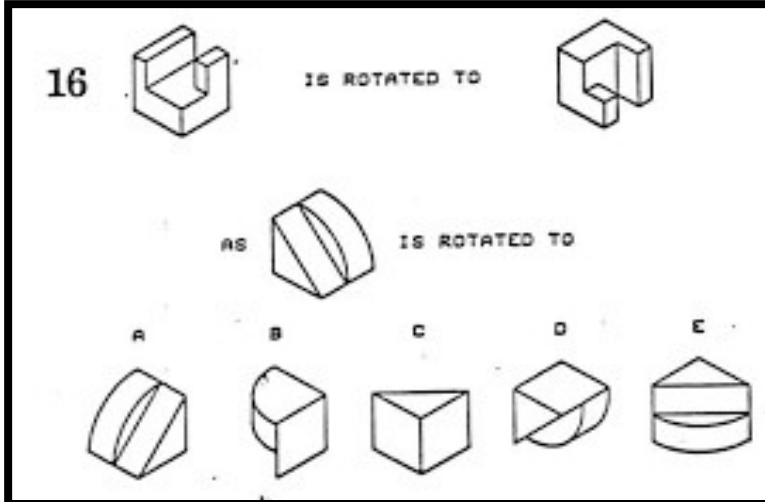


Fig. 3 Example problem in the Rotations section of PSVT

PSVT has been used in engineering and scientific disciplines for above 35 years. If unknown shapes included geometric regularities such as rectangles and parallels, respondents would recognize them very easily (Perkins, 1983). However, problems arose when respondents interpreted perceived information in many ways (Perkins, 1982). Lowe (1987) defined this as a condition of detection. The explanation is that some isometric projections of three-dimensional objects could be interpreted as two-dimensional shapes (Figure 4).

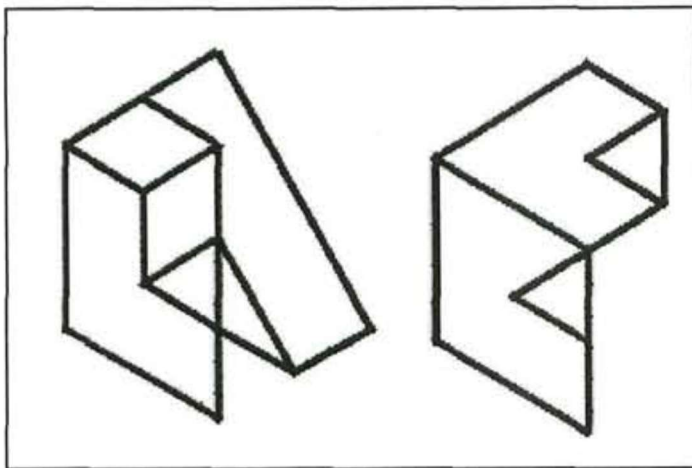


Fig. 4 - 3-D objects or 2-D patterns (Branoff, 2000).

If the presented objects were interpreted as two-dimensional, the question of the validity of the test would be raised with the assessment of a person's ability to mindset manipulate the performance as a three-dimensional object. Therefore, the question was raised whether using trimetric projections of three-dimensional objects on PSVT enables a more accurate assessment of the 3-D ability of spatial visualisation with isometric projections. In addition, another drawback was accidental errors or random edges in the images, which can lead to confusion among the respondents. Therefore, Branoff (2000) proposed remodelling of a set of used drawings to trimetric projections of all 3D objects instead of current isometric projections. (Yue, 2006) in his research

pointed out the shortcomings in the representation of objects in terms of reality (dimensions, colours, lighting, shades, textures and perspectives), which is why a redesign of the drawing was proposed, using modern tools available in today's CAD software. In this way, a better assessment of spatial capacity would be achieved, which should be measured with PSVT (Fig. 5 and Fig. 6). The revised version was approved by Guai himself.

Despite these disadvantages, the use of PSVT has its advantages. The most significant, as Maeda & Yoon, (2013) stated, is “relatively strong reliability and / or proof of validity”. Following „the PSVT contains items that are difficult enough that they distinguish STEM (Science, Technology, Engineering, and Mathematics) students by their level of mental rotation ability” (Campos et al., 2019). Third, the capacity that students have in solving tasks in mathematics, technology and engineering have been expressed as capacity in solving tasks in PSVT. PSVT enables students to solve the set problems mostly by applying holistic spatial thinking, and least by the analytical or analog process.

