Visuospatial Abilities Development of Post-Secondary Students

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Abstract
Research indicates that the individual has certain developmental differences and preferences in the area of spatial processing and visuospatial abilities. Goal of our research was to determine the development of the mental operational skills of students. About 4,500 secondary vocational school students participated in our investigation which was representative of the students in relation to gender and learnt specialization and to geographical position of the schools. Only a slight difference was diagnosed in relation with the different mental operational abilities.

Keywords
Visuospatial abilities, allocentric and egocentric spatial processing, mental operational abilities, secondary vocational education

1. Preliminaries
In our previous study (Toth, 2016) on one hand the components of visuospatial abilities were interpreted and classified, on the other hand the first results of our research conducted in Budapest aimed at mental visuospatial development of operational capabilities presented among vocational high school students. In the study examples were given from the questionnaire package used throughout the examination. The tasks are given in Table 1 once again, but this time the method (self- or object-oriented) which can be triggered by the task was indicated as well.
The egocentric individual can imagine spatial situations from different perspectives, while the allocentric can mentally manipulate objects from a fixed perspective (Figure 1). (Kozhevnikov – Hegarty, 2001; Shah – Miyake, 2005) In a case of a healthy person both ability-components are necessary for the orientation in space.

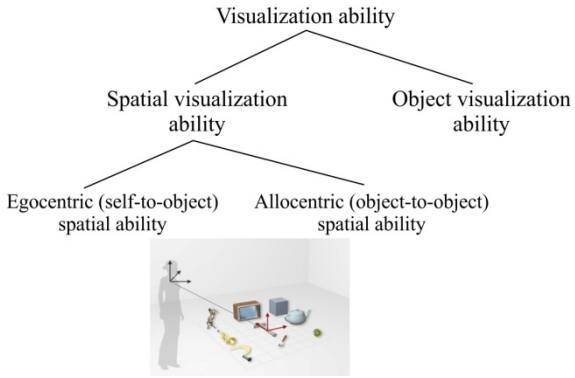

Figure 1. The system of visualization abilities

The inner, egocentric navigation system is used to determine our position in space relative to ourselves, which refreshes continuously when on the move. The allocentric system enables spatial representations (E.g. length, width, reference points, such as attribute) defined in the independent observer coordinate system. The reference point is defined by an external object. Both of these systems is a complex, multi-subsystems and cognitive as well as a variety of encoding or learning strategies are used on the neurological level. While the answer to the egocentric system is learning and internal navigation, the simple stimulus-learning and the more complex location-learning is more common for the allocentric system. (Newcombe – Huttenlocher, 2007; Shah – Miyake, 2005)

Research has shown the individuals with certain preferences and visual - verbal and visual spatial - visual material as well as the egocentric - allocentric in relation to spatial processing and abilities. These preferences gave the basics of the researches with such a direction of cognitive styles. (Blazhenkova – Kozhecnikov, 2009; Dean – Morris, 2003; Mayer – Massa, 2003; Newcombe – Huttenlocher, 2007; Shah – Miyake, 2005)

Table 1. Examined mental operational abilities and their tasks

Mental operations		Tasks
1. Elementary mental operations		
(Allocentric spatial abilities)	Mental analysis	Disassembling formations built from axonometric cubes (T1)
	Mental synthesis	Creating a complex object made from axonometric truncated columns (T8)
2. Complex mental operations		
(Allocentric and egocentric spatial abilities)	Mental rotation	With two-dimensional shapes (T2)
		With (stereoscopic) axonometric shapes (T5)
	Mental mirroring	With axonometric shapes (T4)
3. Multiple complex operations		
(Egocentric spatial abilities)	Spatial image 1	The merge of three projections with different point of views, based on isometric image (T6)
		Connection of two projections to a given point of view with merging (T7)
(Allocentric and egocentric spatial abilities)	Spatial image 2	Combining six-course perspective projection, putting and moving, rotating and connecting to isometric shapes (T3)

The students of 41 secondary vocational schools in Budapest took part in the examination. 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.
The test's reliability coefficients, the complete and sub-patterns are shown in Table 2. The test is considered reliable if the Cronbach's alpha is greater than 0.7. This condition is met in the whole sample, while in a case of some sub-samples it didn't quite hit the mark.

