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ASSESSMENT AND IMPROVEMENT OF SPATIAL ABILITY DEVELOPED BY GRAPHICAL SUBJECTS

Abstract: *The ability to mentally manipulate 2D and 3D figures is defined as spatial visualization ability and can be measured with simple cognitive tests such as Mental Rotation Test and Mental Cutting Test. Improving student's spatial abilities is considered an important component in technical education and graphical subjects, in particular, Descriptive Geometry, have an important role in shaping spatial visualization abilities of future engineers and architects. In this paper are presented the results of MRT and MCT of the students from the Faculty of Architecture. They were tested in the first week of school, in the first year and then at the end of the first semester, following the course of Descriptive Geometry. Test results were analyzed and interpreted from different points of view.*

Key words: *Mental Rotation Test, Mental Cutting Test, spatial ability, descriptive geometry, education*.

1. INTRODUCTION

In the practice of architect and engineer professions, understanding spatial forms and representing them in 2D as well as vice versa is an absolutely indispensable skill. Therefore, at the time of obtaining the student status, it is particularly useful for teachers to correctly/objectively assess the level at which they are located, in order to be able to further improve their perception.

It must be specified that these students benefit from a relative training in the field, whether they come from high schools with architecture or construction profiles or art schools, either they had private lessons for the admission to the drawing test that is being practiced at this university. However, the level of knowledge that students rely on is different and varies according to the level of knowledge gained in high school but obviously also to the personal capabilities of each subject.

Unfortunately, the level of knowledge about geometry that candidates bring with them are reduced due to the fact that the syllabi changed a lot and have been unstable over the last years. In addition, the digital era that we are going through makes the information of the students not solidly grounded, relying heavily on their accessibility through the Internet.

The role of teachers is very important, namely, to bring each student to exceed a minimum level and help those talented to excel. Students have to master the geometric reasoning of generating three-dimensional spatial forms, to learn geometric abstraction so they can develop their ability to see in space.

Descriptive geometry is the first subject that students go through during the first year, followed by other disciplines such as Study of Forms, Perspective, Geometry of Architectural Forms, Basics of Design etc., which complete and perfect their thinking.

Paraphrasing Professor Architect Tanasescu A., one specifies that architecture students must be endowed with a geometric and constructive intuition, allowing the expression and transposition of the space in the plane, both to represent a basis for the calculus of structures and to meet the functional and aesthetic needs of the designed themes (buildings, interior design, urban design).

There are several verification methods, but in this paper the authors intend to analyze the abilities of the students admitted to the Faculty of Architecture and Urban Planning of the Technical University of Cluj-Napoca with the help of the following tests also used by other higher education institutions [1], [2], [3], [6]:

- Mental Rotation Test (MRT);
- Mental Cutting Test (MCT)

The two tests were administered to 80 students, (49 females and 31 males) in the first week of the academic year 2018-2019 and then repeated in the last week of school in January 2019, after they studied a semester of Descriptive Geometry.

2. MENTAL ROTATION TEST

2.1. Presentation of the evaluation process

Mental Rotation Test (MRT) is one of the methods used to measure spatial ability and it consists of 20 items. Each problem contains a criterion 3D figure and students must choose from four possibilities the two correct rotating forms of the figure - as seen in Figure 1. Students had 20 minutes to solve the test, one minute for each item. Although the recommended asses method involves scoring with 2 points if both answers are correct and one point for choosing one correct answer [4], in this case, taking into account the previous training of the students, it was considered a simpler correction system:
- one point for the right choice of both answers;
- no points for choosing a single correct answer one or none.

