CREAT. MATH. INFORM. 24 (2015), No. 2, 131 - 138
Online version at http://creative-mathematics.ubm.ro/
Print Edition: ISSN 1584 - 286X Online Edition: ISSN 1843 - 441X

Interactive dynamic tests for evaluating the development of spatial abilities in high school

LÁSZLÓ BUDAI

ABSTRACT. In the last 10-15 years the number of studies examining spatial abilities of students has increased rapidly. The development of the spatial ability system components is important since these skills are used in everyday life and in order to reach our goal (position) people need good spatial perception in many cases. GeoGebra is a suitable and effective tool for developing these abilities. New methods for measuring these abilities can be developed that would be better adapted to today's needs. The dynamic and interactive adaptation of available GeoGebra tests for measuring spatial abilities would place these measurements on a new ground. However, there are many unanswered questions. The technical background, results and experiences of pilot a test of these methods are presented here.

1. INTRODUCTION

Research experience in recent years has shown that the development of spatial abilities should play an important role in all stages of education. The world of high technology grows exponentially and requires these abilities. We live our everyday life in space and we use our spatial abilities in many ways every day (instructions, guides, orientation based on a map...). In case of some workplaces (maybe there is already a growing number of these) the existence of good spatial perception is almost indispensable. However, what is spatial vision/perception?

Before the development and the measurement of spatial perception development, it would be good to clarify what is spatial perception and how can it be defined. Since without knowing the definition we will not be able to work with it.

Let's look at a few approaches without being exhaustive:

- It is a mental ability, which makes people able to sense and set a unified overall picture of objects, based on their shape, their expansion and their spatial relation to each other (The Hungarian Language Interpreter Dictionary, 1962, p. 640).
- Imagining objects based on pictures and their reconstruction (Drahos, 1988)
- The ability to solve spatial problems (Gulyas, 1996)
- The ability to create, maintain and manipulate abstract visual pictures (Lohman, 1979)
- The ability to search for the individual possibilities in the field of view, and understanding the spatial space as visually sensed for the form of the objects and their shape.
- Development of mental representation of forms, shapes and situations (Carroll, 1993).

We can see that definition problems may arise, since it is not so obvious to define spatial abilities. For example, in psychology the phenomenal (psychological space) and physical

Received: 19.03.2015. In revised form: 08.10.2015. Accepted: 15.10.2015
2010 *Mathematics Subject Classification.* C30, G20, U70.
Key words and phrases. *3D in GeoGebra, IT tools, spatial perceptions.*

(geometric) spaces are differentiated from each other. The different versions of the National Curriculum illustrate the definition of these problems as well, but without satisfactory accuracy. Summarising all kinds of approaches as processing spatial abilities and information as of the general ability "with coding the spatial stimuli, recalling, comparing and modifying, we can consider these as a series of abilities related to each other" (Haanstra, 1994). Therefore, we have to understand spatial ability as sensing two and three-dimensional shapes. This includes the ability to use spatial information including object shapes and positions for problem solving.

These definitions bring to the foreground the measuring aspect of visual spatial abilities.

2. Measurements of spatial abilities

More than 400 psychological testing tools have been developed for evaluation of spatial abilities as a result of hundred years research (Eliot & Smith, 1983). The history of statistical methods used to test the effectiveness of psychometrics dates back to the first work on the measurement of intellectual abilities in the beginning of the 1900s. Alfred Binet French, a psychologist, published the first intelligence tests in 1905, which were further developed in collaboration with Theodore Simon. This coincides with the time of development of factorization.

The goal of these tests is ultimately to measure and define intelligence, a task that in practice involves statistical correlation analysis. Most of this statistical analysis has concentrated on test results related to analytical skills and spatial skills (Smith, 1964, McGee 1979, Lohman, 1979, Eliot, 1987, Carroll, 1983, 1993).

Charles Spearman suggested general and special assessments of intelligence, a two-factor concept of intelligence. Even today his work is part of the debate about intelligence and the extent to which it is inherited. One of the tests that evolved from his thinking is a paper-pencil based test attributed to Stanley Porteus, who published a labyrinth test in 1915.

