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Spatial ability of engineering students

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Abstract

We made the survey in September 2004 and 2006 in the University of Debrecen, Faculty of Technical Engineering among first year engineering students. In the beginning of the semester on the first week we examined with a test whether the students have sufficient differences between their spatial ability, their fundamental knowledge on descriptive geometry, since it is essential for the students to look at projections and to make operations with them and also to see the bodies with their mind's eye. We prepared the test in a way that it contained the important components of the spatial ability.

Keywords: spatial ability

1. Introduction

This article reports about a survey about the topic of spatial ability. In the University of Debrecen, Faculty of Technical Engineering we surveyed the knowledge of 80 first year mechanical engineering students. We get most of our knowledge in a visual way so it is very important for us how much we are aware of the language of vision. The definition of spatial ability according to Séra and his colleagues – relying on the ideas of Haanstra [5, p. 88] and others – is the following: "the ability of solving spatial problems by using the perception of two and three dimensional shapes and the understanding of the perceived information and relations" [12, p. 19].

Gardner [4] distinguishes between seven different types of intelligence: linguistic, logical-mathematical, spatial, musical, physical-kinaesthetic, interpersonal and intrapersonal. According to Gardner [4, p. 9] the "spatial intelligence is the ability of forming a mental model of the spatial world and manoeuvring and working with this model". The multiple intelligence theory was improved by Maier [8], distinguishing between five branches of spatial intelligence:

- spatial perception: the perpendicular and horizontal fixation of direction regardless of troublesome information;
- visualisation: it is the ability of depicting of situations when the components are moving compared to each other;
- mental rotation: rotation of three dimensional solids mentally;
- spatial relations: the ability of recognizing the relations between the parts of a solid;
- spatial orientation: the ability of entering into a given spatial situation.

Vásárhelyi's definition of geometrical spatial ability [16]: the mathematically controlled complex unity of abilities and skills that allows:

- the exact conception of the shape, the size and the position of the spatial configurations;
- the unequivocal illustration of seen or imaginary configurations based on the rules of geometry;
- the appropriate reconstruction of unequivocally illustrated configurations;
- the constructive solution of different spatial (mathematical, technological, etc.) problems, and the imagery and linguistic composition of this solution.

Séra and his colleagues [12] are approaching the spatial problems from the side of the activity. The types of exercises:

- projection illustration and projection reading: establishing and drawing two dimensional projection pictures of three dimensional configurations;
- reconstruction: creating the axonometric image of an object based on projection images;
- the transparency of the structure: developing the inner expressive image through visualizing relations and proportions;
- two-dimensional visual spatial conception: the imaginary cutting up and piecing together of two-dimensional figures;
- the recognition and visualization of a spatial figure: the identification and visualization of the object and its position based on incomplete visual information;

- recognition and combination of the cohesive parts of three-dimensional figures: the recognition and combination of the cohesive parts of simple spatial figures that were cut into two or more pieces with the help of their axonometric drawings;
- imaginary rotation of a three-dimensional figure: the identification of the figure with the help of its images depicted from two different viewpoints by the manipulation of mental representations;
- imaginary manipulation of an object: the imaginary following of the phases of the objective activity;
- spatial constructional ability: the interpretation of the position of three-dimensional configurations correlated to each other based on the manipulation of the spatial representations;
- dynamic vision: the imaginary following of the motion of the sections of spatial configuration.

The conventions of the spatial representation can be taught effectively at the age of 9–12. The demand for the visualisation and drawn expression of the three-dimensional space appears at the age of 12–14. According to the experience of art teachers, the space representation has to be taught for some children because they would never reach that level by themselves. [12] Therefore our image and definitions of space are not congenital; they are the result of a long developmental and experimental learning process.

