Visuospatial Abilities and Mental Operations

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Abstract - **The components of mental operations in the current studies are in different levels of development. The goal of our research was to determine the development of thinking skills for vocational secondary school students. A total of 4,624 students in 41 vocational schools, in Budapest, took part in the examination. The geographical position of the school, the gender and the specialization of the students was taken into consideration. Only a slight difference was noted in relation to rotation and mirroring of axonometric shapes and the ability of mapping and manipulating of the spatial elements.**

I. The Interpretation of Visuospatial Abilities

Spatial abilities are considered cognitive functions that enable humans to perform spatial manipulation of objects, spatial orientation and to solve visuospatial tasks [1]. According to another interpretation, the perception of two and three dimensional shapes, the detected information, objects and the understanding of relations, as well as, the use of problem solving is what we mean by spatial ability [2]. According to a third interpretation, spatial ability is manifested by creating two and three dimensional shapes in mental representations then transforming and analyzing the properties [3].

The aspect of visuospatial cognition, which opposes certain point-of-views, is the figurative and operational aspects. While the former grabs the form of the reality, the latter grabs the "state" of the mental representation of established images. The operational aspect can be interpreted as visuospatial thinking through which mental changes; transformations can be performed [4]. According to Piaget the image located between perception and operational thinking can be interpreted as a temporary capacity, which, by its function, can be anticipated (predictable), and reproduced (again using his memory to recall) according to the image.

A number of studies deal with the storage of visuospatial and verbal information, processing of system-wide connections, the characteristics of the system and their different approaches [5] [6] [7] [8]. The storage is done with elementary images, direct (detection), analog (real and imaginary operations based on similarity) representations and their units which are organized in higher order structures. In the visuospatial information processing process the spatial and visual characteristics' (shape, form, size, position-air, color, etc.) organization and transformation takes place [9]. In the visuospatial imagination, with real operations we can execute analog operations as well. While the visuospatial mental images (perceptions, beliefs) and operations are analogical, their operations executed with images can be interpreted by their progresses. These analogical processes are especially effective in the performance of complex outdoor structures and operations performed upon them [7].

Many researchers have tried to identify the components of spatial abilities by factor analysis:

- Spatial orientation (identification of three dimensional shapes from different perspectives), spatial operations (two or three dimensional shape mental restructuring) [3]
- Spatial perception (spatial links conception, definition), spatial visualization (spatial operations), mental rotation (two- or three-dimensional shapes on the mental rotation) [10]
- Spatial visualization (spatial operations), spatial orientation, air connections (mental rotation) [11] [12]

Spatial abilities have been integral parts in intelligence testing from the beginning, as primary mental abilities (Thurstone), as the detection of spatial conditions, mental transformation, visual memory (Gardner), as the component of fluid intelligence (Cattell), as coordination with perceptuomotor, mental operations (Wechsler) [1]. In Carroll's cognitive structure the visual perception is a factor of general intelligence which has different sub-components, e.g. spatial relation, spatial visualization. The ability of mental rotation appears between spatial reactions too [13].

Based on the above, it can be said that the most important components of spatial abilities are spatial orientation and visuospatial operations, in which the latter was the center of our research.

II. The Purpose of the Research, Methods

As we have seen, the operational aspect of visuospatial cognition can be interpreted as visuospatial thinking [4]. That said, if you want to explore the development of students' thinking condition, it can be done through graphical tasks which trigger the thinking operations.

Accordingly, *the aim of the research was to determine development of the thinking skills of vocational secondary school students.*

When students are compared, differences are virtually revealed. Effective learning can only occur if the teacher chooses teaching methods, forms and tools of work (teaching strategies) and the unique characteristics of the students are taken into account.

As seen, the preference of visual or conceptual thinking is an individual cognitive characteristic. However, it is important to emphasize the fact that it is not enough just to narrow the factors influencing the effectiveness of cognitive learning side, the development of thought, perception and memory development is also greatly influenced by it.

Thus, our research is focused on the mental development of spatial operations. The most basic operations of visual thinking – similar to the conceptual thinking – is analysis and synthesis (representative intelligence). The presence of the object is not required for the operations, carried out by mental imagery (with images). It can be performed, based on a real image of the object (projection, axonometric diagram) or without it.

