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Spatial intelligence: Why do we measure?

Rita Nagy-Kondor

University of Debrecen, Faculty of Engineering, Hungary
rita@eng.unideb.hu

Abstract. Intelligence tests are widely used to measure intellectual performance and prophesy the academic, professional achievement in the future, or to select successful employees. There are correlations between various measures of spatial intelligence, problem solving and Science, Technology, Engineering and Mathematics (STEM) performance. Spatial visualization skills are essential for an expert to be successful in numerous disciplines. Spatial intelligence has an important role in learning and teaching of engineering studies. This report investigated the spatial visualization skills of international engineering students at the University of Debrecen – in unique way in our university, simultaneously examining four types of sub-abilities in plane and space – in comparison with the international results.

Keywords: problem solving, spatial ability, mathematics education, engineering education

AMS Subject Classification: C30, G20, G30, G40

1. Introduction

The numbers define and make visible what is real. These numbers can be produced by measurement. There are some questions about measurement [30], which are worth considering: How can we measure our skills and competences? How can we keep measures useful? Do these measures create information that increases our developmental ability? Will this information help individuals, the organization grow?

Adequate mastery of cognitive and mathematical skills essential so, that children can clearly understand the world that around them [8].

We can not develop cognitive skills, intelligence, especially spatial intelligence without measuring. Intelligence tests are widely assumed to measure max intellectual performance and associations between IQ scores and later-life outcomes are

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typically interpreted as estimates of the effect of intellectual ability on academic and professional accomplishment [5]. Furthermore, pre-employment testing is a method to select successful employees within organizations. Cognitive tests measure for an applicant's ability to apply learned concepts to new situations during day-to-day work activities [4].

According to Gardner [6] there are seven different types of intelligence: linguistic, logical-mathematical, spatial, musical, physical-kinesthetic, interpersonal and intrapersonal intelligence. “Spatial intelligence is the ability of forming a mental model of the spatial world and maneuvering and working with this model” [6, p. 9].

According to previous studies spatial intelligence, spatial abilities are predictors of success in technical education and have a high importance in engineering education, computer graphics, architecture, arts and cartography [2, 10, 14–16, 24, 27]. Many studies have shown that there are correlations between various measures of spatial intelligence, problem solving and performance in Science, Technology, Engineering and Mathematics (STEM) [1, 11, 12, 15, 20, 29, 31]. Students with higher ability in mental rotation in regular score higher on anatomy examinations [28]. According toBennett-Pierre, Gunderson [3] fiber arts may be particularly relevant for understanding critically understudied non-rigid spatial skills. Spatial visualization skills are essential for an expert to be successful in several disciplines. Spatial intelligence has an important role in learning and teaching of engineering studies. The skill of imaginative manipulation of the object is particularly important for engineering students. So, we can define spatial ability as the complex system of cognitive component, consisting the ability to connect constructed and perceived images of 3D world [15], that is essential for success in many scientific fields [14].

Several different methods are used to test the spatial intelligence, among which Mental Rotation Test, Mental Cutting Test (MCT) and Purdue Spatial Visualization Test are widely used. During the last years researchers started developing Virtual Reality (VR) aided applications [7] to generate MCT exercises [22] with the use of Blender and its Python API [21, 23, 24]. However, in some cases we may need a more comprehensive measurement.

There are various factors effecting spatial ability; one of these is gender. Female students may not have the same spatial ability skills as male students, which can partly explain gender differences in spatial ability test; also female students choose typical mistake in some tasks more frequently, than male students [17]. Males have a higher spatial ability than females in Mental Cutting Test [16, 18]. Some articles show a significant difference on mental rotation tasks at every age [19]. There are conflicting results in the reviewed studies. Some articles found no significant difference between male and female groups in spatial intelligence of student in mathematics [25, 26]. Due to these contradictory results gender difference of spatial intelligence is still an intensively researched topic.

In the light of the existing literature, this report investigated the spatial intelligence of international engineering students in Hungarian higher education –

especially the imaginary manipulation of an object, which is essential for training.

2. Research questions and hypotheses

The goal of this article was to measure spatial intelligence – especially the imaginary manipulation of an object – freshman engineering students.

During the research, the research questions are the following:

RQ1: Is there a significant relationship between first-year international engineering students' performance in four different task types of spatial ability?

RQ2: Is there a significant difference between male and female first-year international engineering students in terms of spatial intelligence in four difficulty levels?

RQ3: What are the types of spatial intelligence tasks on which first-year international engineering students perform less well?

The hypotheses are the following:

H1: There is significant relationship between engineering students' performance in four different task types of spatial ability.

H2: There is a difference between male and female first-year international engineering students in terms of spatial intelligence, but not significant.

H3: There is lower performance of engineering students' in task of imaginary manipulation of three-dimensional object with hard mental cutting (the plane section is not triangle, quadrilateral, circle or ellipse).

