FROM RESEARCH ON SPACE IMAGINATION

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Abstract

The work looks for phenomena related to the development of spatial imagination. In theoretical part, we define spatial imagination and the aim for finding factors which influence its development, e.g. schooling, sex, laterality or the role of senses. Research investigation forms the practical part of the paper. In the individual investigations, we search for the relation between spatial imagination and general intelligence, between spatial imagination and imagination in plane. By means of the Top-view or bottom-view test, we search for the answer to the question how spatial imagination relates to laterality. Based on the findings obtained in the research investigations, we developed the worksheet Wire and cube that was checked during the class work at an elementary school. The benefit of the paper for the development of the scientific branch and pedagogical practice is the study of phenomena related to the performance and the results of the spatial imagination tests that can be influenced by these phenomena.
Key words: *knowledge of solid geometry, laterality, schooling, spatial imagination, teaching geometry.*

Introduction

Using modern technology has become commonplace of our every-day life. We often search for the answer to the question "what abilities are indispensable for us in this context?" Spatial imagination is surely one of them. Seeing objects, which are at present not constructed, is related to creativity, the ability to create new objects. When solving geometrical problems, we also make use of a sketch, the contribution of which lies in the visualization of a given situation. The sketch enables us not only to see a problem in the visual sense, but it also involves understanding the problem and its dependencies. Now, in the days of computerization, the graphical language and environment represent an important tool for communication among people. Sketch drawing, good spatial imagination and graphical data processing rank among indispensable skills of a man.

It is generally known that the level of spatial imagination is influenced by internal and external factors. The internal factors comprise not only the current state of sexual hormones and the overall state of a given organism, but also the hormones level in the pre-natal stage of the individual's development. The external factors are then represented by geographical and social environment, culture and especially upbringing and education (Molnár, 2004).

The researches have shown that the performance of the probands might be influenced by other phenomena. We have therefore focused on the connections of spatial imagination to some of these phenomena in our further research work, the realization of which we present this paper.

What is it spatial imagination?

We were concerned with defining the approach to the term "spatial imagination". In literature, imagination is defined in a number of ways. Albert Einstein is credited with an opinion that "imagination is more important than knowledge". A man is distinct by the ability to recall certain experiences and evoke imaginations. Imaginations are a visual reflection of objects and phenomena that we do not percept (see) in a given moment and they arise as a result of a psychic process called "imaginativeness". For the needs of our research, we have defined the spatial imagination as follows: Josef Molnár (2004) defines spatial imagination as "the set of abilities concerning reproductive and anticipation, static and dynamic imagination of shapes, properties and mutual interactions among geometrical figures in space". Slavomíra Schubertová (2008) understands spatial imagination as the set of skills of an individual which develops in the interaction with the environment on the basis of learning and experience ensuring accurate perception of the visual world. This means to recall, create and store geometrical forms in mind, to manipulate with them, restructure and to remold them, group them, transform them, make a graphical record of a given spatial situation as well as to model it and orientate oneself in a three-dimensional part of the real world.

Methodology of Research

The research has been carried out in two areas and thus two main hypotheses have been formulated:

Hypothesis 1 states that there exists a relationship between spatial imagination, geometrical imagination in plane and the general intelligence.

Hypothesis 2 asserts that there exists a relationship between spatial imagination and laterality. More specifically, we have formulated a hypothesis that the right-handers will do better when solving the tests pictured in the plan view or bottom view from the right, the lefties will then do better when having the plan view or bottom view form the left.

Relationship between spatial imagination, geometrical imagination in plane and the general intelligence

Hypothesis 1 has been solved using two different tests – Amthauer's test (1968) and Wechsler's test (2002).

Firstly, we will have a closer look at the methodology of Hypothesis 1 verification by means of Amthauer's test. One of the aims of our researches was to verify the relation among spatial imagination, geometrical imagination and general intelligence. Taking into consideration that spatial imagination is regarded as one of the components of general intelligence, problems (tasks) examining the current level of its development tend to appear in standardized psychological tests as well as in non-standardized didactical texts.