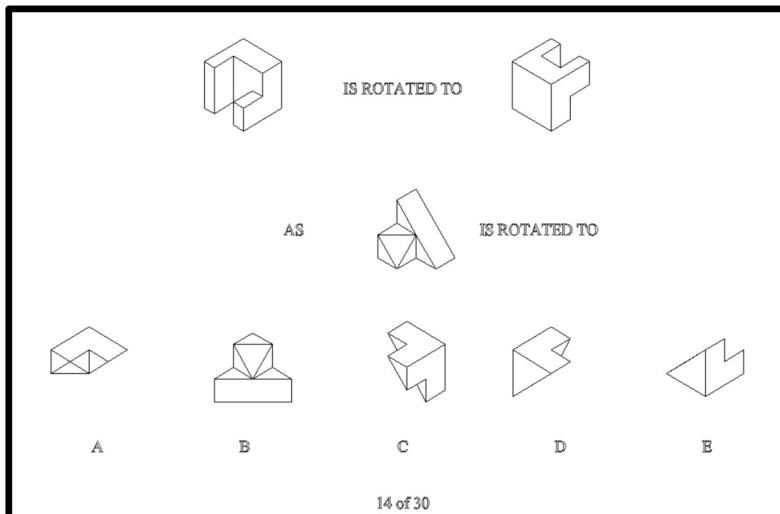


Fig. 5: Original views of the question #14 in the PSVT-R test (Guay, 1977)

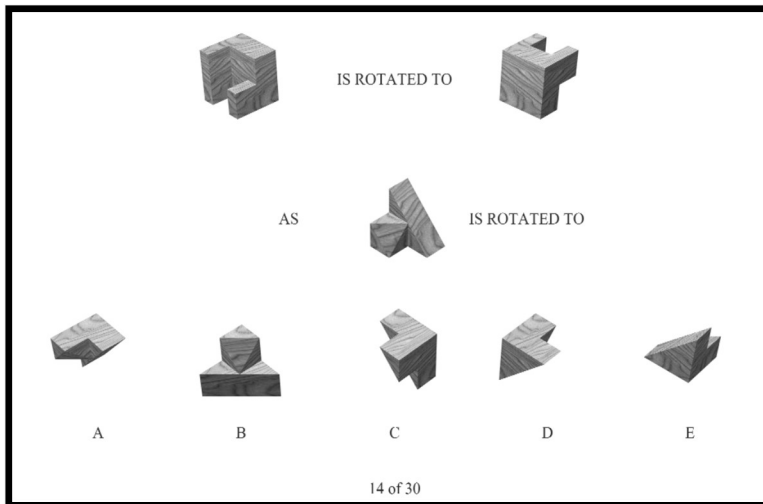


Fig. 6: Realistic 3D views with perspective effect

PSVT has a great application in engineering schools for measuring the spatial capacity of students, especially before the start of teaching. Some researchers have used PSVT-R to determine students' visual capacity (Guay, 1978a March, 1978b June, 1980; Guay & McDaniel, 1978; Sorby & Baartmans, 1996; Battista, 1981; Branoff, 1998a, 1998b; Branoff & Connolly, 1999; Sorby, 1999, 2001; Yue & Chen, 2001; Yue, 2000, 2002a, 2002b; Czapka et al., 2002; Brus et al., 2004; Study, 2004, 2006; Towle et al., 2005; Ardebili, 2006; Hamlin et al., 2006; Kinsey et al., 2006;). Recently, PSVT tests created using CAS software are often used to obtain 3D more realistic representations (Ardebili, 2006; Kinsey et al., 2006). Based on the obtained results, support courses that aim to improve student work can be adapted and designed. Students who have shown good results at PSVT have a high chance of achieving success while following curricula that include extensive use of visualization skills.

3. Methods

3.1.Participants

Participants in this research were students enrolled in studies of Information Technology at Technical Faculty in Zrenjanin, Serbia, in total 154, divided into two groups: experimental and control. The research was done through the winter semesters of 2022 and 2023.