Table 2. Reliability coefficients

	Boys	Girls	Year 9	Year 10	Right hand	Left hand	Both hands	All
T1	.898	.883	.870	.887	.897	.867	.855	.894
T2	.917	.903	.880	.936	.924	.863	*.648*	.914
T3	.880	.842	.810	.920	.867	.870	.886	.867
T4	.751	*.696*	*.692*	.760	.734	.705	.864	.733
T5	.711	.705	*.698*	.719	.700	*.694*	.826	.709
T6	.928	.868	.898	.912	.903	.906	.892	.903
T7	.917	.819	.880	.890	.889	.870	.941	.888
T8	.755	*.695*	.757	.870	.833	.708	.910	.716

Note: See the abbreviations of the number of tasks

In this study we try to answer two questions:
How do the connections of mental process variables develop?
What connections can be demonstrated between the complex operational ability and variables for each student?

2. Correlations of mental operational abilities

Table 3 shows the correlations between the variables. The strongest correlation is measured in relation to the two spatial image tasks. Because the components of different operational abilities were examined, so it is not exactly the best if there is a strong correlation between these variables. The task examining the two spatial images can now be merged or one of them can even be omitted. The correlational coefficients ranging between 0.2 and 0.7 show and

average connection. The relation between mental mirroring 3D and mental rotation 3D, and mental rotation and synthesis variables are considered to be weak.

Table 3. Correlations between individual ability-components I

	T1	T2	T3	T4	T5	T6	T7	T8
T1	1	.356*	.329*	.265*	*.184**	.352*	.338*	.237*
T2		1	.425*	.300*	.228*	.427*	.421*	.269*
T3			1	.303*	.215*	.410*	.405*	.255*
T4				1	*.162**	.353*	.345*	.226*
T5					1	.208*	.209*	*.129**
T6						1	.610*	.218*
T7							1	.337*
T8								1

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

Thus it can be establishes that the tasks which measure the mental operational abilities are sufficiently differ from each other, except for the two tasks of spatial image.

The Task 6-7 was formed by averaging the scores of the two spatial image tasks (merging three projections with different point of views based on a stereoscopic (axonometric) image, connecting two other projections to an image with a given point of view with merging). According to the amended again, the correlations were examined. The connection of 3D mental mirroring - 3D mental rotation, 3D mental rotation - synthesis and 3D mental mirroring - synthesis shows a low grade (less than 0.18; p=0.01). Therefore it can be concluded that students in the aspect of the analysis - mental rotation - mental mirroring - synthesis have performed in very different ways.

Table 4. Correlations between individual ability-components II

	T1	T2	T3	T4	T5	T6-7	T8
T1	1	.352* .348*	.313* .334*	.231* .286*	*.196** *.172**	.364* .399*	.235* .222*
T2		1	.429* .407*	.265* .322*	.239* .219*	.467* .464*	.277* .239*
T3			1	.267* .326*	.207* .229*	.449* .445*	.303* .166*
T4				1	*.161** *.169**	.391* .357*	.204* .227*
T5					1	.250* .212*	*.154** *.096**
T6-7						1	.332* .213*
T8							1

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

Table 4 shows the correlations of the operational abilities in the aspect of boys (higher values) and girls (lower values). In the aspect of boys a significantly stronger correlations were measured in the aspects of 2D mental rotation - spatial notion, 2D mental rotation - synthesis, spatial image - synthesis, mental mirroring - spatial image, 3D mental rotation - spatial image and spatial image - synthesis. In the case of girls there was a stronger correlation in the aspects of analysis - spatial image, 2D mental rotation - mental mirroring, spatial image - mental mirroring and mental mirroring - synthesis.

The correlations were also examined in the aspect of grade, in the case of the Year 9 and Year 10. Apart from the correlation of analysis - 3D mental rotation and analysis - spatial image, significantly higher results were encountered in some of the aspect of connection. It can be concluded that with the progression of studies, the individual components of development of abilities converge with each other.

In the case of right-handed students in almost all operational aspects a much stronger correlation was found in almost all aspects of operational variable of the preferred hand for drawing. The exceptions are analysis - 3D mental rotation, analysis - mirroring, 2D mental rotation - mirroring and 2D mental rotation - spatial image. However, these can be established in the aspect of the highest correlational coefficient.