3. Methodology

At the University of Debrecen, Faculty of Engineering 43 (4 female 9%, 39 male 91%) first-year international mechatronics engineering students took the tests, who came from 17 different countries (from Africa 33%, from Asia 67%). This group represents well the population of foreign students of the Faculty of Engineering.

The students came from 17 different countries, with different levels of spatial geometry preknowledge. There are few female students in the engineering training, despite this, we consider it important to examine the difference between gender. Subjects of the study are volunteered to participate and confidential feedbacks were given to those participants who are interested in. Standard instructions were given to tasks.

The instrument used in this study is a test of imaginary manipulation of an object – in four difficulty levels –, considering the literary background. This test was used to imaginary following of the phases of the objective activity. Our test includes four sections:

1. plane geometry task: imaginary manipulation of two-dimensional object (rotation, translation, reflection);

2. spatial geometry tasks:

a) imaginary manipulation of three-dimensional object with simple mental cutting task (the plane is parallel to base of the object);

b) imaginary manipulation of three-dimensional object with hard mental cutting task (the plane is not parallel to base of the object);

c) imaginary manipulation of three-dimensional object with surface development task.

This is a descriptive-analytic study. Data were analysed using the SPSS statistical analysis program in order to data analysis.

4. Results

The frequency of performance of test of imaginary manipulation of an object is presented in Figure 1. Few students scored between 0–20% (1 student) and between 81–100% (4 students) in total test. More students scored between 21–40% (9 students) and between 61–80% (12 students). Most students scored between 41–60% (14 students).

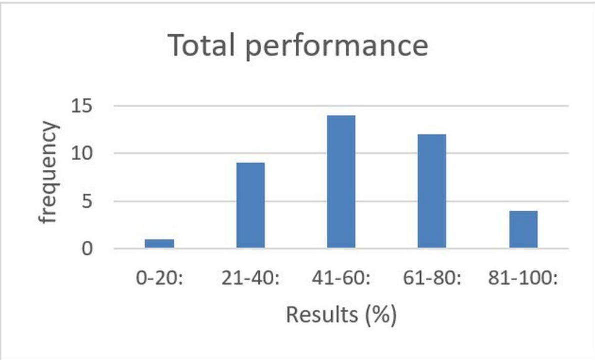

Figure 1. Frequency of total performance.

Data analysis in Table 1 showed that there was not a significant correlation between task 1 scores and task 2a scores of first-year students ($p = 0.532, r = 0.100$). There was not a significant correlation between task 1 and task 2b ($p = 0.105, r = 0.257$).

Data analysis in Table 2 showed that there was not a significant correlation between task 1 scores and task 2c scores ($p = 0.510, r = 0.106$). Similarly, there was not a significant correlation between task 2a and task 2c ($p = 0.054, r = 0.303$), and between task 2b and task 2c ($p = 0.242, r = 0.187$).

Data analysis in Table 3 showed that there was a significant correlation between task 2a scores and task 2b scores of first-year students ($p = 0.003, r = 0.448$). H1 was only partially fulfilled: So, there is significant relationship between international engineering students' performance in different task types of spatial ability,

Table 1. Relationship between task 1 scores and task 2a scores.

		task 1	task 2a
task 1	Pearson Correlation	1	,100
	Sig. (2-tailed)		,532
	N	41	41
task 2a	Pearson Correlation	,100	1
	Sig. (2-tailed)	,532	
	N	41	41

Table 2. Relationship between task 1 scores and task 2c scores.

		task 1	task 2c
task 1	Pearson Correlation	1	,106
	Sig. (2-tailed)		,510
	N	41	41
task 2c	Pearson Correlation	,106	1
	Sig. (2-tailed)	,510	
	N	41	41

Table 3. Relationship between task 2a scores and task 2b scores.

		task 2a	task 2b
task 2a	Pearson Correlation	1	,448**
	Sig. (2-tailed)		,003
	N	41	41
task 2b	Pearson Correlation	,448**	1
	Sig. (2-tailed)	,003	
	N	41	41

**. Correlation is significant at the 0.01 level (2-tailed).

but just between imaginary manipulation of three-dimensional object with mental cutting task if the plane is parallel to base of the object and imaginary manipulation of three-dimensional object with mental cutting task if the plane is not parallel to base of the object. That is why it is worth examining the components that are important to us separately.