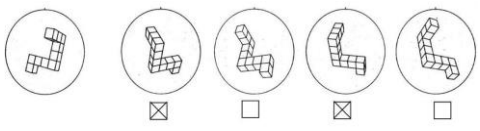

Fig. 1 Example of MRT problem

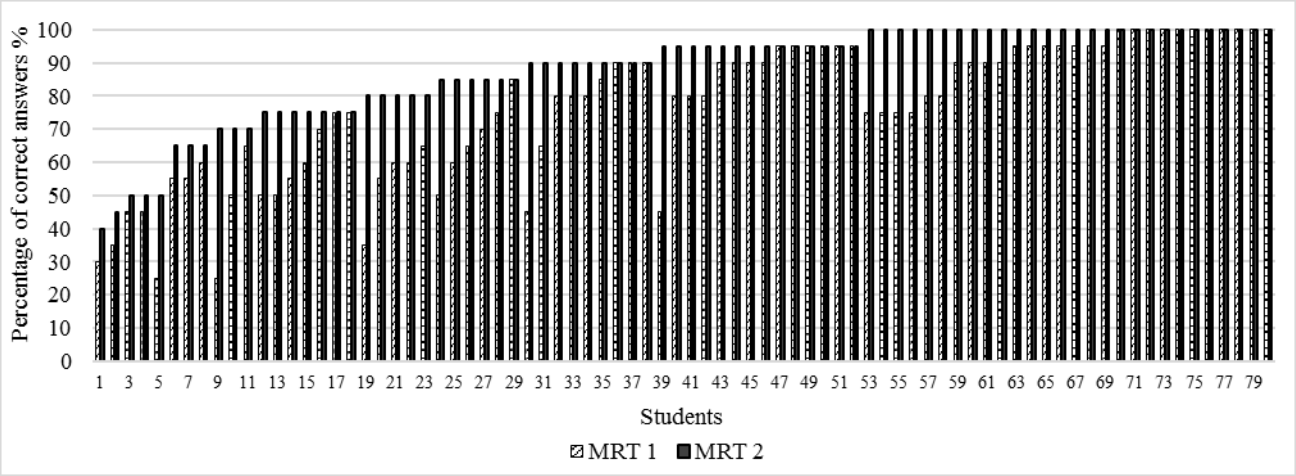

Fig. 2 Detailed results of the Mental Rotation Test

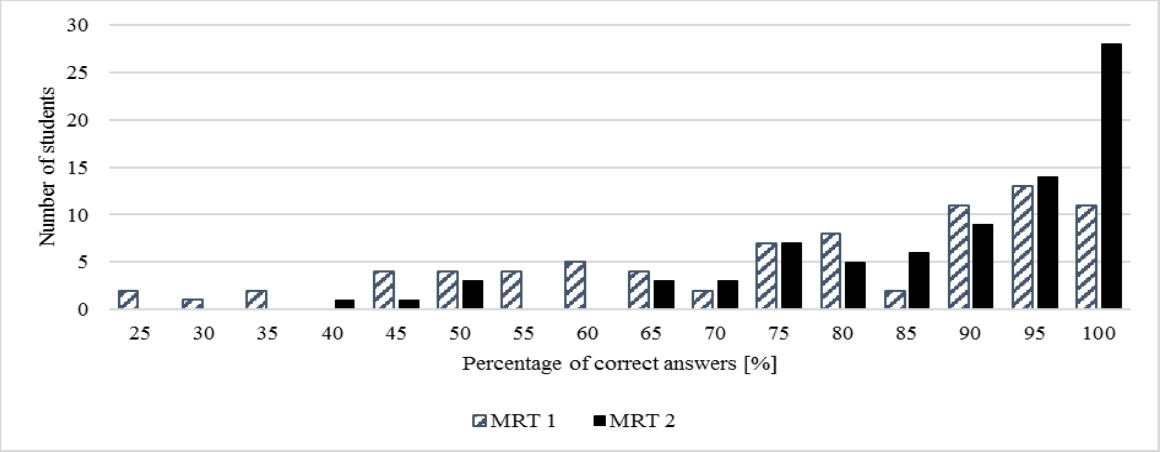

Fig. 3 Results according to the number of correctly solved problems

2.2. Results and discussions

Figure 2 shows graphically the results obtained by the 80 participants to the test in the two evaluation sessions: MRT 1 - October 2018, respectively MRT 2 - in January 2019. One can observe that 71.25% of the total number of students obtained better results at the test in January 2019.