Over the decades, many people supplemented the factor-based analytical method, which was also used in the World Wars in testing the intelligence of soldiers. Several development stages are differentiated by the factor analysis method. An important angle is to determine particular abilities that contribute to spatial abilities and to understand abilities related to complex relationships. We can distinguish between two spatial abilities according to today's factor analytic models: imaginary visual and spatial orientation abilities.

Today several different models contribute to the research on spatial thinking. For example, James Pellegrino et al. present a two factor spatial ability model using both speed of performance and simple-complex process dimensions.

More recent multivariate statistical methods are also used, which include models with different structures. These studies have lead to very important results concerned with spatial abilities developed in accord with the previous approach of factor analytical concepts related to spatial abilities.

3. Statistical test adaptation in GeoGebra

In 2000, a pencil and paper based test series was developed and standardized to measure spatial abilities (Séra-Kárpáti-Gulyás). It was designed to demonstrate the development of space perception concerned with drawing and mathematics during general education. The test is complex since it takes several different aspects of education into consideration. It is basically a norm oriented, ability test, but suitable for application to several age groups.

The problems used in the test are classified in line with two ability factors: recognition and manipulation. These can be defined similarly to the McGee orientation factor and its visualization.

The problems are arranged as A, B, C series and each containing 9 problems with different partial capabilities.

There are 27 problems in all with some overlap between them. Based on these we can obtain the GeoGebric adaptation in order to balance its justification.

It is possible that the static problems in this set are not suitable for dynamic adaptation or only on a limited scale. Perhaps due to its dynamic nature the adapted test can become very easy, since with the correct settings it gives the solution itself. The adaptation of the test may also encounter technical difficulties in terms of implementation (difficult 3D figure mapping).

For adaptation from static to dynamic, the static problems have three classifications:

- The problem is suitable for dynamic adaptation and measurement.
- The problem is suitable for dynamic adaptation and measurement but improvements can be made (with minor changes).
- The problem is not suitable for dynamic adaptation.

7 problems can readily be adapted to the dynamic test series suitable for measurements. Four are suitable for developer evaluation with only a few restrictions. Beyond this, there are 8 problems, which are suitable for application and practice during class hours as a worksheet. In many cases the problems have a, b, and c sub points also. Thus it is possible to obtain a sufficient set of problems for use in testing these abilities. The 8th worksheet, presents kinetic problems and other possibilities. It can be used as a tutorial to strengthen the technical background knowledge of students, so none would start with disadvantages due to the new environment.

It is important during the analysis of the problems that the dynamic measurement problems touch on several components that contribute to overall spatial ability. In this respect, 7 problems fulfil the two-factor model and within these, we can examine four basic abilities:

- The recognition and the display of the spatial configuration (A8) the visual information seem to be contradictory in this problem they are crowded and the figure is noisy i.e. contains too many details.
- Oversight of the structure (B1, C4, A4): Serves the measurements of the accuracy of the inside image through the display of destinations and ratios. It measures how the internal picturesque image reflects the true destination of the object. The solution level of the problem reflects the accuracy of distortion corrections originating from the aspects and representation (in case of B1 it refers to a kind of preciseness of cognitive map). In public education, the most common basic object is the cube. We need to perform different procedures on the surface and inside the cube.
- Mental Rotation of 3D objects (A6, C7); the C7 problem is a cube rotation problem. Here, outside of the manipulation of spatial representation other solution strategies may arise.
- 6A is a complex problem, which consists of the recognition of a transcendental contoured figure and the imaginary rotation of this object or the identification of its different projections.

- Imaginative manipulation of an object (C5): In this case, the task is the imaginary tracking of the phases of the activity of such objects, which consist of complex spatial transformations of objects or two-dimensional-figures.