The performance of test of imaginary manipulation of an object – in four difficulty levels – is presented in Figure 2, answers given by male and female students are compared:

task 1 (81% male students and 75% female with difference of 6%), task 2a (49% male and 38% female with the difference of 11%), task 2b (46% male and 35%

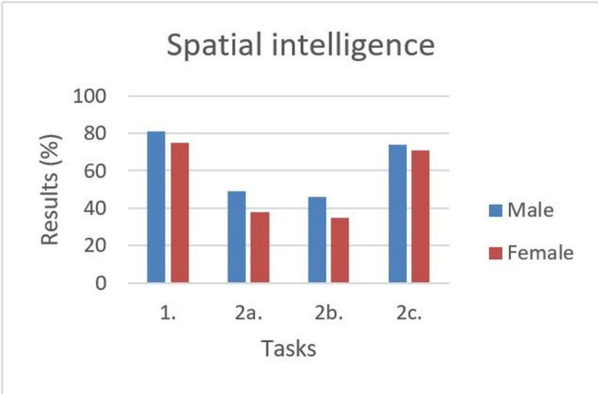

Figure 2. Results of test of imaginary manipulation of an object – in four difficulty levels.

female with the difference of 11%), task 2c (74% male and 71% female with the difference of 3%). There is a difference between male and female students in terms of spatial intelligence in all task types.

H2 was fulfilled: Independent T-test results indicated that there was no significant difference between gender and scores of imaginary manipulation of an object in all tasks (task 1: $T = 0.285, p = 0.777$; task 2a: $T = 0.420, p = 0.677$; task 2b: $T = 0.864, p = 0.393$; task 2c: $T = -0.040, p = 0.968$).

Female and male students achieved the lowest score in task 2b, this is imaginary manipulation of three-dimensional object with mental cutting – if the plane is not parallel to base of the object –, so we examine this task separately. Frequency of performance task 2b – imaginary manipulation of a three-dimensional object with mental cutting if the plane is not parallel to base of the object – is presented in Figure 3.

Few students scored between 61–80% (4 students) and between 81–100% (1 student) in total test. More students scored between 0–20% (12 students) and between 21–40% (10 students). Most students scored between 41–60% (14 students).

Results of engineering students in MCT are comparable with an average around 60% in Australia, in the US, in Europe [1] and in Hungary [14].

H3 was fulfilled, but performance of engineering students' are lower not only in task 2b, but 2a as well. Spatial skills of first-year international mechatronics engineering students are lower, we can see it in task 2a and 2b. This can be explained by the fact that Jansen et al.[9] examined cultural differences in the performance of spatial skills in mental rotation and the performance of some Asian countries such as Thailand and the Philippines was lower than that of participants with Western cultures. Spatial ability of freshman engineering students in Africa at Polytechnic of Namibia is significant lower [1]. According to Ault, John [1] the cause of these differences are the factors of previous experience and educational background.

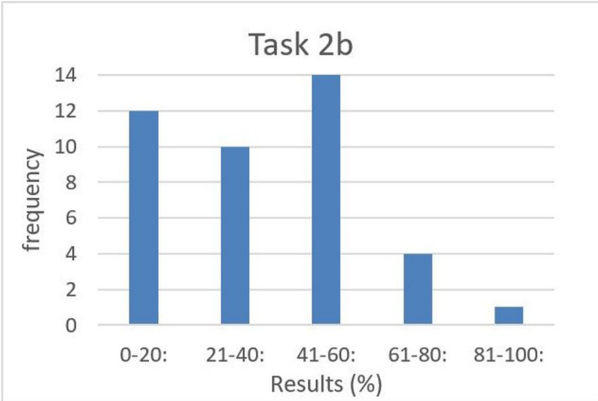

Figure 3. Frequency of task 2b.

5. Conclusion

Why Do We Measure spatial intelligence? Performance in engineering studies is related to spatial intelligence, furthermore spatial skills shows close relationship with STEM skills, so it is worth paying attention to examining several components of spatial intelligence at the same time.

The spatial intelligence – imaginary manipulation of an object – of first-year international engineering students have been studied in this paper, in four difficulty levels. The students came from different countries, with different levels of previous knowledge of spatial geometry.

Based on our survey, we can conclude that many engineering students had problems with the imaginary manipulation of spatial objects, and the mental image is incorrect in many cases. Students found the imaginary manipulation of three-dimensional object with mental cutting tasks more difficult than imaginary manipulation of two-dimensional object and imaginary manipulation of three-dimensional object with surface development. Therefore, the students achieved better results in the plane geometry task and the spatial geometry task which requires less mental manipulation (with surface development), than in imaginary manipulation of an object with mental cutting spatial geometry tasks.

We have observed gender differences in spatial abilities between male and female in our research. If teachers devote more time to improve a students' spatial ability, it help to reach better skills, regardless of students' gender.

Spatial intelligence is deemed o high priority for STEM education, so this finding is essential. It is therefore necessary to develop spatial skills at the university level as well, so that students do not have problems with this deficiency in their university studies. This is not only necessary in engineering education, but in all majors that require this ability.

We can achieve better results in understanding of spatial relationships with the use of Dynamic Geometry Systems, interactive animations and traditional paper models [15]. Studies showed [13] that use of VR and navigate in space are positively affects spatial skills. Our results can help in choosing the appropriate educational aids.

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