An experimental group consists of students who attended a computer animation course during the IV year and voluntarily wanted to participate and who met one basic condition: to listen to CA for the "first" time (i.e. did not renew the year). Besides that, there were no additional conditions for this group selection. This provided a very diverse sample (men, women, singles, married, young, older ...). The experimental group involved 88 students. 60 of them were full-time students whose study costs are covered by the government and classes for this group are organized on weekdays – hereinafter GB (budget group). 28 of them were part-time self-financing students - hereinafter GS (self-funded group). For this group, classes are organized only on weekends. The demographics of the participants are shown in the following tables and graphs.

Regarding the gender structure of the respondents, the majority population of students at this faculty is male. The gender structure of the respondents in this group is in line with that. The gender structure ratio in GB is 14/46 (women/men), and in GS students it is 10/18 (women/men). In relation to the whole group, this ratio is 24/64 (Table 1).

Table 1. Gender Distribution of Sample

Value	Budget students		Self-funded students		Experimental group	
	Frequen cy	Percent	Frequen cy	Percent	Frequen cy	Percent
Femal e	14	23.33%	10	35.71%	24	27.27%

Male 46 76.67% 18 64.29% 64 72.73%

The age of the students ranged from 21 to 34 years, with a mean value of 21 which is also the most common age. These numbers differed among full-time and self-financing students, the average age was 21.88 and 23.39, respectively (Table 2./Fig. 7, Table 3./Fig. 8 and Table 4./Fig. 9).

Table 2. Distribution of age in the sampled budget students

Mean	21.88
Mode	21.00
Minimum	21.00
Maximum	33.00
Median	21.00
No	60

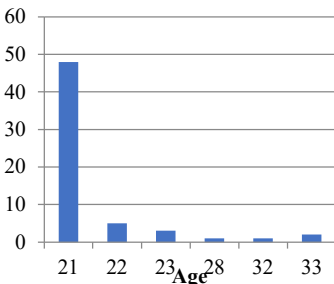


Fig 7. Distribution of age in the sampled budget students

Table 3. Distribution of age in the sampled self-funded students

Mean	23,39
Mode	22.00
Minimum	21.00
Maximum	34.00
Median	22.00
No	28

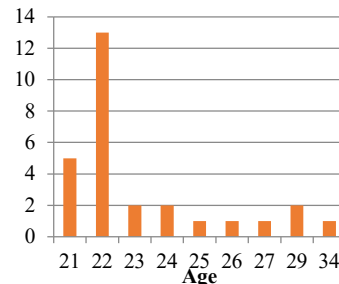


Fig 8. Distribution of age in the sampled self-funded students

Table 4. Distribution of age of experimental group

Mean	22,36
Mode	21.00
Minimum	21.00
Maximum	34.00
Median	21.00
No	88

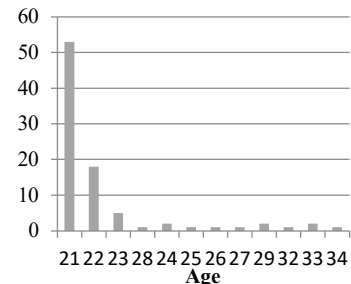


Fig 9. Distribution of age in the total sampled students

The control group consisted of second-year students of Engineering Management (66 students), who had no contact with the CA course. Their average age was 20.53 years, and the most common age was 20 years. The gender ratio was 24.36% women and 75.64% men.

3.2. Research instruments

The survey and PSVT (The Purdue Spatial Visualization Test) were used as research instruments. Before the test, students gave an opinion on the following two questions, which were supposed to help to get a correct picture of the levels of visual-spatial ability of students. The first question was about their self-perception of coping in mental manipulations with 3D objects or coping in 3D (real or virtual) environments. The answers are given in the form of choosing the degree of agreement / disagreement with the given statement (1 - "Too difficult", 2 - "Difficult", 3 - "Medium", 4 - "Easy", and 5 - "Too easy"). Another question was about previous experiences of using any 3D design program (N - "None", P - "Poor", M - "Medium" and S - "Significant").

Apart from the survey, participants were tested only with PSVT "rotations" and "views", because the tests from this area are mostly related to the content of the CA course. Another reason why PSVT was chosen as a research tool is that it is focused on educational research, to which this research belongs. Unlike PSVT, other tests, such as MRT or MCT, are about solving problems that require "bending" tasks on 3D models. PSVT-R and PSVT-V have a total of 60 questions, 30 each. In order to make the test available to all participants, an online version of the test was created. The recommended time for finishing each test is 20 minutes, so the time for each question is 40 seconds. After 40 seconds, the next question is automatically shown, without the possibility of returning to the previous one.