Out of the 23 students who obtained the same result in both tests, 11 scored the maximum (20 points) and 12 correctly resolved the test in a proportion of 75-95%, namely between 15 and 19 correct answers.

The diagram in Figure 3 represents the statistical results according to the number of correctly solved problems. If in October at the first evaluation only 13.75% of the students (6 girls and 5 boys) correctly answered all the questions, in January their percentage reached 35% (15 girls and 13 boys). In addition to the 11 students who continued to respond correctly to all the problems, 17 students were added, which progressed from 75% - 95% to 100%. It is noticed that after the second evaluation, the largest share of students (63.75%) ranged between 90-100% of correct answers.

3. MENTAL CUTTING TEST

3.1. Presentation of the evaluation process

Another method used to measure spatial ability is the Mental Cutting Test (MCT), which was originally used as an admission exam at a New York University and consists of 26 items. For each problem, there is a figure represented in axonometry that is sectioned with a plane in different positions. Students must choose the correct cross-section from five given options, always one being correct. Students had 26 minutes, one minute for each item. There are two categories of problems: "pattern recognition problems" and "dimension specification problems" [8]. In the case of pattern recognition problems, students must identify only the correct form of the cross-section from given alternatives [7]. In the case of dimension specification problems, besides identifying the cross-section shape correctly, choosing the correct answer is conditioned by its dimensions, such as the correct length of an edge or the angle between two edges.

Figure 4 shows a pattern recognition problem and in Figures 5 and 6 are presented two examples of dimension specification type problems.

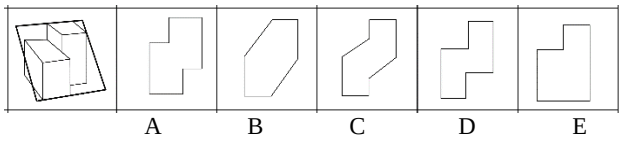

Fig. 4 Example of „pattern recognition problem"

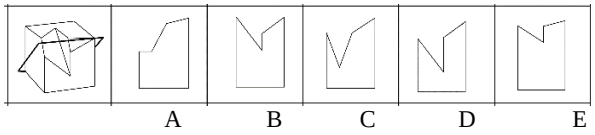

Fig. 5 Example of „dimension specification problem"

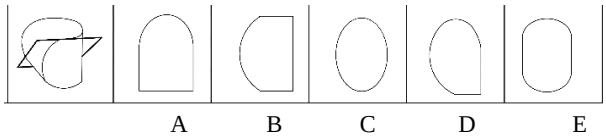

Fig. 6 Example of „dimension specification problem"

To be able to resolve the MCT test, students need to follow a few steps. First, they must recognize the solid represented in axonometry. The next step is to cut the solid with the indicated plane, then to recognize from the five possible alternatives the dimensional characteristics of the resulting cross-section. It is very important for students to visualize the correct position of the cutting plane to identify the right answer - Figure 7.

3.2. Results and discussions

In the diagram from Figure 8 are comparatively presented, according to the percentage of correctly solved problems, the results obtained by the students at the test in the two evaluation stages, namely:

• MCT 1- in October 2018;

• MCT 2 - in January 2019.

If at the first evaluation the majority of the students have resolved the test in the proportion of 50-80%, after the study of descriptive geometry, one can notice an improvement of the results.

This time the percentage of students who have improved their performance in the second test reached to 78.75%, representing 63 students. Instead, the 17 students who achieved the same result did not get the maximum score as in the MRT test. They scored between 7 and 13 correct answers.

3.3. Typical mistakes

Evaluating the statistical results, a pattern was observed regarding the wrong answers, also called typical mistake [5]. One of the problems with many wrong answers is the one presented in Figure 4.

As can be seen in the chart in Figure 9, which shows the distribution of answers to this problem, most students chose the wrong answer, although it is one of the simplest items in this test.

One of the causes of this mistake can be the relatively short time so the students didn't carefully study all the given options, stopping on answer A, which has the shape similar to the correct answer.

Another item that caused uncertainties among students was the one presented in Figure 5, being a dimension specification type problem.