Mental Cutting Test (MCT) is one of the most widely used evaluation method for spatial abilities. Németh and Hoffmann [9, 10] presented an analysis of MCT results of first-year engineering students, with emphasis on gender differences. They used the classical MCT test for first-year engineering students of Szent István University. Németh, Sörös and Hoffmann [11] attempted to find possible reasons of gender difference, concluding, that typical mistakes play central role in it. They show typical mistakes can be one of the possible reasons, since female students made typical mistakes in some cases more frequently than males.

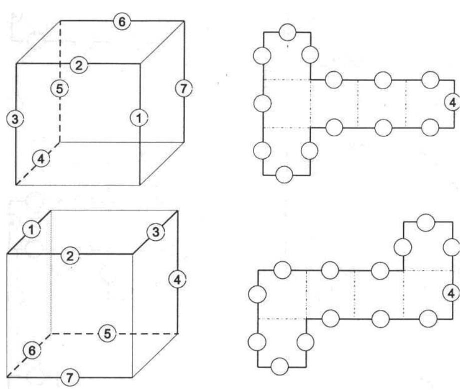
2. The survey and its results

We made the survey in September 2004 and 2006 in the University of Debrecen, Faculty of Technical Engineering among first year mechanical engineering students. In the beginning of the semester on the first week we examined the students' spatial ability and fundamental knowledge on descriptive geometry, since it is essential for the students to look at projections and to make operations with them and also to see the bodies with their mind's eye. 80 students took the test. The students had 50 minutes to complete the task sheet. We prepared the test in a way that it contained the important components of the spatial ability.

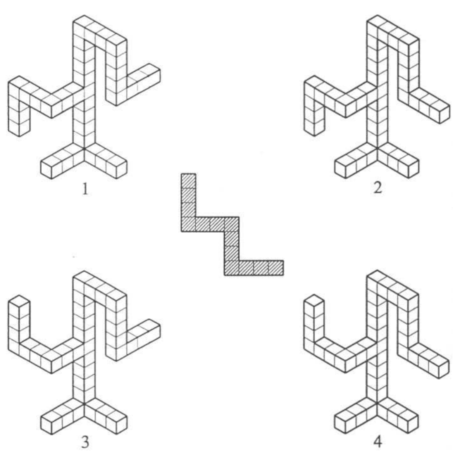
Shea and his colleagues [13] state that the intellectually talented adolescents who has better spatial than verbal abilities are more likely to be found in the field of engineering, computer sciences and mathematics. We according to the researches of Shea and his colleagues [13], expect a good result from engineer students.

The tasks of the test:

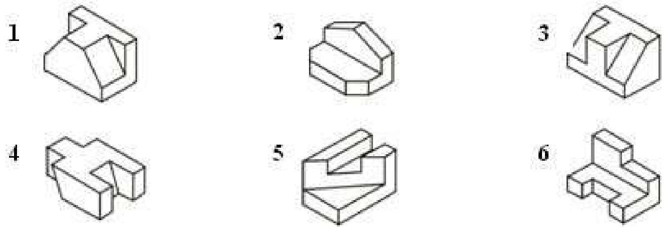
1. The network of a cube was cut by the bordering lines and after making the flexion the cutting lines that became next to each other we stuck together. The axonometric representations of the cube, the stuck edges are marked with a wide line and we numbered them. Mark those cutting lines with the same number on the network that was moved next to each other by sticking! [14]