Cubes, truncated as stimulus and axonometric projection images were used in their development tasks. In addition to triggering the elementary mental operations, tasks that require complex operations (mental rotation, spatial image) were used as well. The phases of mental rotation is representation, the rotation, the comparison, the decision about identity or difference [14], while according to another approach, attention is visual scanning, visual memory and perceptual decision [15]. The spatial image is created by integrating multiple points of view, based on experience and observation of the change of perspective, objects and spatial relations can be recalled, imagined and operations can be performed with them by axonometric manner.

The complex spatial image involves visual space, spatial image, the mental placement of objects and the operations executed there. The spatial image is affected by reconstructive (on the basis of projection reconstruction) and constructive (spatial correlations understanding of the concept of spatial transformation) detection [9].

Considering the above, the following types of tasks were used in our research for investigating the mental operations:

I. Operations which require primary mental tasks

1. Mental analysis
   - Disassembling formations built from axonometric cubes (Fig. 1).

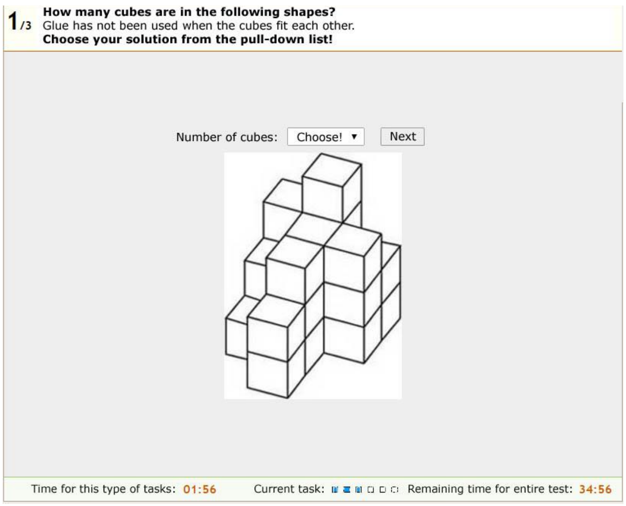

Figure 1. Mental analysis with axonometric shapes

2. Mental synthesis
   - Creating a complex object made from axonometric truncated columns

II. Operations which require complex mental tasks

1. Mental rotation
   - With two-dimensional shapes
   - With axonometric shapes (Fig. 2)
2. Mental mirroring
   - With axonometric shapes
3. Spatial image 1
   - The merging of three projections with different point of views, based on isometric image (Fig. 3)
   - Connection of two projections to a given point of view with merging

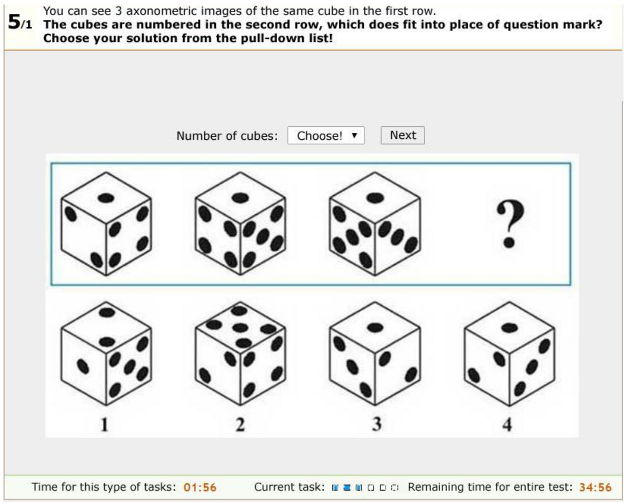

Figure 2. Mental rotation with axonometric shapes (Rotating in 3D)

4. Spatial image 2
   - Combining six-course perspective projection, putting and moving, rotating and connecting to isometric shapes.

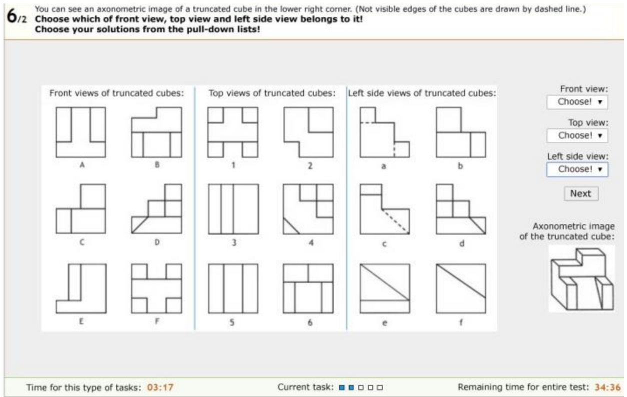

Figure 3. Spatial image, Task 1

Our studies were carried out between 2007 and 2010, the first year with paper tests, then during the next three years, in electronic form.

