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How can we improve the spatial intelligence?

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Abstract

H. Gardner introduced the idea of multiple intelligence. One type of these intelligences is the spatial intelligenc. P. H. Maier in his thesis distinguished five elements of the spatial intelligence: spatial perception, visualization, mental rotation, spatial relation, and spatial orientation. Maier showed a modular construction system of polyhedrons, and different activities to improve the student's spatial abilities using these polyhedrons. Our aim is the students can work without actual models, just imaging the solids. To reach this level we prepared for our student several programs to generate different kinds of spatial problems, and correct their answers. Our experiments show by using these programs the students' results are getting better and better, so we can improve their spatial intelligence. In this paper we introduce our programs and our experimental results.
Key Words and Phrases: Spatial geometry, multiple intelligence

1. Introduction

In elementary and in secondary school mathematics one of the most difficult parts is geometry. While in analysis and in algebra there are algorithms, in geometry there are no algorithms. The students can easily learn the solving method of the second order polinoms, and they can apply them later for any problem reducible to solving of this kind polinoms. In geometry there are no solving methods, the students need to construct a new proof different from the previous proofs. Several researchers [3, 5] in different articles suggested us to use Dynamic Geometry Systems (DGS) to teach geometry. Lot of experiments proves that it is a good idea. But we cannot apply it always. The most difficult part of geometry is the spatial geometry. The well-known DGS, namely Cabri and Geometer's Sketchpad are two dimensional. There are some three dimensional DGS, too, but the Cabri 3D Java in development, and in the GeospaceW we cannot rotate object freely. The most problematic issue is the following: the computer screen is two dimensional. So if we picture on it three dimensional objects, we lose information, and as the experiment [2] shows, lot of student treats these pictures as two dimensional figures. For example on figure 1 we connected vertex A and the midpoint B of an edge with a line. Some of students believe that this line segment touch two other edges in points M and N. These students cannot *read* this picture. We need to teach them how they can understand it, and how they can create a mental image of it in their mind. In this article we show how we can improve the students' spatial abilities using computer programs.

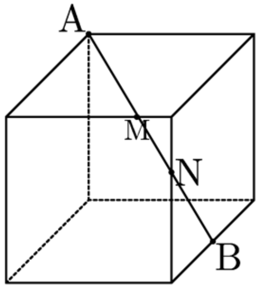

Figure 1. An example for problem of comprehension.

The structure of the paper is the following: in section 2 we show the elements of spatial intelligence. Next we introduce our computer programs which can improve the students' spatial abilities. In section 4 we discuss our experiments and result, and finally we conclude.

2. Elements of spatial intelligence

In the eighties Howard Gardner introduced the concept of multiple intelligence [4]. The theory of multiple intelligence challenges the traditional view of intelligence as a unitary capacity that can be adequately measured by IQ tests. Instead, this theory defines intelligence as an ability to solve problems or create products that are valued in at least one culture. These intelligences are:

- visual/spatial intelligence
- musical intelligence
- verbal intelligence
- logical/mathematical intelligence
- interpersonal intelligence
- intrapersonal intelligence

- bodily/kinesthetic intelligence
- naturalist intelligence

Dr. Gardner says that our schools and culture focus most of their attention on linguistic and logical-mathematical intelligence. To solve spatial geometric problems we need visual/spatial intelligence. Several author examined this ability. Peter Herbert Maier in his papers distinguishes five elements of spatial intelligence. He wrote that *based on psychological research findings, all five elements of spatial ability have to be specifically trained.* Maier introduced a modular construction system based on the traditional system where polygons were joined with rubber bands. He used real models, because his experiments have shown that experiments with solid models are extremely successful. With these models he introduced activities for all elements of spatial abilities. These elements are the following: spatial perception, visualization, mental rotation, spatial relations and the spatial orientation.

Spatial perception tests require the location of the horizontal or the vertical in spite of distracting information. Horizontality is measured by "water-level tasks", that ask person to draw or identify a horizontal line into a tilted glass. On figure 2 in the first row you can find a typical example of this kind of test.

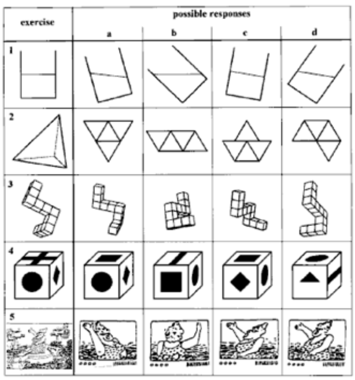

Figure 2. Traditional tests.