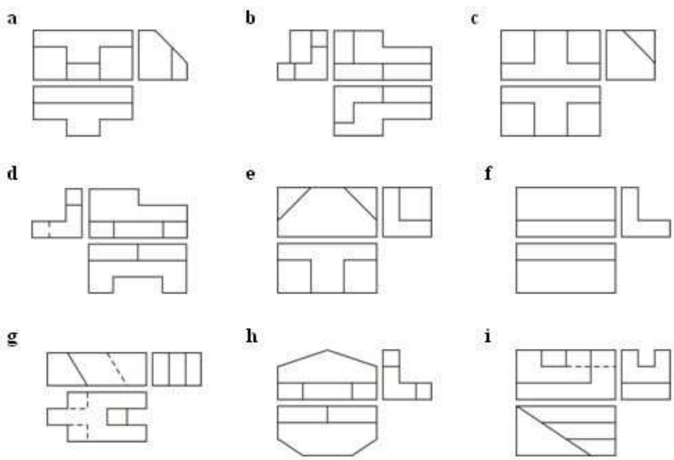


2. Which of the bodies that are numbered on the sheet can enter the lined gap? [14]



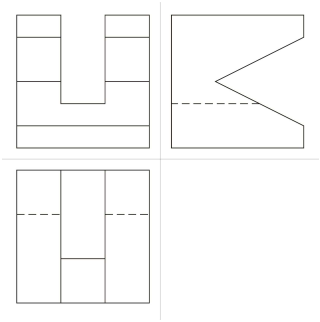
3. Make pairs of these bodies and projection pictures! [3]





1	
2	
3	
4	
5	
6	

4. Make an axonometric picture according to the projections!



5. Make the projections of the given body!

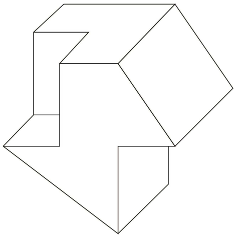


Figure 1 shows the performance of the students on the test.

Following the theory of Séra and his colleagues [12] we made the task sheet from the more important types of tasks. The first task focuses on the imaginary manipulation of the solid. The task is to follow such phases of the objective activity that consist of the complex spatial transformation of the solid. The second task focuses on the imaginary rotation of a three-dimensional figure. The third and fifth tasks belong to the types of tasks that deals with representation and reading of the projection. By mobilizing the experience of the motion, changing the inner viewpoint, imaginary rotation, manipulation of mental representations, and the task is to produce and draw the two-dimensional projection picture of a three-dimensional solid. This type of task is characterized by analytical operations from concrete to abstract. The fourth task is a reconstructural task. We have to create the axonometric picture of the solid based on the projection pictures. During the reconstruction the student synthesizes the visual information by studying the projection pictures. The map will be constructed by the series of changing the inner viewpoint by harmonizing three channels.

The first three tasks were solved with an 80 percent success or more. The imaginary manipulation of the object, the imaginary rotation of a solid and reading of projection went well. Some of the students wrote the numbers to a wrong place in part two of task 1. The 14 percent of the students gave only one solution in

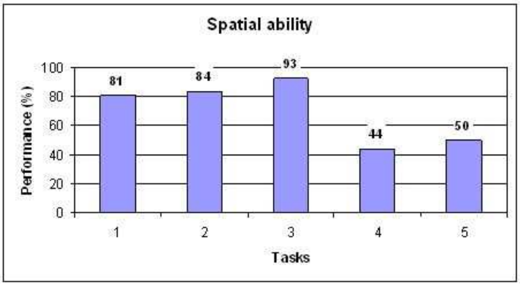


Figure 1: The results of the test

task 2.

The task 3 was the biggest success, where the bodies had to be compared with the projection pictures. To make the task more difficult, there were more projections as bodies. Some of the students wrote wrong letter to body 1 or body 3 or body 6.

Task 4 and 5 were like task 3, but here the projection or the body was missing. As opposed to this, these tasks were the least successful. The 36 percent of the students reconstructed the solid incorrectly or incompletely based on its projection picture in task 4 (Figure 2). Some of the students did not even start the task at all.