The study was conducted in collaboration with Mérei Ferenc Institute of Education and Career Guidance and the support of the Municipality of Budapest Mayor's Office of Education, Child and Youth Protection Department.

Training sessions for the teachers involved, were held each academic year in September and detailed, printed measurements were delivered. In addition, teachers' IDs were distributed in advance, to test the different measuring devices.

The measurement, at the intermediate school sites and computer labs was led by a fully trained teacher.

The students received immediate evaluation and interpretation of the results upon completion, which greatly contributed to the development of their self-esteem and self-image shaping.

Another agent of feedback was the head teacher and teachers who taught the class. They could receive both educational and useful information more efficiently based on the immediate results of the class. Therefore, an online platform could be formed, where teachers could watch the results of their classes, as well as its assessments and interpretations immediately after the measurement. This contributed greatly the choice of appropriate teaching strategies.

A total of 4624 students from 41 vocational schools in Budapest took part in the examination. There were 1,530 students from year 9, 1,319 from year 10, 948 from year 11 and 827 from year 12 participated in the examination considered representative as for the geographical position of the school and the gender and specialization of the students.

During the four years of research, conducted in October and November, two test models (longitudinal section, cross-sectional) were allowed. In the present study we only focus on the results of the student years 9 and 10.

III. Results

First, the statistical analysis was carried out to describe the obtained results (Fig. 4). Students achieved the best result of the spatial notion task when they had to fit together a truncated cube based on an axonometric, stereoscopic image. The shape didn't have to be rotated during the fit, the projections of images can be easily adapted to the axonometric image, the individual planes and edges were easy to correspond. However, it is important to note that the highest difference between the students was during the problem solving test. The results of the students practically show a u-distribution (Fig. 5) which means they could either overcome the test (47.5%) or not (25.9%).

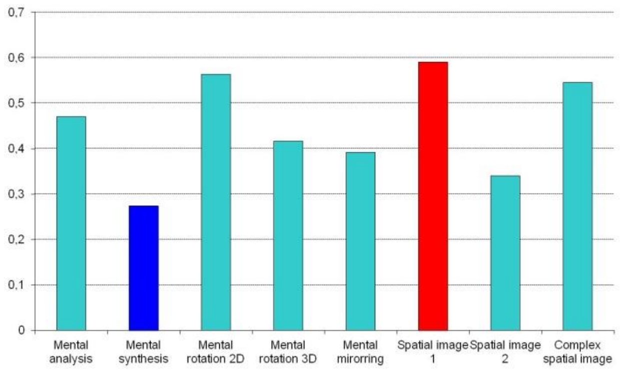

Figure 4. Results of students as operational components

We thought that the evolution of the results was due to territoriality, which means, that those who belong to the technical areas can achieve better results than, for example, the vocational secondary school students. This was not really proven in the results (Fig. 6). The best results were by vocational secondary school students, while the weakest were achieved by the students in the agricultural area. Students in the technical area performed nearly 10% less than their vocational secondary school counterparts, but approximately 10% higher than the human sciences (health, social services, education) students. The area of expertise and the result achieved on the first task of spatial image are significantly related to each other (χ^2 =208.140; df=20; p<0.05).