3. Individual dimensions of the complex operational variables

Using the variables of mental operations a complex variable was created then the students' results according to that variable were categorized. The values obtained were subjected to cross-table analysis.
The relative values resulting complex variables were first examined by gender (Fig. 2-3).

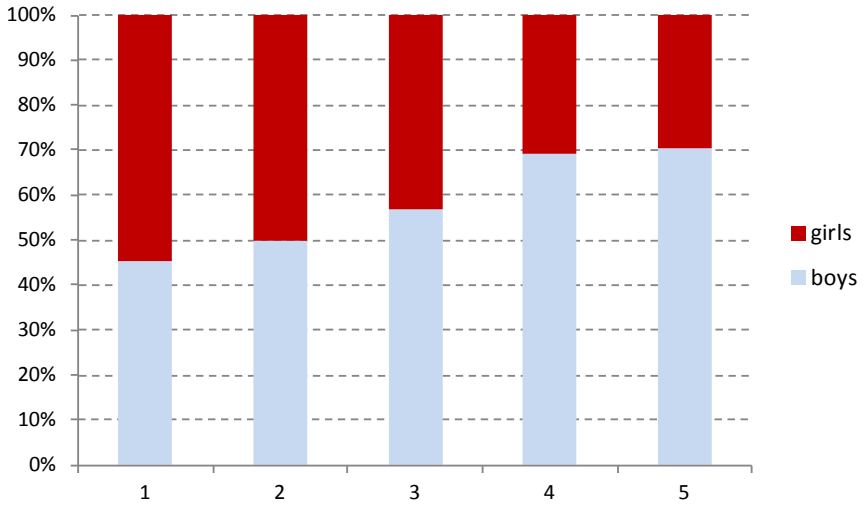

Figure 2. The distribution of the complex mental variable by gender I.

The boys performed better than girls. The students who achieved a 5 (Grade A, excellent) or a 4 (Grade B, good) were 70% boys, while 21.3% of the boys performed that well, only 11.6% of the girls could achieve a good or an excellent rating.
The variables were examined whether they are related. To examine the relation between the variables Pearson's Chi-squared test was chosen. The observed value of the indicator is 65,168 (df = 4) which exceeds the value of the theory (threshold) even when examined on a double-sided significance level of 0.000, that said, the significance level is lower than 0.05, which we have chosen. This means that we reject the null-hypothesis that says there is no correlation between the two variables. Accordingly, it is assumed that there is a significant correlation between sex and the complex mental process variable of the students.

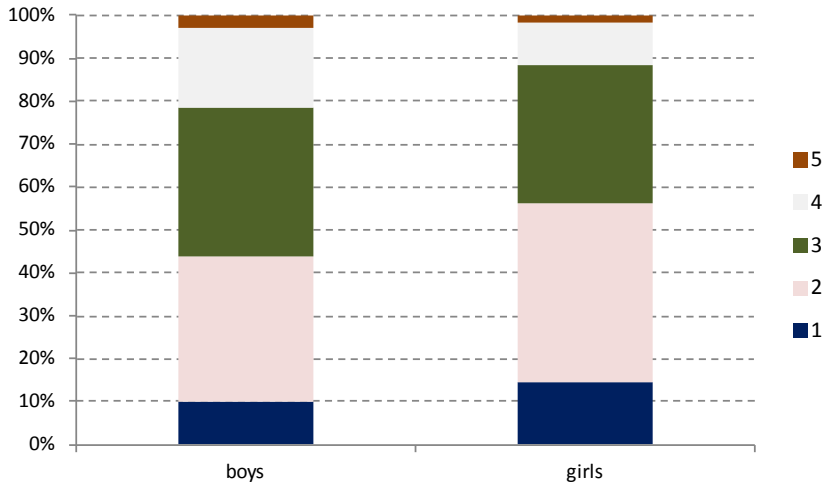

Figure 3. The distribution of the complex mental variable by gender II.

The performance of the students according to grades is shown in Figure 4-5. The students who achieved a 4 or a 5 are 60%, and 70% 10th graders, while 22.6% of the Year 10 students got a 4 or a 5 rating, this number was only 12.0% on the Year 9.