The visualization comprises the ability to visualize a configuration in which there are a movement or displacement among parts of configuration. On figure 2 in the second row on the left there is a tetrahedron. You need to find which nets belong to this tetrahedron.

Mental rotation involves the ability to rapidly and accurately rotate a two or three dimensional figure. On figure 2 in the third row you need to find the identical bodies.

Spatial relation means the ability to comprehend the spatial configuration of objects or parts of an object and their relation to each other. Figure 2 in the fourth row shows cubes with a different design on each face. You need to find out, whether the drawings could represent the same cube, or the cubes are necessarily different.

The spatial orientation tests require a person's own orientation in any particular spatial situation. To solve the last problem on figure 2 you need to pair cameras and figures on right according to the leftmost figure.

3. Computer programs

Meier's method is ideal to introduce some knowledge, but too expensive to practice it. It needs a lot of models if the students work individually, and takes a lot of time of the teacher to follow the improvement of the students. In this situation the computer aided education could help the teachers, but we have no suitable programs. Hence the authors wrote some program to show that it is not so hard to develop such programs, and we take experiments to prove that these programs are useful.

For spatial perception we didn't make tests. We believe that for this element the traditional "rod and frame" or the "water level" tests are sufficient. On the computer screen the vertical and the horizontal lines are parallel with the edges of the screen, so to solve these kinds of tests on computer are trivial tasks.

For all other elements we made tests. In each test the students get seven problems. If he/she solves all of them, he/she can continue on the next level. For each element we implemented three levels of problems.

At the first and second level at visualization of each problem the computer shows five purple and four numbered squares. You need to find out with which numbered square with the purple squares make a net of a cube. A similar picture is on figure 3.

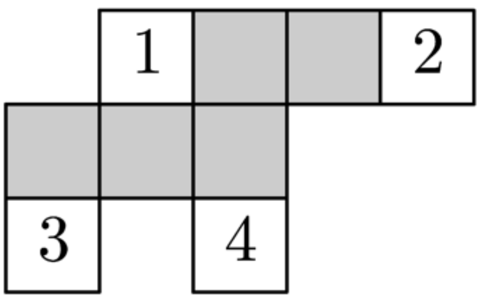

Figure 3. Complete the net of the cube!

At third level there is a closed line on the cube like on figure 4.

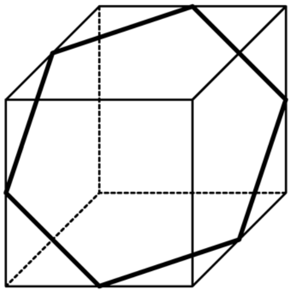

Figure 4. There is a closed line on the surface of the cube.

The problems show a net of this cube, but the direction of one face is wrong, like on figure 5. Which face is it?

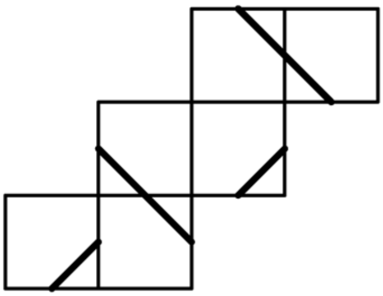

Figure 5. Which square need to rotate to get a net of the cube on figure 4?

At mental rotation the users need to rotate a cube in their mind. At the first level we need to rotate around axis like IJ (figure 6), at the second level around axis like KL, and at the third level around axis like AG. Which vertex gets to the place of vertex D?

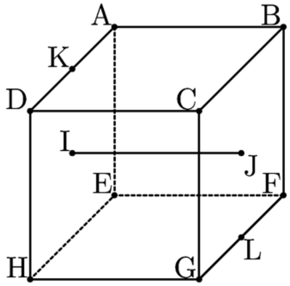

Figure 6. Mental rotation test.

At spatial relation tests we have two nets of the same cube. The second net is not finished, the student need to finish the coloring. At first level the shape of the nets are the same (figure 7), at the second level the shape is different,

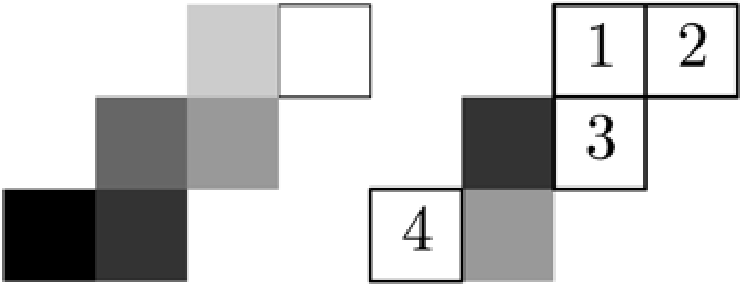

Figure 7. First level spatial relation test.

and at the third level the faces have orientation (figure 8); hence these tests are very difficult.