3.3. Organization of research

The research was done in two terms. The first time, at the beginning of the semester for both groups. The second time: for the students of the experimental group -at the end of the semester, in the 15th week, while for the students of the control group, the retest was in the 6th week.

The research tested three cases:

- Case 1: Testing whether VSC increased after completing a CA course. For this case, a paired t-test was chosen as the statistical test. It was applied to three data sets, on the results that students achieved on the PSVT pre-test and post-test. The first set consisted of the results of all students of the experimental group. For consistency testing, the other two sets consisted of GB-only and GS-only results.
- Case 2: Testing whether PSVT scores increased after repeating the test. Participants in this test were control group students. Also, the obtained results were analyzed by paired t-test. The purpose of this case was to determine whether repeating the test (when a student does the same test twice) affects the improvement of PSVT results. If there is no improvement in the test results, then this would mean that listening and monitoring CA classes are an important factor in increasing students' VSC.
- Case 3: Comparative analysis of the results of the PSVT pre-test and post-test of the experimental group in relation to the previous level of experience in working with 3D design programs. The aim of this is to determine how previous experience affects the level of VSC possession.

The same set of students was tested in the pre-test and the post-test. Students who were unable to participate in the post-test were excluded from further consideration. Before testing, all participants were familiar with the purpose and goal of the research and gave their consent to voluntary participation, whereby they could withdraw from the testing at any time. During the semester, the participants did not receive any special treatment, and they attended the CA course in standard conditions with other students.

4. Research results

To the question related to coping with 3D surroundings, most students of the experimental group believe that they have "medium" VSC (58%), less of them chose "easy" – 23%, as the smallest

number of participants chose one of the following options (“too difficult”, "difficult” or “too easy” respectively 8%, 5%, 8%). The expected results were obtained on the question related to the experience of using 3D design programs. A large number of students – 43% – have not encountered 3D design programs so far, 29% had a poor, 18% medium, while the least of them (10%) had a significant experience.

As for the control group, 5% reported having medium experience in the use of software for 3D design, a poor 16%, while 79% do not have previous experience. 46% of students marked the level of their coping with the 3D environment as "medium", a smaller number chose "easy" - 34%, while the rest chose: "too difficult" (7%), "difficult" (5%) and " too easy ”(8%).

Table 5 shows the results of a paired t-test obtained based on the results of all subjects. In case 1, the null hypothesis was that the difference in the mean values between the paired samples was equal to zero. This would mean that the students did not progress in VSC after completing the CA course, i.e. that the mean value remained the same as before the course. However, the attained results show that the mean value of PSVT increased from 35.85 to 42.93, i.e. per 7.08 (Table 5). Based on this, it can be concluded that the average difference between pre-test and post-test is different from zero and for $t_{88} = 14.37$ and $p < 0.0005$.

Table 5

Paired Sample Statistics

	N	Mean	Std. Deviation	S.E. Mean
Pair 1 PSVT post-test	88	42.93	10.37	1.10
PSVT pre-test	88	35.85	9.93	1.06

Paired Samples Correlations

	N	Correlation	Sig.
Pair 1 PSVT post-test & PSVT pre-test	88	.897	.000

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	95% Confidence Interval of the Difference							
	Mean	Std. Deviation	S.E. Mean	Lower	Upper			
Pair 1 PSVT post-test PSVT pre-test	7.08	4.62	.49	6.10	8.06	14.37	87	.000

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To deny or accept the null hypothesis from case 1, paired t-tests were done separately for full-time and self-financing students. Table 6 and Table 7 show their results, where it can also be seen that there was an increase in mean values on PSVT, after completing the CA course. The mean value of full-time students (Table 6) increased from 36.28 to 45.23, i.e. per 8.95, showing a significant difference between $t_{60} = 15.19$ and $p < .0005$. In contrast to full-time students, with whom there is a major increase in the mean value, self-financing students (Table 7) had a smaller increase: from 34.93 it increased to 37.14, with $t_{28} = 5.06$ and $p < .0005$.