From the viewpoint of technical execution, it is interesting to mention the possibilities of GeoGebra for the display of spatial objects. Currently, the 5.0 beta version can be suitable for this. The problem is that this version is still under in development phase and in certain cases, the worksheets may become unstable. To supplement this, a 3D based system can be implemented [Buda, TMCS 2013], which is stable for displaying dynamic 3D elements and various manipulations with them. Overall, during the dynamic adaptation of the static tests, we have to combine the benefits of different possibilities in order to obtain an optimal set of tools (Figure 1)

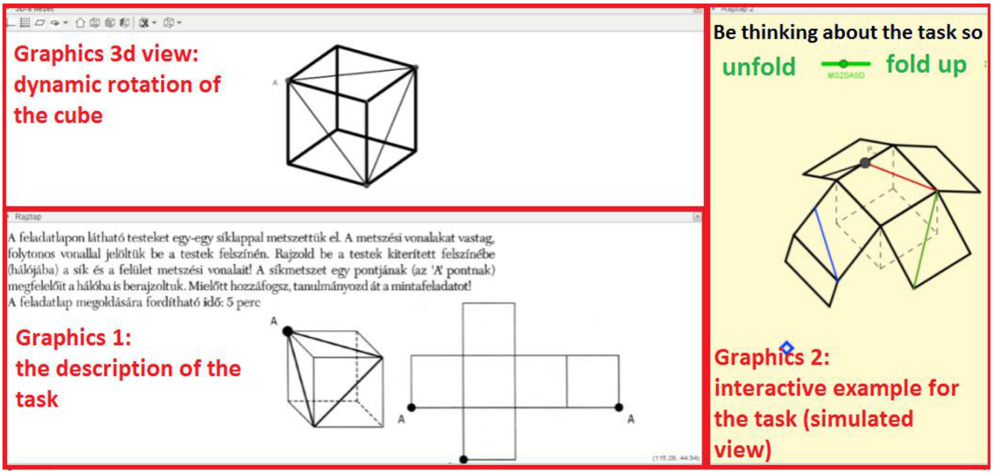

FIGURE 1. Parallel use of many views

4. THE MODEL OF THE PILOT EXAMINATION AND ITS COURSE

59 10^{th} grade (10a -32, 10b- 27) students (22 girls and 37 boys) participated in preliminary testing. The test site was the Szécsényi (Hungary, Nógrád) II. Rákóczi Ferenc Elementary School, High School and Vocational School. In these schools, the students participate in an 8-grade high school education. In the class hours, both classes were improved with GeoGebra. Therefore, the surface was familiar to all students. 10a filled the dynamic test, 10b filled the static test and both groups of students produced their solution on a page. At present, the technique does not allow for web-based testing (java – problems, GeoGebra 5.0 cannot be exported as a web page), because of that the GeoGebra worksheets were implemented from a central network drive via a local computer (i.e. running the GGB source files). For this reason continuous control was important in the background (personal presence is necessary in case technical or other problems arise).

5. THE RESULTS OF THE PILOT EXAMINATION AND EXPERIENCE

Figure 2 shows the results from students of the static (10b) and dynamic (10a) test.

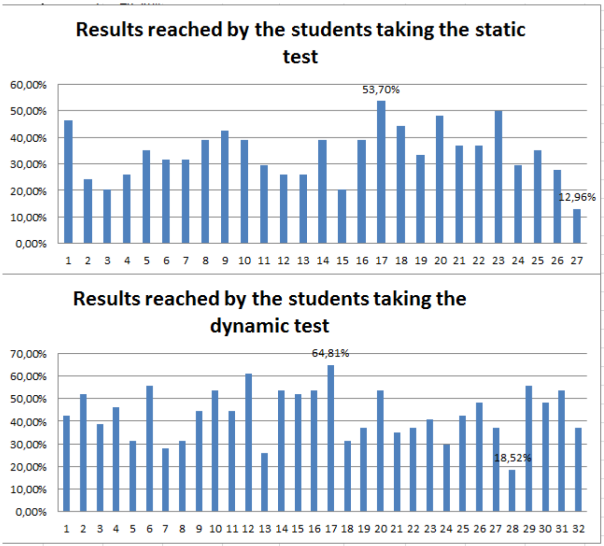

FIGURE 2. Student results of the static and dynamic tests

The average result of the static test is 34.22%, with 0.0961 standard deviation. This is reasonable taking into consideration the specific psychological features of the testing situation. The average dynamic test result is 43.29% with 0.1095-degree deviation.

The best result in case of the static test was 53.7% and 5 students reached above 40% performance. The best results in case of the dynamic test were from one student who achieved a 64.81%. One student had a score of 60% and 9 students reached 50% or above. In case of the static test the lowest score was 12.96%, while in case of the dynamic test based on the same criteria a 18.52% lowest score is shown.