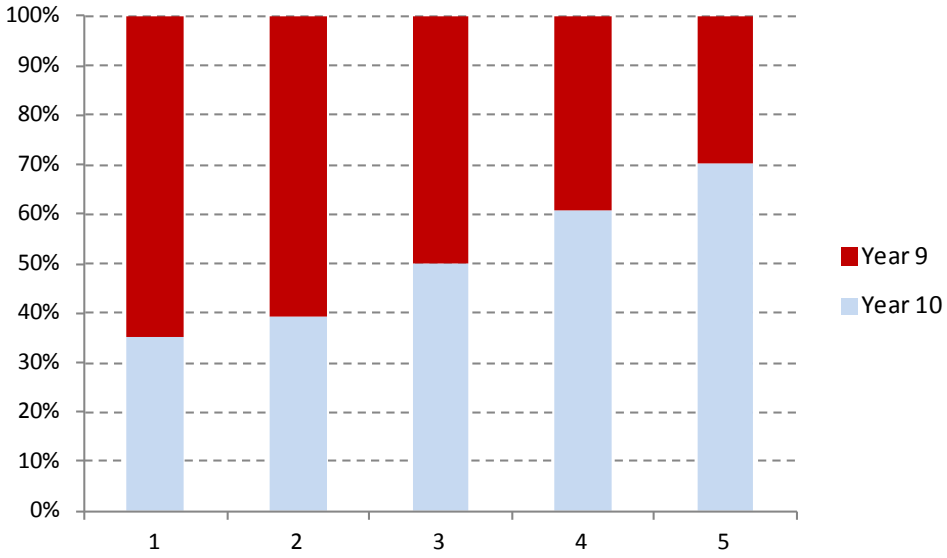

Figure 4. The distribution of the complex mental variable by Year I.

Pearson's Chi-squared test was chosen again to examine the connection between the two variables. The observed value of the indicator is 91,330 (df = 4) which exceeds the value of the theory (threshold) even when examined on a double-sided significance level of 0.000, that said, the significance level is lower than 0.05, which we have chosen. This means that we reject the null-hypothesis that says there is no correlation between the two variables. Accordingly, it is assumed that there is a significant correlation between year of the students and the complex mental process variable.

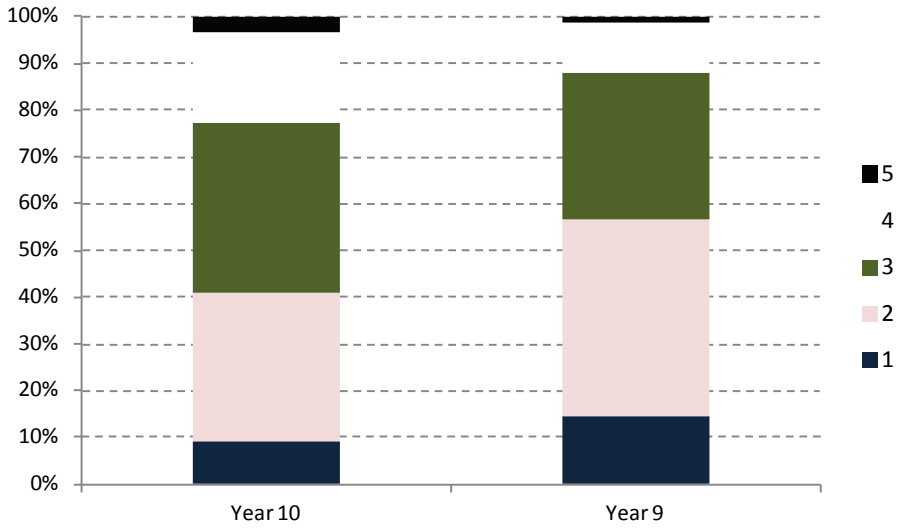

Figure 5. The distribution of the complex mental variable by Year II.

In the aspect of the preferred hand for drawing, no essential difference was found in the performance of the students. Good or excellent performance was achieved by 17.3% of right-handed, 14.1% of left-handed and 16.9% of both-

handed students. It is important to note that the students didn't have to draw during the test. Weak performance was achieved by 48.8% of right-handed, 53.3% of left-handed and 51% of both-handed students.
Pearson's Chi-squared test was chosen to examine the connection between the two variables. The observed value of the indicator is 4,712 (df = 4) which does not exceed the value of the theory (threshold) even when examined on a double-sided significance level of 0.318, that said, the significance level is higher than 0.05, which we have chosen. This means that we accepted the null-hypothesis that says there is no correlation between the two variables. Accordingly, it is assumed that there is a significant correlation between the preferred hand of the students and the complex mental process variable.