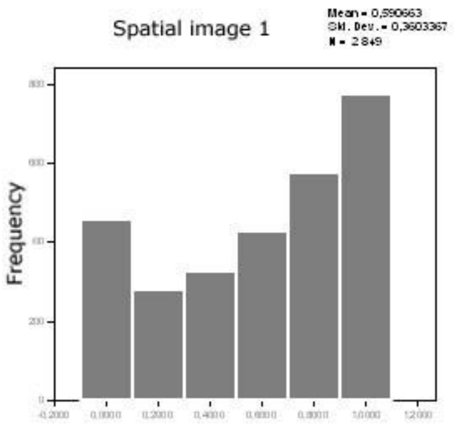

Figure 5. The distribution of the results of the Task 1 of spatial image

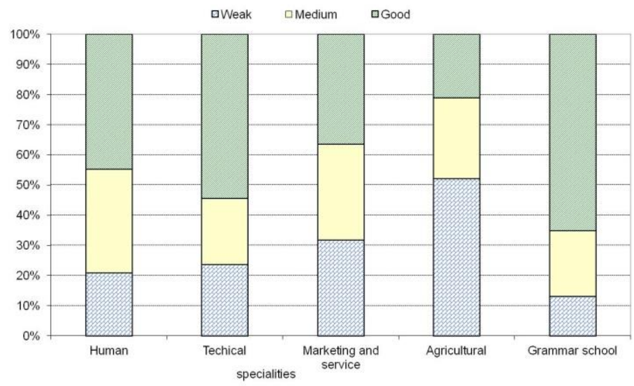

Figure 6. The distribution of the results of the Task 1 of spatial image based on the profession

The results of the Task 1 of spatial image have improved by the progression of the studies. For example, 30% of year 9 is poor, while 42.5% of them achieved good results, while these rates were 21.3% and 53.4%, respectively, in the year 10.

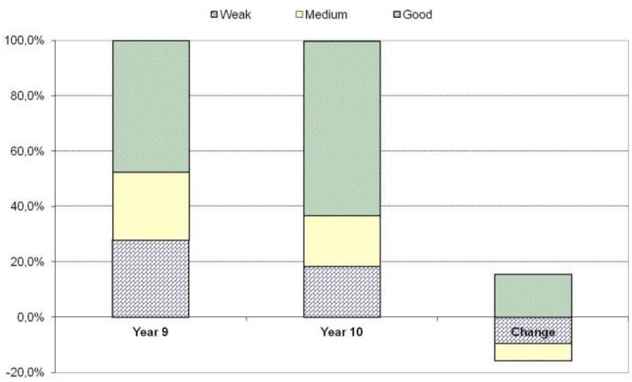

Figure 7. The distribution of the results of the Task 1 of spatial image based on the profession – technical area of vocational secondary education

As the results above were examined, the performance of the students varies as the study progresses of the first task of spatial notion (Figs. 7-9; the change, comparing to the year 9, was given on the right side of the figures), as this is the type of assignment, which is clearly reflected in the technical drawing curriculum. It is an integral part of the technical vocational secondary education in the year 9 and year 10 however, it is not curriculum in the economic areas and only appears partly in the grammar school education as visual culture. The diagrams clearly observed that the most significant improvement in the engineering field can be observed, the percentage of good results rose from 47.5% to 63.2%, paralleling the performance of the year 9 grammar school students (62.5%). The latter made a more modest rise, but they started from a higher level. The change in the economic and service area is negligible apart from the students who perform poorly, a 4.1% decrease.

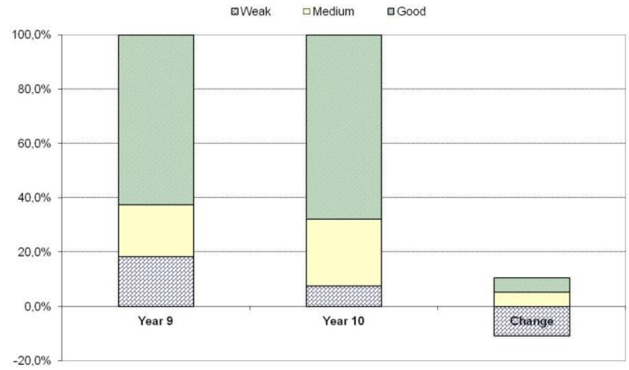

Figure 8. The distribution of the results of the Task 1 of spatial image based on the profession – grammar school

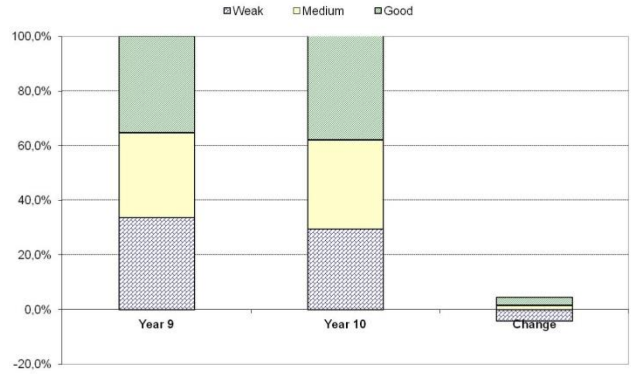

Figure 9. The distribution of the results of the Task 1 of spatial image based on the profession – economic and service area of vocational secondary education