Based on this we can conclude that there is no significant difference in point range and the lowest score obtained. However, the best result of the dynamic test was higher with 17.15%, than the highest score for the static test.

Let us now look at the results in the light of the problems (Figure 3).

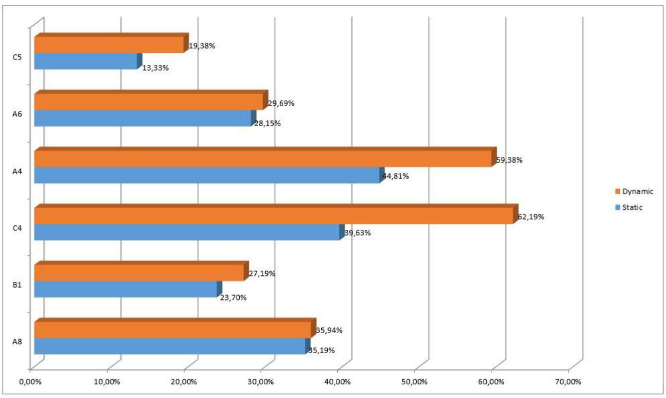

FIGURE 3. Results reached per problem

One of the main questions of our current examination is whether the dynamic nature of the test is significantly influences the results of the students in certain problems. If yes, in what direction and in what extent.

Based on Figure 3 in the A6 and A8 test problems, there was no significant difference in any direction. Based on this, the dynamic nature did not provide a great advantage for the students. Those who correctly rotated the easily recognizable shapes (Figure 4) could figure out the solution. On the other hand, in case of the difficult wire framework shapes it was hard for the students to find the appropriate view. Here, we cannot completely address mental rotation abilities, but in any case, we can examine a particular aspect of the ability to mentally manipulate objects in space, even from the viewpoint of new solution strategies.

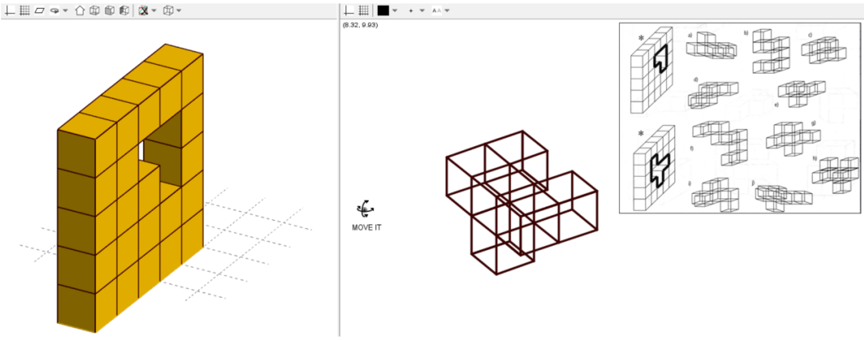

FIGURE 4. A6 dynamic and static test problems

In case of C5 and B1 test problems (Figure 5), the dynamic addition resulted in a slight positive shift. However, this performance is lower than expected, since in this kind of problem (where the operation carried out on the surface of the cube needs to be projected to the net (Figure 1). Due to the dynamic nature a greater performance would have been expected. These types of worksheets contained (Figure 1) a support on the right side surface, which was a further development of a similar problem in dynamic environment. In addition, the cube could be rotated above the description of the problem.

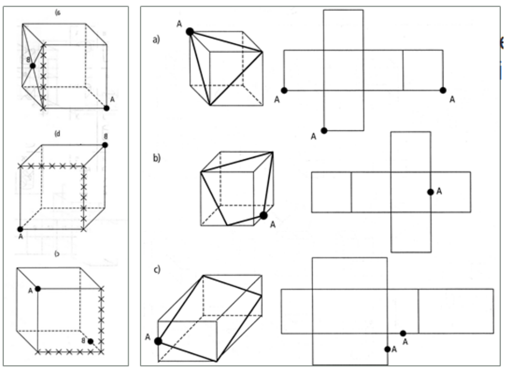

FIGURE 5. A C5 and B1 test problems.