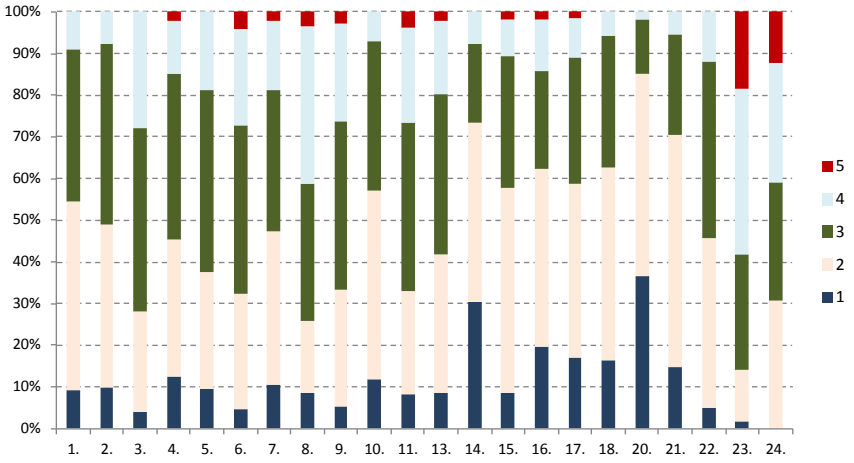

Figure 6. The distribution of the complex mental variable by group of profession.

The situation is different in the aspect of the students' group of profession and type of high-school (Fig. 6). The interpretation of this is seen in the 2nd annex. Good or excellent performance was achieved by 58.3% of six-year grammar school, 40.8% of four-year grammar school and 41.3% of secondary vocational school students in chemical specialization. Good result was achieved by students in the profession groups of education (28%), electronics (27.2%), architecture (26.1%) and wood industry (26.6%). There are two other groups of profession where visual operations have an important role in professional work. It is noteworthy that only 18.8% (mechanical engineering) and 19.8% (transportation) of the students of these groups achieved good or excellent results.
Pearson's Chi-squared test was chosen to examine the connection between the two variables. The observed value of the indicator is 570,871 (df = 84) which exceeds the value of the theory (threshold) even when examined on a double-sided significance level of 0.000, that said, the significance level is lower than 0.05, which we have chosen. This means that we reject the null-hypothesis that says there is no correlation between the two variables. Accordingly, it is assumed that there is a significant correlation between the group of profession of the students and the complex mental process variable.
The comparisons of the groups of professions are carried out along grades. The change, throughout the progression of studies is shown in Fig. 7. It can be concluded that as the studies progress, nearly all the students in the groups of professions could achieve better results. The students of three types of secondary vocational school specialization, mechanical engineering, electronics, IT, architecture, wood industry, transport and administration particularly stand out. Students of these areas can be divided into two groups: grammar schools and administration specialization groups, engineering groups in secondary vocational school. In the first group, mainly the developer impact of the subjects of mathematics and visual culture can be highlighted, in the technical group, mathematics technical drawing and visual culture had an impact.
Pearson's Chi-squared test was chosen to examine the connection between the two variables in Year 9. The observed value of the indicator is 354,275 (df = 80) which exceeds the value of the theory (threshold) even when examined on a double-sided significance level of 0.000, that said, the significance level is lower than 0.05, which we have chosen. This means that we reject the null-hypothesis that says there is no correlation between the two variables on Year 9. Accordingly, it is assumed that there is a significant correlation between the group of profession on Year 9 of the students and the complex mental process variable.