In this context, the Amthauer's test of intelligence structure I-S-T (1968), which is frequently used, seems to be useful for this purpose. We have therefore asked the workers of pedagogical-psychological advisory center in Olomouc for cooperation. The workers often use this test for examining fifteen-year-old students, who attend the last class of elementary schools and visit the advisory center in order to make their choices concerning their future job or an appropriate secondary school. Thus, we have obtained results from a sample of 104 respondents, 44 boys and 60 girls. We were comparing the results of the measured IQ with the results of the subtests number 7 (A Geometrical Form Selection) a number 8 (Dice Problems). The program STATISTICA has been used to compute the correlation coefficients.

Secondly, the methodology of the verification of Hypothesis 1 by means of Wechsler's test improves the methodology described above. A disadvantage of the subtest 8 of Amthauer's I-S-T is that the respondents solve the problems by means of mental rotation of imaginations without

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using models. Therefore, we were looking for a test, where the respondents would show their level of spatial imagination when manipulating with real objects. Finally, we found and used the test of Wechsler Intelligence Scale WISC III from 1996 (Nicholson, Alcorn 2008). In order to search for statistically significant differences, we were provided with the results processed by the staff of the pedagogical-psychological advisory center in Olomouc. These results comprised in total 108 pupils, out of whom 54 were girls and 54 were boys. The average age of the pupils was 14. It should be pointed out that pupils, who visit the advisory center to solve their difficulties during school teaching, took part in the testing.

An advantage of the subtest entitled “Cubes”, which we were particularly interested in, is the explicit activity of a pupil, who constructs various formations using two-color cubes while being limited by time and also by the difficulty level which gradually increases with time. The pupils’ performance in the test is influenced by the following factors: the level of spatial imagination, manual skills, sensor-motor coordination, the extent of logical thinking, analysis and synthesis of the concrete visual stimuli, visual perception, operating memory capacity or experience. Other factors should be mentioned too – change in environment, the attitude to testing, emotional state (mood), balance, fatigue, task motivation, stress tolerance, attitude toward the school teaching, the situation in the family. We computed the value of the average score by means of t-test.

The subtest “Repeating Numbers”, as its name suggests, is based on repeating a sequence of numbers in its original order as well as backwards. These number sequences are presented to a pupil orally. The performance is influenced by the level of concentration and the quality of short-time memory.

Another subtest is called “Similarities” which assesses the achieved level of concrete formal operations, abstraction abilities and the flexibility in thinking. In this subtest, a pupil is being offered different couples of objects, such as an apple and a pear, and the pupil looks for the connections (links) between the two terms, in our case “fruit(s)”.

Yet another subtest that has been assigned to the pupils is entitled “Picture ordering”. It assesses the level of non-verbal thinking, where a pupil tries to determine the correct order of pictures lying on a mat. The result is influenced by the pupil’s visual perception and vigilance.

Relationship between spatial imagination and laterality

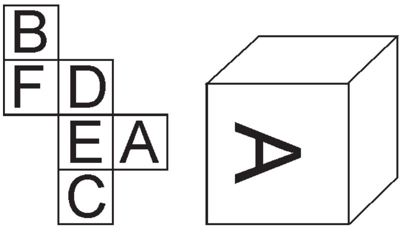
The other area of our interest is the relationship between spatial imagination and laterality (hypothesis 2). In real life, we often observe the world around us from the bottom or side view. In textbooks, geometrical figures (solids) are usually pictured as viewed from above and the right-hand side (i.e. the right plan view). A following question has come to our minds: “does this illustration of solids suit all the pupils”?

For the needs of the research, we have created and assigned exactly the same test on spatial imagination, but illustrated in different views:

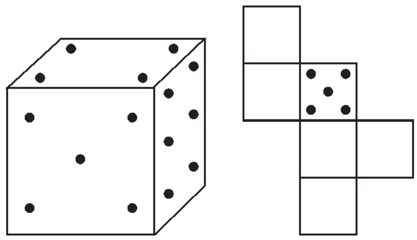
Test

Group A – view from above and the right

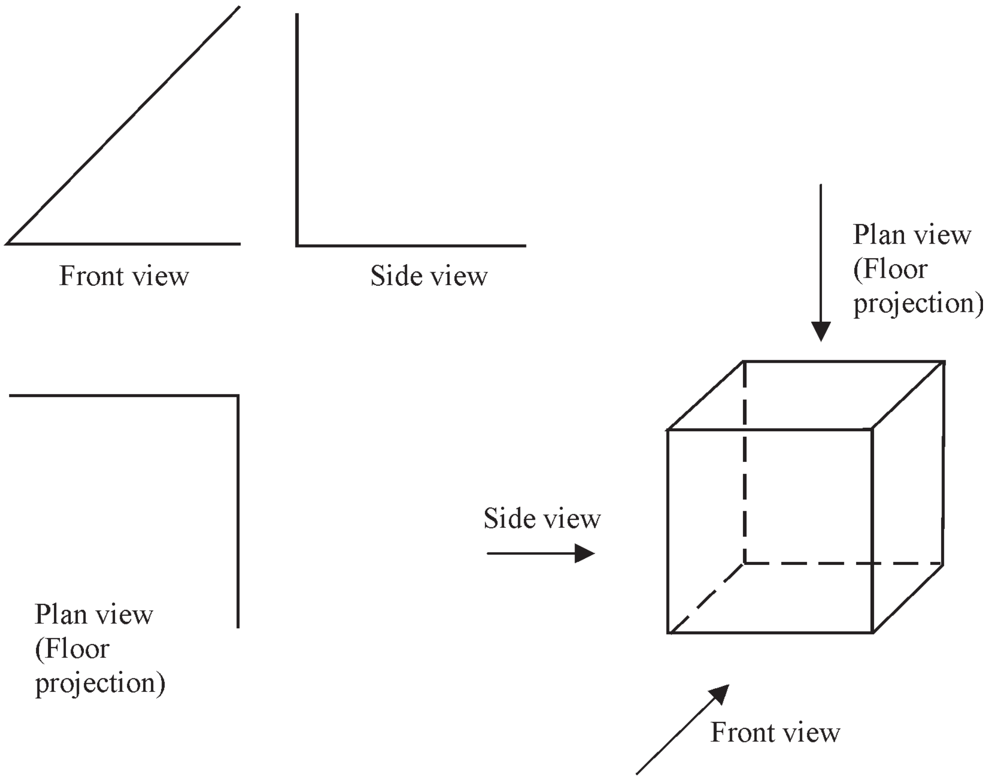
1) Label the visible sides of the cube using the letters according to the assignment, keep the rotation (i.e. orientation) of the letters too so that it corresponds to the grid.



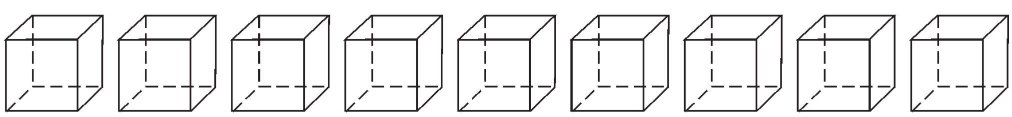
2) Fill out the grid of the cube with the appropriate number of dots according to the assignment if you know that the sum of dots on mutually opposite sides is always equal to 7.



3) A piece of wire is placed into a cube. The plan view, front view and side view is shown in the picture. Coil the wire up the cube and highlight it in color.

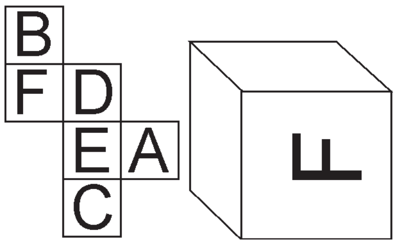


4) A cube has nine planes of symmetry. Draw them.