Although most students have chosen the correct answer E, a high percentage has chosen option D, which has the shape similar to the correct cross-section but has other dimensions of the edges. Figure 10 has graphically represented the distribution of answers to this problem.

Also, the item presented in Figure 6 has put the test participants in difficulty, being one of the problems with many wrong answers, as can be seen in Figure 11.

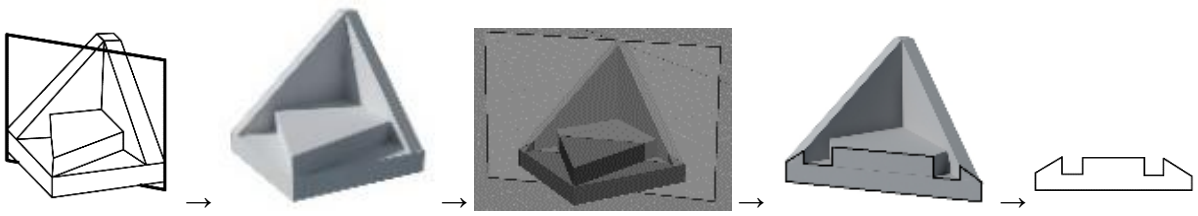

Fig. 7 Example of MCT problem

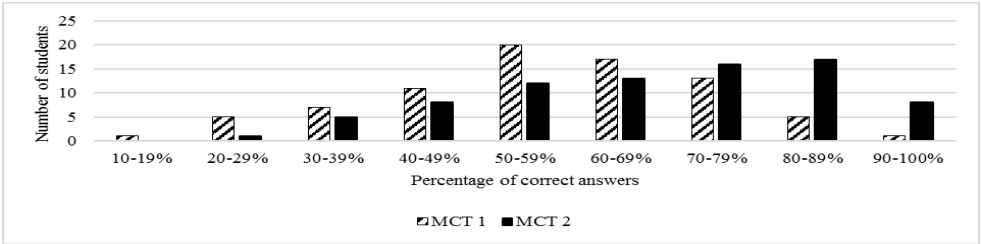

Fig. 8 Distribution of answers in percentages

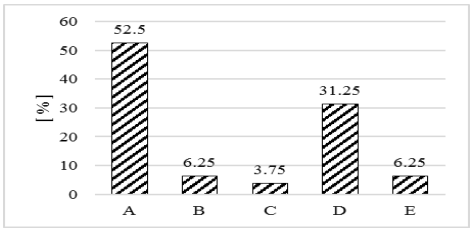

Fig. 9 Distribution of answers in percentage for the problem in Figure 4 (the correct answer is D)

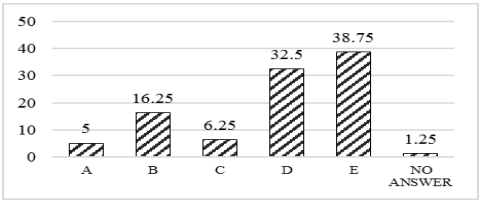

Fig. 10 Distribution of answers in percentage for the problem in Figure 5 (the correct answer is E)

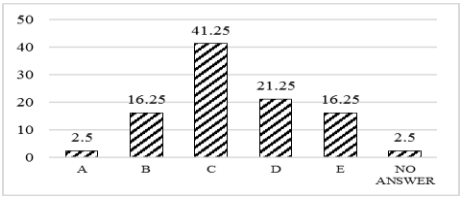

Fig. 11 Distribution of answers in percentage for the problem in Figure 6 (the correct answer is C)

4. CONCLUSIONS

The Mental Rotation Test and the Mental Cutting Test were conducted to assess the spatial ability of the first-year students from the Faculty of Architecture and Urbanism. The motivation was given by the changes made in the curriculum to emphasize the importance of graphic disciplines in the training of future architects.

Evaluating the results, an improvement was observed in the majority of students following the study of Descriptive Geometry. In both MRT and MCT, the highest percentage of students achieved better results in the January session than at the beginning of the semester.

In conclusion, the spatial abilities of the students have developed after the study of Descriptive Geometry in the first semester.

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