Table 6

Paired Sample Statistics

		N	Mean	Std. Deviation	S.E. Mean
Pair 1	PSVT post-test	60	45.23	9.96	1.29
	PSVT pre-test	60	36.28	9.23	1.19

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	PSVT post-test & PSVT pre-test	60	.890	.000

Paired Samples Test

		Paired Differences							
		Mean	Std. Deviation	S.E. Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Pair 1	PSVT post-test PSVT pre-test	8.95	4.56	.59	7.77	10.13	15.19	59	.000

Table 7

Paired Sample Statistics

		N	Mean	Std. Deviation	S.E. Mean
Pair 1	PSVT post-test	28	37.14	10.96	2.07
	PSVT pre-test	28	34.93	11.41	2.16

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	PSVT post-test & PSVT pre-test	28	.979	.000

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Paired Samples Test

	Paired Differences						t	df	Sig. (2-tailed)
				95% Confidence Interval of the Difference					
	Mean	Std. Deviation	S.E. Mean	Lower	Upper				
Pair 1 PSVT post-test PSVT pre-test	2.21	2.32	.44	1.32	3.11	5.06	27	.000	

To determine whether an increase in VSC can occur by repeating the test, another paired t-test was performed - case 2. This time, students who did not take the CA course were tested, i.e. control group students. Table 8 shows the outcomes of the paired t-test of the mean values of the pre-test and post-test - for these students. Observing these results, it can be seen that there was an increase in the average from 31.16 to 32.93, i.e. per 1.76 and that the difference for $t_{68} = 4.50$ and $p < .0005$.

Table 8

Paired Sample Statistics

	N	Mean	Std. Deviation	S.E. Mean
Pair 1 PSVT post-test	68	32.93	9.43	1.14
PSVT pre-test	68	31.16	11.14	1.35

Paired Samples Correlations

	N	Correlation	Sig.
Pair 1 PSVT post-test & PSVT pre-test	68	.964	.000

Paired Samples Test

	Paired Differences						t	df	Sig. (2-tailed)
				95% Confidence Interval of the Difference					
	Mean	Std. Deviation	S.E. Mean	Lower	Upper				
Pair 1 PSVT post-test PSVT pre-test	1.76	3.23	0.39	0.98	2.55	4.50	67	.000	

Table 9 shows the results of a comparative analysis of the results of the PSVT pre-test and the post-test of the experimental group. The results were sorted based on the obtained answers to the question about having experience in 3D programs. The investigation aimed was to establish whether students' knowledge of using 3D design software could affect the improvement of owning VSC.

Table 9

Experience	PSVT pre-test	PSVT post-test
N	34.24	43.68
P	36.44	43.72
M	38.69	42.13
S	36.00	39.00

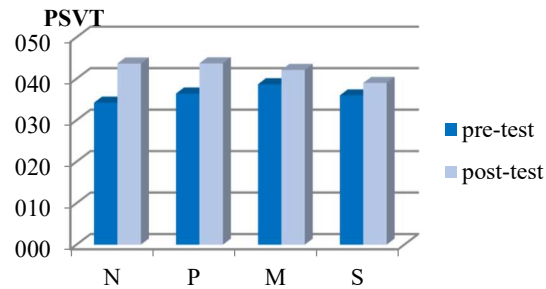


Figure 10.

The change in VSC possession between the pre-test and post-test is observed in all groups. The most significant difference is observed among respondents who had no prior experience working with 3D design programs, from 34.24 to 43.68, i.e. for 9.44. Unlike them, respondents who had previous experience working with 3D design programs made the least progress in conditions of owning a VSC, only for 3.00, which is both understandable and expected.

5. Discussion

Visual-spatial ability is becoming increasingly important with the development and spread of new technologies such as computer graphics, computer animation, data visualisation and supercomputing. Therefore, it has become important to investigate whether and in what way these cognitive capacities can be improved.

In this study, it was examined whether an increase in VSC could occur by attending CA classes or by retesting itself. The results confirm that attending the CA course can influence VSC, which is concluded based on the collected results of the paired t-test. These results confirmed the null hypothesis - that there is a statistically significant difference between the mean values of the pre-test and post-test. Similar results have been obtained in many studies (Yue & Chen, 2001; Brus et al., 2004; Kinsey et al., 2006; González Campos et al., 2019; Sorby, 2009; Friess et al., 2016).