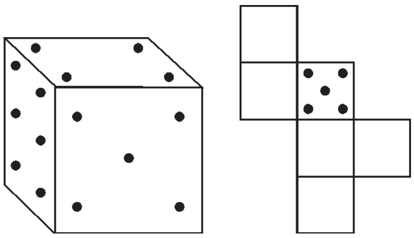


Group B – view from above and the left

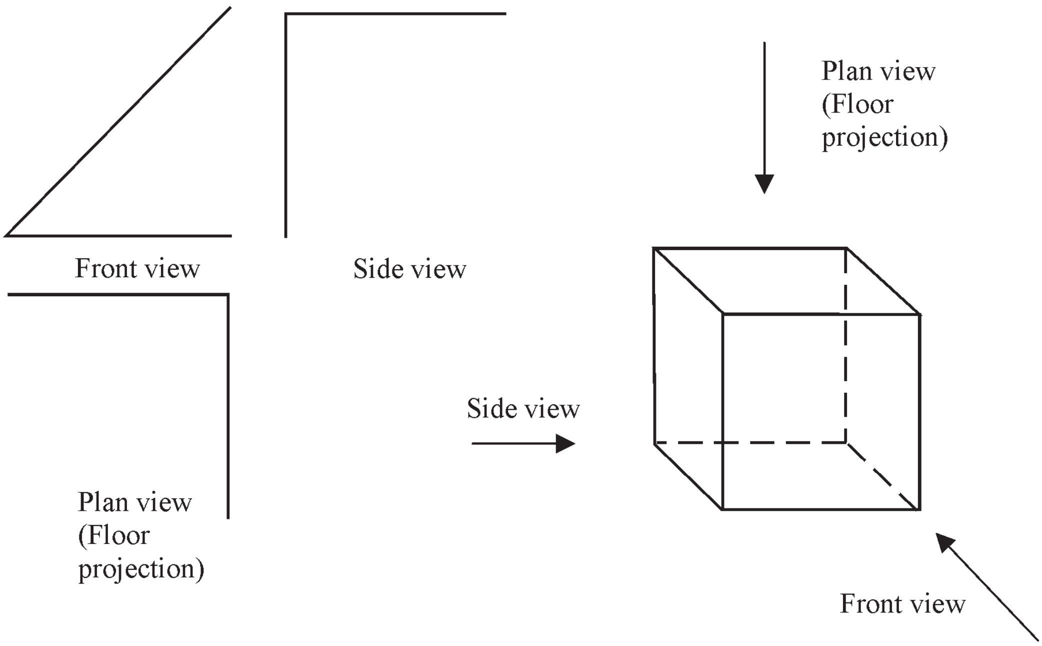
1) Label the visible sides of the cube using the letters according to the assignment, keep the rotation (i.e. orientation) of the letters too so that it corresponds to the grid.



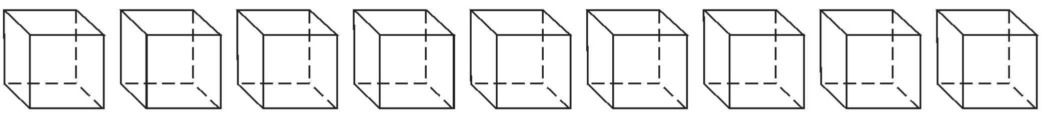
2) Fill out the grid of the cube with the appropriate number of dots according to the assignment if you know that the sum of dots on mutually opposite sides is always equal to 7.



3) A piece of wire is placed into a cube. The plan view, front view and side view is shown in the picture. Coil the wire up the cube and highlight it in color.

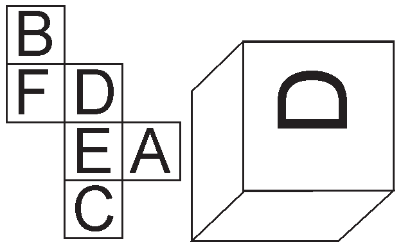


4) A cube has nine planes of symmetry. Draw them.