The technical drawing subjects of the technical area definitely develop this componential ability however it is also pointed out that grammar school students are likely to start from a higher level because of their more advanced intellectual abilities. That said, two things are claimed: first, the spatial image can be successfully develop with the education of technical drawing, and on the other hand, the students with better results, aiming the grammar school education and having better intellectual abilities, perform better in this area. It will be certified with an intelligence test in the future.

Within the economic and service areas, it can be observed that the distribution of the poor (less than 0.25), medium (the range of 0.25 to 0.75) and high (greater than 0.75) results had nearly even, and is hardly changed in year 10.

Next, the results of the 3D mental rotation task should be examined, even more so, because similar tasks often occur during intelligence tests. The field distribution of student performance is shown in the Fig. 10. Nearly half of the students achieved a poor performance on vocational education, while this ratio was 40% of the grammar school students. Close to a third of the grammar school student achieved good results (31.5%), while the students on the technical area only reached 20%). The relationship between the variables was tested to verify, using the Pearson Chi-square test, which confirmed that the results achieved in 3D mental rotation task and the field variables significantly correlated ($\chi^2 = 34.442$; df = 16; $p < 0.05$).

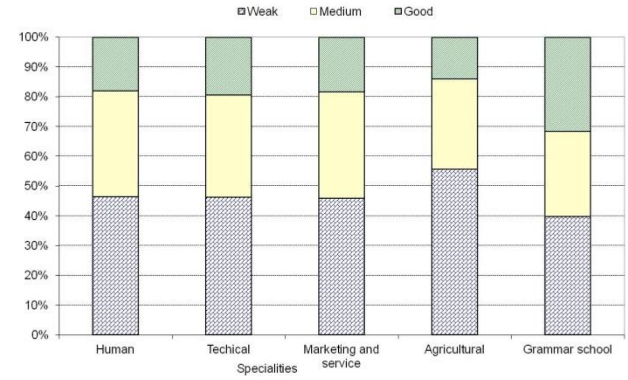

Figure 10. The distribution of the results of the 3D tasks by specialization

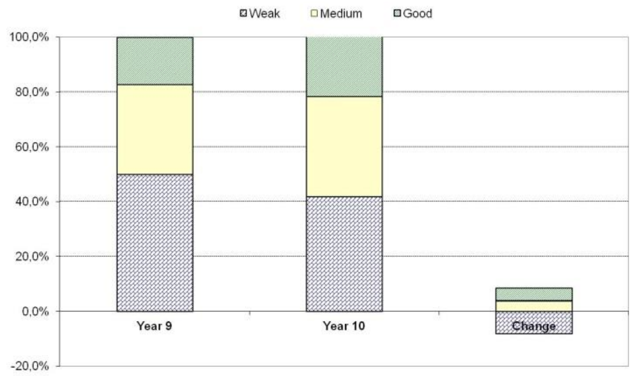

Figure 11. The distribution of the results of the 3D tasks by specialization - technical area

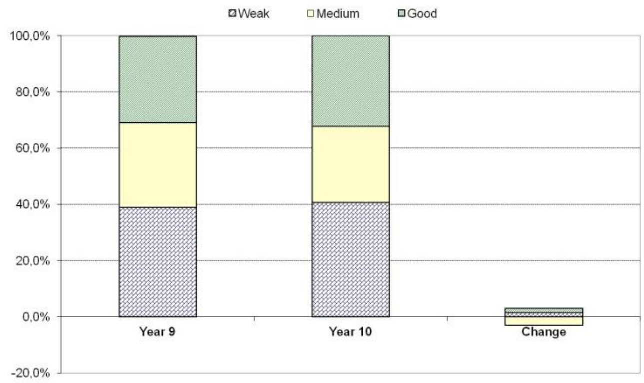

Figure 12. The distribution of the results of the 3D tasks by specialization – grammar school

If the results of the students are compared in a componential capability by profession, then the change is much lower during the progression of the study. There is virtually no change in the result of the grammar school students (Fig. 12), in the technical area of vocational secondary education, it decreases by 8.2% (Fig. 11), while in the economic and service area, the ratio of poor students is decreased by 5.1% (Fig. 13). In these two areas by examining the ratio of good performers, we can conclude that the proportion significantly increase in the engineering area (4.6%) than in the economic and service areas (0.9%).