It is interesting to observe the separate results of the students of the full-time and self-financing groups. Both groups followed the CA course but to a different extent. GB students had regular classes throughout the semester, but unlike them, GS students had a shortened course on weekends. Although there was an increase in VSC in both groups, the results show a higher level of growth

in GB. Such results could indicate that to increase the VSC, in addition to the qualitative one, a quantitative factor is also necessary, i.e. a larger, continuous number of classes is desirable. The progress made in this way is a significant factor in terms of a student's ability to communicate with programs in 3D environments (Sorby, 2009). Ardebili (2006) also talks about a significant increase in spatial ability after completing a computer modelling course.

On the other hand, the results of case 2 show that a statistical increase in VSC can occur by repeating the PSVT-R test. The control group students received the test at the beginning of the semester and again after 6 weeks of classes. The very short interval between these two tests allowed students to "remember" the solutions and to achieve better results in the post-test than in the pre-test. Similar results were obtained by: (Lohman, 1996; González Campos et al., 2019). With results, obtained as a result of retesting, the standard deviation usually ranges from 0.2 to 1.2 and higher, for simpler tests, shorter retest intervals, or when participants receive some feedback (Lohman, 1996).

Certainly, the increase in the average value of PSVT was smaller than among members of the experimental group. Differences between the average values of the control, i.e. experimental groups, are respectively 1.76 i.e. 7.08.

It was interesting to compare the results pre and post-SPVT with prior students' experiences in working with 3D design programs. The gained results show that students who had previous experience made less progress in acquiring VSC. Their experience and knowledge grew after the CA course, but to a lesser extent with students who did not have or have very little prior knowledge, with whom significant progress had been made. This is obvious, considering that by attending the CA course, they have gained new experiences and knowledge, which they were able to show on the post-test. Students with previous experience showed this knowledge on the pre-test, while on the post-test they showed only the progress made during the course.

6. Conclusions and future work

The results of this research should be analysed with several limitations. First, although the research was conducted only at the faculty in Zrenjanin (Serbia), on a small sample, it could be said that it has an international character, given that students from all over Serbia, as well as from Montenegro, Bosnia and Herzegovina, Croatia and Hungary are also present. Doubtless, to draw general conclusions, it would be necessary to extend the research to other IT faculties, besides the country and neighbouring ex-Yugoslav countries. On the other hand, as another limiting factor, the different conditions in which the students took the test (fatigue, drowsiness, lack of concentration, lack of interest, guessing the answer) should be considered.

The obtained results show that the possession of VSC can be influenced by different variables, which cause various degrees of increase: the way of attending the course (the full-time group had regular classes, with a larger fund of classes than the self-financing group, and achieved a more significant increase in VSC results); prior knowledge of using 3D design programs (students who

did possess, progressed, but to a much lesser extent than students who did not have); then, just repeating the test (the control group increased the VSC results by retesting). While in all these cases was an improvement in the VSC results, this progress was not the same everywhere. The greatest was achieved after taking the CA course, and the smallest by repeating the test.

Possession of the VSC, as one of the important factors for advancing in understanding and coping in a 3D environment, has been studied by many researchers around the world, for example: (Bo Leeuwen et al., 2023, Yue, 2008; Katsioloudis et al., 2014; Meneghetti et al., 2016; Roca-González et al., 2017; Cole & Farrell, 2016). It may be said that the conclusion that dominates all studies is that the level of VSC can be increased by influenced 3D technologies. The results of this study confirm the above tendency and thus allow students the opportunity to actively participate in the implementation of the basic goal and task of their education, which is to develop the ability and intellectual readiness to deal with various problems, including those that will appear in the technological future.

The significance of this study is reflected in the information obtained regarding possible further directions for the improvement of educational policies, which would have an even greater impact on increasing the level of VSC. For that reason, as an imperative that should be considered, when creating content and tasks necessary for the growth of visual-spatial capacity, there is an adequate choice of tools and activities that will attract students' attention, even after the course. At the same time, the optimal duration of the courses should be provided, so that students would not lose interest in the courses themselves, along with the technology that was applied. This can be achieved through appropriate and diverse course scenarios.

Further directions of research are to determine whether VSC has an impact on success during the study process. Then, can learning strategies be created that further increase VSC? Does the gender of the respondents affect the increase in VSC? One of the directions of future research could be to examine the interaction between VSC, learning strategies and student performance, with special emphasis on noticing the benefits that applied strategies provide, concerning other factors in the participant's environment.

7. References

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