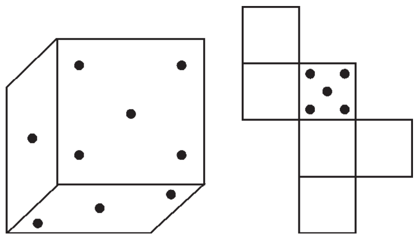


Group C – view from bottom and the left

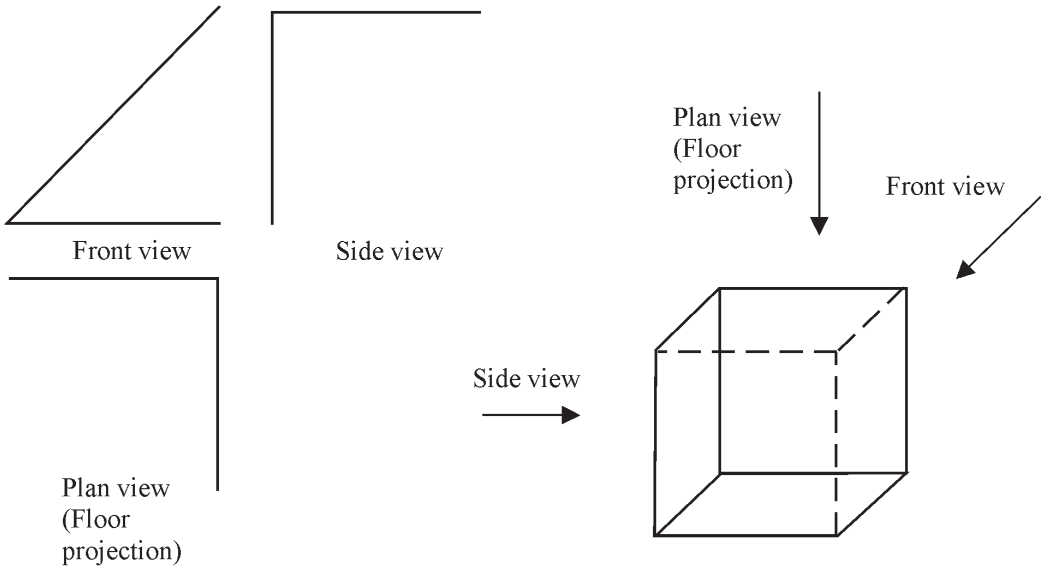
1) Label the visible sides of the cube using the letters according to the assignment, keep the rotation (i.e. orientation) of the letters too so that it corresponds to the grid.



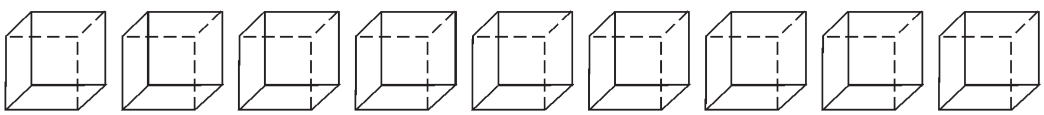
2) Fill out the grid of the cube with the appropriate number of dots according to the assignment if you know that the sum of dots on mutually opposite sides is always equal to 7.



3) A piece of wire is placed into a cube. The plan view, front view and side view is shown in the picture. Coil the wire up the cube and highlight it in color.



4) A cube has nine planes of symmetry. Draw them.



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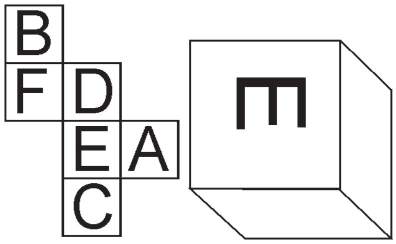
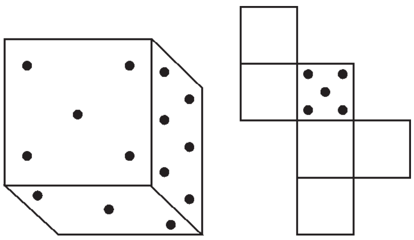
Group D – view from bottom and the right

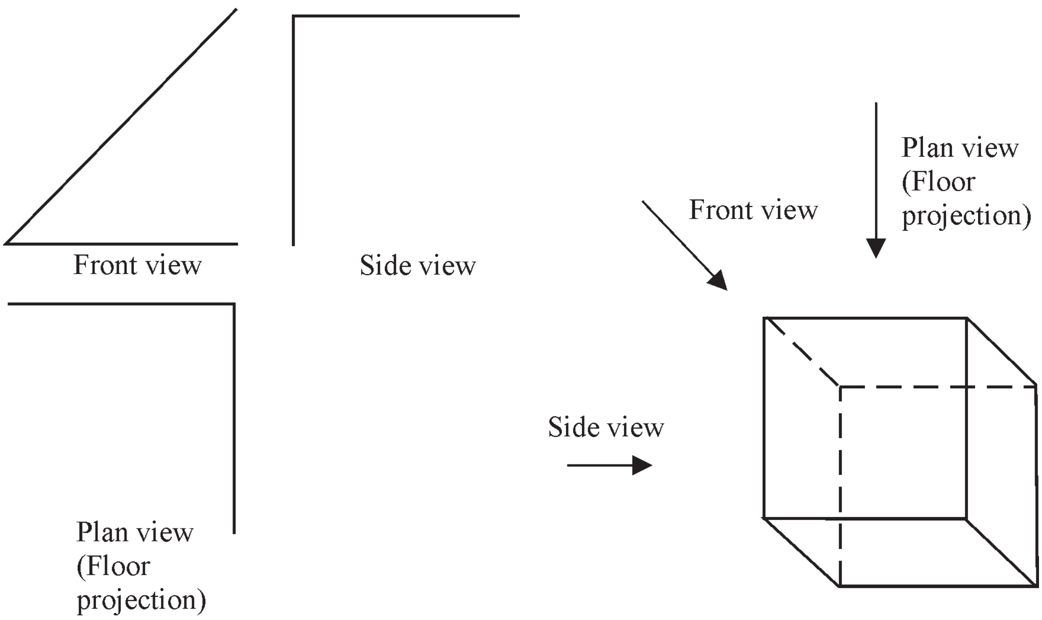
1) Label the visible sides of the cube using the letters according to the assignment, keep the rotation (i.e. orientation) of the letters too so that it corresponds to the grid.