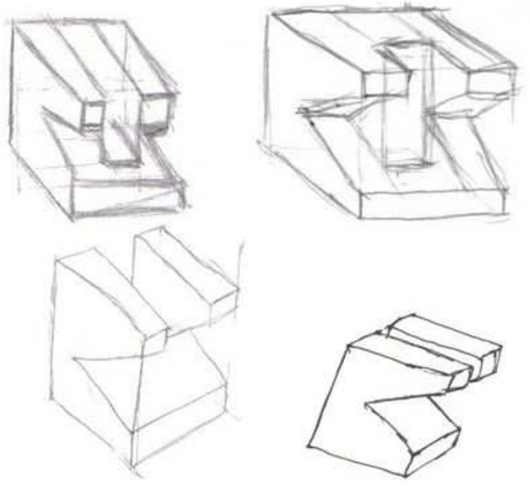


Figure 2: Some solutions of the students (Task 4)

55 percent of the students reversed the order of projections or represented in-

completely (Figure 3).

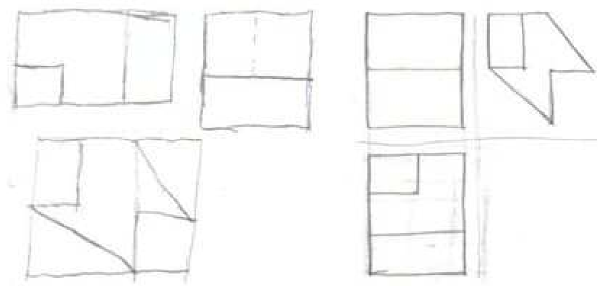


Figure 3: Some solutions of the students (Task 5)

Further study of spatial ability and other tests with more tasks from the more important types of tasks are among our future aims.

3. Summary

The results of the survey prove that it causes a problem for many students to imagine a spatial figure, the reconstruction and representation of the projection. In contrast to Shea and his colleagues [13] we found that the students of our survey, they do not have really good spatial ability. How could we develop the spatial ability?

Lord applied a 30 minutes practise on a 14 weeks course with first/second year students where they had tasks in which they had to cut three-dimensional solids in their mind and then they had to draw the surface of the two-dimensional planes they got. [7] In the post-test the spatial awareness and efficiency became better.

Field [2] describes work conducted at Monash University aimed at measuring spatial skills, improving the sensitivity of visualisation tests, and developing the skill for some engineering undergraduates. The testing of undergraduate students at Monash University has indicated the following factors:

- First level engineering students are to possess specially higher spatial skills than the general population.
- Spatial skills are not measurably developed by a conventional mechanical engineering undergraduate course.
- A special course with about 50 contact hours appears to have been successful in developing visualisation skill in first level engineers. (There is some evidence that freehand drawing of three dimensional objects, in orthogonal, isometric and perspective views makes a major contribution to the development of spatial skill.)

According to Horváth and his colleagues [6] in the teaching and learning of geometry the three-dimensional models can be a great help. It is much easier to imagine and represent the different views of a solid when we can see the formal characteristics. The proper use and frequent study of spatial visual aids can result in such an inner spatial vision that makes the individual imagination of the spatial relations possible. [16] The effectiveness of teaching spatial geometry can be influenced to a great extent by using several different models that we can even prepare ourselves. Vásárhelyi [15] calls the attention to the use of computers besides the traditional models, because they provide help for the motivation of the students. According to Vásárhelyi [16] it is practical to make four periods in the usage of models:

- with models,
- with models and their pictures,
- with pictures and their prepared models or animated pictures,
- problemsolving only with the help of pictures.

Bakó [1] was studying the conditions of the beneficial usage of computer in the teaching of spatial geometry. On the grounds of her researches she concluded that in acquiring the basic definitions of spatial geometry and the cognition of solids, the usage of models are still needed. After the development of basic abilities, the computer can get a role in developing the spatial intelligence from the 7th year of the primary school. She found that the help of the computer could develop all of the skills given by Maier [8]. At the same time, she experienced that we should not overdo the use of computers, because the explanation of the teacher, the usage of models and individual work are needed as well.

Development of the spatial ability is a very important task because we have to understand and develop the geometry knowledge of the students in the unity of the theoretical knowledge and the spatial abilities. Every skill, like the spatial ability as well can be developed at the right age with the suitable teaching strategy.

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