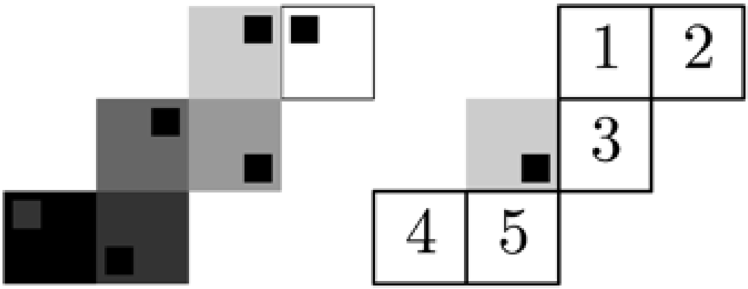

Figure 8. Third level spatial relation test.

At spatial relation a beetle roams on the surface of a cube. At the first and the second level the beetle roams on the edges (figure 9). At the third level the beetle goes from center of a face to center of adjacent face (figure 10).

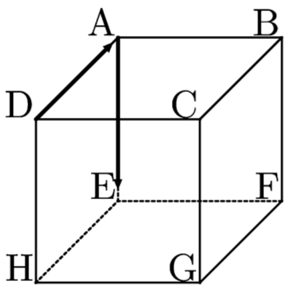

Figure 9. Walking on the edges on the cube.

In each test we have a list of movements, for example the beetle at first goes along over the edge, turns left, goes along over the edge and stops. The students need to find the vertex where the beetle stopped.

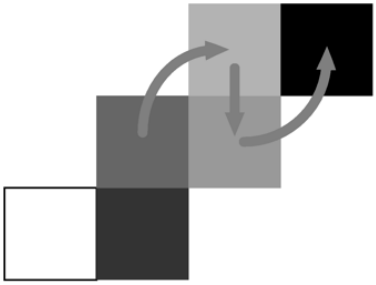

Figure 10. Walking on the surface on the cube.

4. Discussion

The programs generating the tests were written in Javascript and were embedded in the source of the HTML pages, as well the routines of checking. On the server a Perl program runs which collects the students' results and sends it in email to the authors and moreover creates a HTML page for the student which contains the correct solution for the wrong answers. With a minor modification of the source of the HTML page there is no need to use servers with Perl programs, so the programs could be installed everywhere.

If the student gave only good answers, then the Perl program generates a HTML page with congratulation, otherwise the program generates a HTML page where the student can examine the wrong answers and the solutions. Next the student continues with tests of the same level. At different problems the number of different examples is varying from 72 to 10^{11}, so the students seldom need to solve the same problem. Hence the memorization of previous solutions or copying the others' solutions doesn't help here, nor does the fortune, because the student need to solve all the problems, so his/her chance is at least 1 to $3{\cdot}10^5$, therefore he really needs to solve the problems.

In our opinion the tests of the mental rotation are the easiest. Hence we made experiments about this element of spatial intelligence in France and in Hungary [1]. 69 students took part in experiments in the school-year 2002-2003. The students were different (from mathematics faculty, from human faculty), and the results were different, but the tendency was the same: the number of errors decreased. So we could improve the mental rotation ability. When we asked the students, the majority said they liked this kind of lessons with this computer program.

To use the other programs to improve the other elements of the spatial intelligence the students need to practice the concepts with real models. The problems implemented here are difficult. Sometimes the authors need to cheat to check the programs quickly, because for example to solve one example of spatial relation at the third level takes two or three minutes and there are seven examples on one page. The problems are more difficult, so 45 minutes are not enough to the students, to pass all three levels of one element, but we believe, that the corresponding ability can be improved. Everybody can test his/her own abilities via HTML page http://www.inf.unideb.hu/∼aszalos/kocka.

5. Conclusion

In this article we gave a little summary of problems of teaching spatial geometry. Next we introduced the multiple intelligence, and the elements of spatial intelligence. We showed some traditional tests and new ones which were implemented by authors. The results of the experiments show that the students' result are getting better and better, moreover the students like to use computer programs to study spatial geometry. We believe that the experiments based on the other programs could give a similar result, so the visual/spatial intelligence can be improved with these kind of computer programs.

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