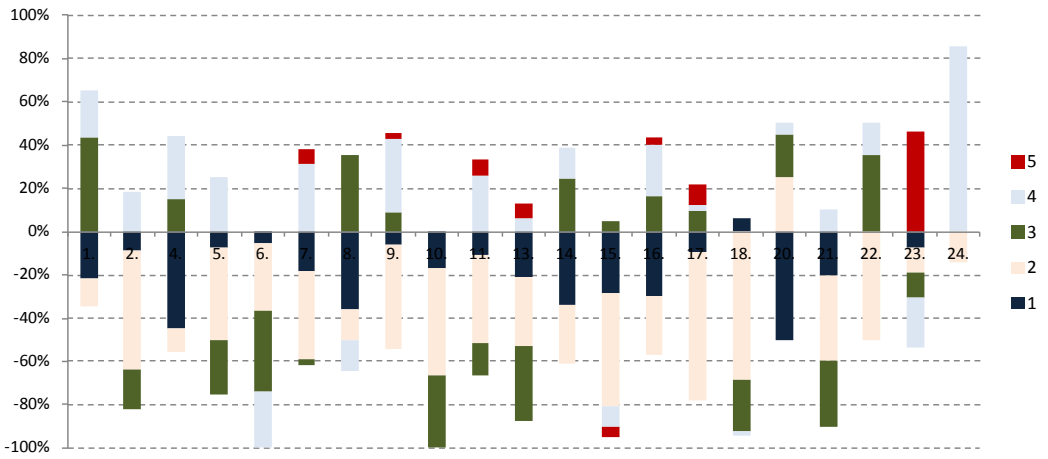

Figure 7. The changes in the results of complex mental variables as the study progresses by profession groups.

Pearson's Chi-squared test was chosen to examine the connection between the two variables in Year 9. The observed value of the indicator is 348,335 (df = 84) which exceeds the value of the theory (threshold) even when examined on a double-sided significance level of 0.000, that said, the significance level is lower than 0.05, which we have chosen. This means that we reject the null-hypothesis that says there is no correlation between the two variables on Year 10. Accordingly, it is assumed that there is a significant correlation between the group of profession on Year 10 of the students and the complex mental process variable.

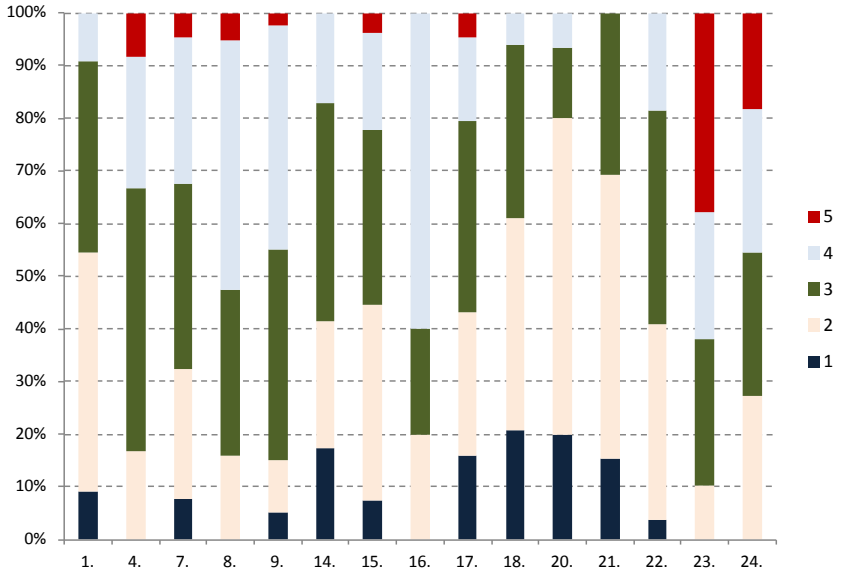

Figure 8. The changes in the results of complex mental variables as the study progresses by profession groups – Year 10, boys.

The observed value of the indicator is 200,219 (df = 84) in the case of boys, in the case of girls this number is 205,421 (df=80) which exceeds the value of the theory (threshold) even when examined on a double-sided significance level of 0.000, that said, the significance level is lower than 0.05, which we have chosen. This means, that in the aspect of genders we reject the null-hypothesis in both cases that says there is no correlation between the two variables on Year 10. Accordingly, it is assumed that there is a significant correlation between the group of profession of boys and girls on Year 10 and the complex mental process variable.

A deeper relationship on Year 10 was looked for, so the results of boys and girls were compared by profession groups. Only those groups were examined where both of the genders were represented. If the performance of the

boys (Fig. 8) was compared with the performance of the girls (Fig. 9), than it could be established (if the group of management doesn't count) that the ratio of excellent students was higher in the case of boys. However, if the good and excellent results are observed together, girls achieved a better performance among grammar school students. In the case of the students who achieved weak results, the ratio between the performance of the genders are equal. Among average students, this ratio is greatly higher for the girls.