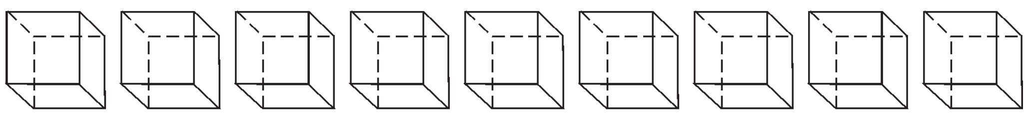
2) Fill out the grid of the cube with the appropriate number of dots according to the assignment if you know that the sum of dots on mutually opposite sides is always equal to 7.



3) A piece of wire is placed into a cube. The plan view, front view and side view is shown in the picture. Coil the wire up the cube and highlight it in color.



4) A cube has nine planes of symmetry. Draw them.



Results of Research

A correlation between spatial imagination and geometrical imagination in plane, which has been measured by means of the Amthauer's test, has been proved (correlation coefficient of 0.408 for the whole sample of 104 respondents), where the level of significance was set to 0.01. The comparison of the boys and girls has shown the following: in case of boys, the correlation of coefficient between spatial imagination and geometrical imagination in a plane was higher, equal to 0.415 at the level of significance less than 0.01. In case of girls, the computed correlation coefficient was 0.3912 at the significance level less than 0.02. The correlation between general intelligence and spatial intelligence has also been proved for the entire sample (correlation coefficient equal to 0.425, the level of significance of 0.01).

T-test has shown the following correlation values between the "Cubes" subtest and the other subtests of Wechsler's intelligence test.

Table 1. Correlation between the subtest "Cubes" and other subtests WISC III.

	similarities	ordering	calculus	comprehension	repeating numbers	IQ
cubes	0,5183	0,5589	0,4209	0,3476	0,4442	0,7212

The low level of dependence can be seen between the subtest "Comprehension", which comprises the ability to understand the reality and react to it in an adequate way. It depends on the ability to use different past experience. Although the computed value of correlation between the subtest "cubes" and the subtest "calculus" is higher, it does participate in the development of the spatial imagination level because of the test's focus. The subtest "Calculus" focuses on the assessment of the level of basic arithmetic operations. It concerns a set of arithmetic tasks, where a pupil gives his/her answers orally, without using a pencil and paper and having a certain time limit. The result of the test is significantly influenced by the ability to concentrate and stay sharp, psycho-motor pace and learning. The largest computed correlation value is the one between spatial imagination and the overall value of IQ. Based on the computed correlation values between the individual tests and the subtest "Cubes", which assesses the level of spatial imagination, we can observe that a higher correlation value has been found out between the tests which are influenced by the level of logical operations, visual perception, working tempo, experience and learning, different connections and relations comprehension, memory capacity, concentration and the ability to find a certain system in solving a given problem. As it has been already mentioned earlier in this section, the overall results depend on the current physical and psychical state of an individual and on his/her emotional state or mood.

Let us compare the results in the tests between the performance of the girls and boys.

Table 2. Correlation between the subtest "Cubes" and other subtests - boys

	similarities	ordering	calculus	comprehension	repeating numbers	IQ
cubes	0,4704	0,4756	0,4188	0,4759	0,4382	0,6822

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Table 3. Correlation between the subtest "Cubes" and other subtests – girls.

	similarities	ordering	calculus	comprehension	repeating numbers	IQ
cubes	0,5561	0,6138	0,4258	0,2438	0,4432	0,7598

In the sample of respondents, larger differences arose between the boys and girls in the subtest "Comprehension", where the girls were discomfited, less adapted to the given environment, more tired of testing and the current emotional state (mood) was influenced by fear, anxiety, uncertainty and natural fear of failure.