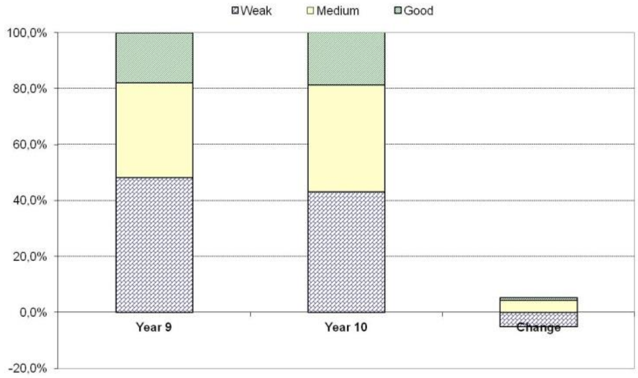

Figure 13. The distribution of the results of the 3D tasks by specialization – economic and service area of vocational secondary education

These indicate that three-dimensional mental rotation is a more stable visuospatial componential capability, than spatial vision. Grammar school students show much better performance in this area too, in the beginning of year 9, which secondary school fellows can only work a few percent of by the year 10.

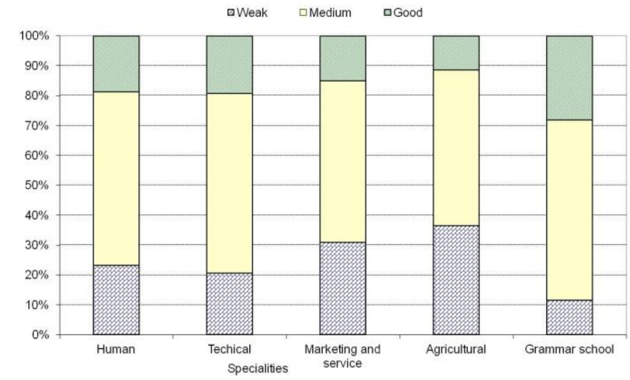

Figure 14. The distribution of results of analysis task by profession

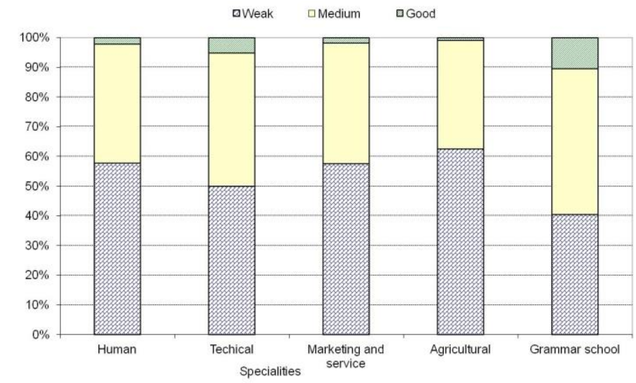

Figure 15. The distribution of results of synthesis task by profession

The primary tasks requiring mental operations have shown very different results. The distribution of the results of the analysis task is similar to the three dimensional rotation (Fig. 14), however the students achieved very poor results on the synthesis task (Fig. 15), nearly 10% of the grammar school students reached good results while in the engineering school, only 5%.

IV. Conclusions

Components of mental operations of the studies show different levels of progress… but still progress. The axonometric image greatly simplifies alignment of individual projections. The synthesis operations proved to be less developed due to greater use of axonometric shapes of complex relations and visual memory.

The level of development of basic mental operations is very diverse. The average results of the analysis are double of their syntheses. The factors of mental operations of the latter were the least developed. It also contributed to the lower performance, that, throughout the mental adaption, more and more complicated components were simultaneously stored in visual memory. The spatial relations of the tasks also differed; the non-visible should have been inferred in the analysis of the relations of the building blocks.

Similar differences were shown in the two tasks of spatial notion. As expected, the given axonometric image made the spatial connection of the projections much easier. The best average result was obtained for this task, but also having the highest standard deviations.

Only a slight difference was observed in relationship for the rotation and mirroring of axonometric shapes and the ability of mapping and manipulating the spatial elements.

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