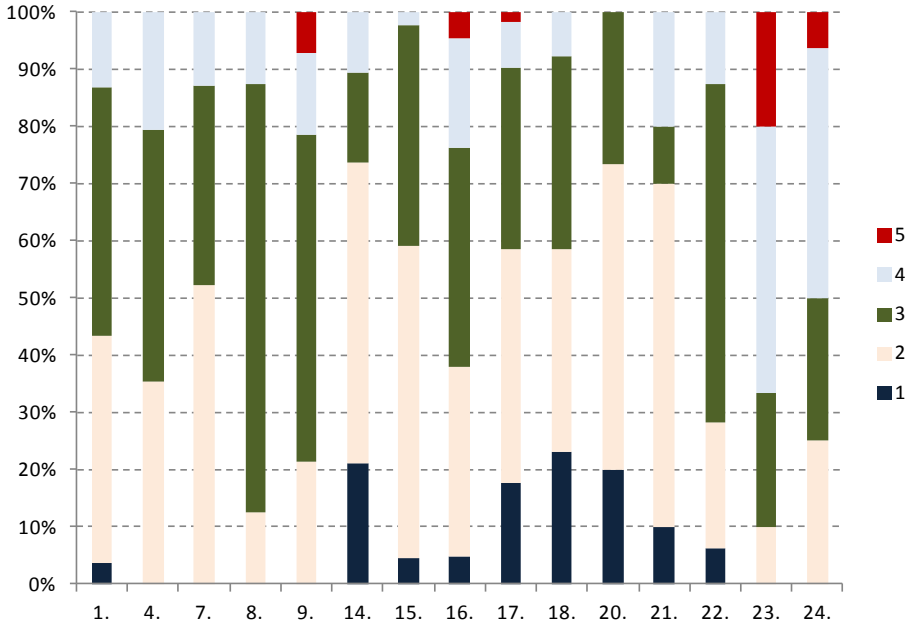

Figure 9. The changes in the results of complex mental variables as the study progresses by profession groups – Year 10, girls.

The Chi-squared test was also done between the variables (professional groups - complex mental variables) of the genders to determine the correlations.

4. Conclusions and considerations

1. How do the connections between the variables of mental operations develop?

In the case of boys, a significantly stronger correlation was shown in the aspect of 2D mental rotation - spatial image, 2D mental rotation - synthesis, spatial image - synthesis, mental mirroring - spatial image and 3D mental rotation - spatial image, while in the case of girls these aspects are analysis - spatial image, 2D mental rotation - mental mirroring, spatial image - mental mirroring and mental mirroring - synthesis.

In terms of grades, in almost all cases of connections a significantly higher correlation was found as the study progresses. Obviously, this has an impact on the development of subject content, such as technical drawing on the technical secondary vocational school context.

2. What network of connections can be found between the complex operational abilities and variables for each student?

Using the mental operational variables a complex variable was defined then it was examined in the individual dimensions of the variables.

A significant connection was set in the gender, grade, group of profession, date of birth and complex variable of the students, but it should be noted that we can only predict the development of operational abilities with a high rate of failure.

In the comparison of the groups of profession a significant difference could be observed between the performance of grammar school and secondary vocational school students in favor of the former. It is particularly interesting that in such areas of profession like engineering or architecture, there are some students with underdeveloped mental abilities. It is particularly appropriate to reconsider the methodology of technical drawing in teacher training.

A deeper context was looked for in the aspect of profession groups in Year 10, so the results were compared by gender too. A significant correlation can be observed between the profession groups and complex mental operational variables of Year 10 boys and girls.

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Biography

Peter Toth is a professor of Trefort Agoston Centre for Engineering Education at Obuda University, Hungary where he is participating in technical initial teacher training and in-service training courses. Currently he is a principle director of the Centre. He earned his MSc in Engineering Education at the Budapest University of Technology and Economics, and Peter Toth has Ph.D and habil. degree in Educational Research from Eotvos Lorand University. He plays leading role in planning, development and managing traditional and virtual engineering programs. He is member of Committee for Teacher Training of Hungarian Rectors' Conference and secretary of Teacher Education Section of Pedagogical Committee of Hungarian Academy of Sciences.