In the subtest "Picture ordering", the girls seemed to be more vigilant, which influenced the result in the test. The level of spatial imagination in the girls and boys, which was determined by means of the subtest entitled "Cubes", correlates with general intelligence.

When verifying Hypothesis 2, we have reached the following conclusions:

Table 4. The successfulness of solving the individual tasks according to the fact whether the pupils use their right or left hand for writing – Variant A (plan view from the right).

	No. of lefties (24)	No. of right-handers (25)	Lefties [%]	Right-handers [%]
Task 1	13	25	52	100
Task 2	16	21	66	84
Task 3	1	9	4	36
Task 4	19	23	79	92

Table 5. The successfulness of solving the individual tasks according to the fact whether the pupils use their right or left hand for writing – Variant B (plan view from the left)

	No. of lefties (28)	No. of right-handers (30)	Lefties [%]	Right-handers [%]
Task 1	24	22	86	73
Task 2	23	20	82	67
Task 3	1	4	4	13
Task 4	23	27	82	90

Table 6. The successfulness of solving the individual tasks according to the fact whether the pupils use their right or left hand for writing – Variant C (bottom view form the left).

	No. of lefties (28)	No. of right-handers (23)	Lefties [%]	Right-handers [%]
Task 1	19	8	68	35
Task 2	24	11	86	48
Task 3	0	0	0	0
Task 4	21	20	75	87

Table 7. The successfulness of solving the individual tasks according to the fact whether the pupils use their right or left hand for writing – Variant D (bottom view form the right).

	No. of lefties (20)	No. of right-handers (22)	Lefties [%]	Right-handers [%]
Task 1	17	8	85	36
Task 2	15	7	75	32
Task 3	2	0	10	0
Task 4	16	15	80	68

Our Hypothesis 2 has not been proved, however, it unexpectedly turned out that the right-handers were more successful in solving the tasks given in the plan view and the lefties were better at solving the problems given in the bottom view. More specifically, the test A – the plan view from the right – was done better by right-handers (as it was expected), the first two tasks in the tests B – the plan view from the left – and the tests C – the bottom view from the left – were done better by lefties and the remaining two tasks of the tests C were more successful for the right-handers. Generally, however, there was no significant difference proved between the results of the right-handers and the lefties.

Conclusions

The surveys have proved the correlation between the spatial imagination and general intelligence. Furthermore, the surveys have proved the correlation between spatial imagination and geometrical imagination in a plane. Other connections and consequences have arisen between the spatial imagination tests and other subtests of general intelligence, even the dependence of the test results on laterality and the way of picturing solids in a plane.

The conclusions of the researches unambiguously confirm the necessity to take the specific uniqueness of every pupil's development into consideration. In addition, it is appropriate to use different efficient methods, worksheets, comprising a larger number of tasks that grade in their difficulty which is adequate to the age of a pupil. When solving the tasks, pupils are allowed to work in pairs, make use of different models, descriptive tools, and thus the precision and fixture of different terms can take place. It is welcome to develop spatial imagination in an interesting (attention-catching) way by means of all experience realized by pupils' own senses – not only by visual perception (sight], but also by touch and hearing. Creative activities done by pupils, such as making paper models, active learning computer programs enable pupils to experience a feeling of joy induced by discovering the mutual relations. Experience – model – sketch – imagination is a sequence which may not be neglected or underestimated when developing spatial imagination. Interconnection of the individual parts of Mathematics, making use of different applications during teaching represents an opportunity to convince pupils of the meaningfulness of the teaching.

Based on the research, it is appropriate to recommend picturing geometrical solids from different views. Such a teaching better respects the individual uniqueness of pupils, their "own perception" of illustrated solids (we keep on doing the research on laterality).

Spatial imagination could also be evaluated in the real space – orientation in an unknown city, solving problems with the possibility for manipulation with concrete objects. There has been no research so far dealing with the influence of professional orientation of a pupil on his/her development of spatial imagination. We could surely reach interesting information by carrying out tests with individuals in a school environment over a longer time period.

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