In A4 and C4 test problems polygons needed to be created according to certain criteria by connecting the points on the edges of the cube (Figure 6). In case of the C4 static problem, the students reached 9.63%, while in case of the dynamic test 62.19%. This is a remarkable performance increase.

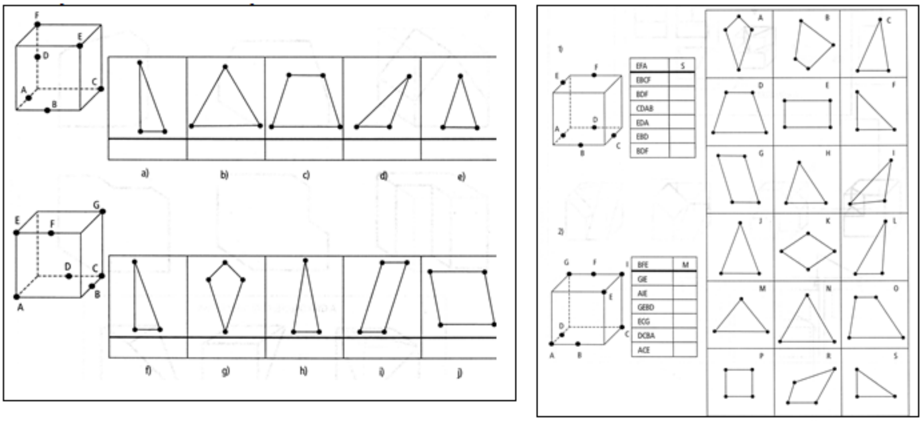

FIGURE 6. A C5 and B1 test problems.

The examination of the time factor was an important aspect. 45 minutes were available for the static test, which the students did not use up (on an average they finished in 32 minutes). 60 minutes were available for the dynamic test, however, this was not enough time and the students showed enthusiasm for doing the dynamic problems.

6. SUMMARY

The pilot examination shed light on many technical questions related to the new measurement techniques; however, many questions remain. We will answer these questions by filling out a background questionnaire, in which we will also examine the students' affective and psychomotor factors (GeoGebra usage patterns, IT qualification...). Another task will be the development of the appropriate testing environment. Namely, the method used for the pilot test cannot be readily applied on a larger scale. Based on experience (opinions of students about the dynamic worksheets, observations...) some worksheets should be amended.

REFERENCES

[1] Hoffmann, M., Németh, B., and Sörös, Cs., *Typical Mistakes in Mental Cutting Test and Their Consequences in Gender Differences*, Teaching Mathematics and Computer Science, **5** (2007), No. 2, 385–392

[2] Hoffmann, M., and Németh, B., *Gender differences in spatial visualization among engineering students*, Ann. Math. Inform., **33** (2006), 169–174

[3] Lord, T. R., *Enhancing the Visuo-spatial Aptitude of Students*, Journal of Research in Science Teaching, **22** (1985), 395–405

[4] McGee, M. G., *Human Spatial Abilities: Psychometric studies and environmental, genetic, hormonal and neurological influences*, Psychological Bulletin, **86** (1979), 899–918

[5] Nagy-Kondor, R., *Spatial ability of engineering students*, Ann. Math. Inform., **34** (2007), 113–122

[6] Nagy-Kondor, S., *Engineering students' spatial abilities in Budapest and Debrecen*, Ann. Math. Inform., **40** (2012), 187–201

[7] Nagy-Kondor, R., *Spatial Ability, Descriptive Geometry and Dynamic Geometry Systems*, Ann. Math. Inform., **37** (2010), 199–210

[8] Schröcker, H.-P., Stachel, H., Tsutsumi, E., and Weiss, G., *Evaluation of Students' Spatial Abilities in Austria and Germany*, J. Geom. Graph., **9** (2005), 107–117

BUDAPEST BUSINESS SCHOOL, UNIVERSITY OF APPLIED SCIENCES
COLLEGE OF INTERNATIONAL MANAGEMENT AND BUSINESS
INSTITUTE OF BUSINESS TEACHER TRAINING AND PEDAGOGY
DIÓSY LAJOS S. 22-24. 1165 BUDAPEST - XVI. DISTR.
E-mail address: budai0912@gmail.com