THE INFLUENCE OF BIRTH ORDER ON THE RESULTS OF THE STATE E-TEST IN MATHEMATICS

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Abstract: *Many studies have shown that the birth order in the family can affect personality traits, the choice of career or even health. Based on the exam results and personal questionnaire gathered among a group of Polish school-aged children we have conducted a statistical analysis to prove that the birth order in the family is a key factor in shaping mathematical abilities, which are connected with mathematical and digital competences.*

Keywords: birth order, state test, school performance, mathematics education

INTRODUCTION

The importance of the birth order was recognized in the year 1918 by an Austrian psychologist, Alfred Adler, (see Adler, 2013). Consequently, Michael Grose revealed that the birth order had the most decisive impact on the creation of personality (see Grose (2003)). At present many studies have presented the effects of birth order in the family on educational attainment (see Black, Devereux, & Salvanes, 2005). In Hotz, & Pantano (2015) the authors provide robust empirical evidence that school performance of children declines with birth order. These findings are the basis for further research into the topic and checking whether the birth order in the family can also influence the performance in mathematics.

It is important according to Hejný et al. (2006) to respect individual character of every pupil in the class. For this reason findings in the research devoted to birth order of some pupils in the family can have substantive value for teacher in the class in specific subject or for class teacher. We will underline in our paper the influence of birth order of some pupils in the family for his/her results in mathematics education.

Worth noting is also the fact that the results presented in this paper differ from any other on this topic so far because this study is a longitudinal survey. Such a survey provides a reliable source of information on the influence of birth order on the scores in mathematics. For every student, we consider 3 scores at three different points in time. The first result is the mark in mathematics the student received at the end of the sixth grade (the result for the whole year), the second one is the result obtained in the exam taken at the end of the sixth grade, and the last one shows the result of the so-called "Diagnosis of mathematics" exam taken in the first year of middle school.

In accordance with Polish legal regulations, compulsory uniform examinations for all students of primary and secondary schools have been carried out for over 10 years. The exams are carried out at the following levels: K-6, K-9 and K-12. K-6 is a test at the end of primary school, K-9 assesses students after graduating from middle school, K-12 is taken at the end of secondary school. All of them are written examinations. K-6 consists of mathematics and the Polish language tests, whereas K-9 consists of three parts, one of the being mathematics. The condition for primary and middle school graduation is to take K-6 and K-9 exams respectively. Neither K-6 nor K-9 specifies a minimum score that a student should obtain in order to pass the exams. K-12 consists of three compulsory tests at a basic level, the Polish language, a selected modern language and mathematics as well, as at least one other subject at an extended level. In order to pass K-12 it is necessary to score at least 30% in each of the three compulsory parts. The results of the additional tests do not affect the final result.

The exams K-6, K-9, K-12 perform three basic functions:

1. They determine pass rates.
2. They provide a certificate of mathematics achieved by the examinee.
3. They are used as entrance exam to a higher level of education.

1. DIGITAL AND MATHEMATICAL COMPETENCES

Examination of children is more widespread nowadays in electronical form. The root is that the use of technology is slowly becoming a substantial part of today's education (see Hohenwarter, & Lavicza, 2010). Although due to the increased accessibility of affordable computing technologies in the 1980s and 90s it was predicted that computers would become rapidly integrated into mathematics teaching and learning (Kaput, 1992), technology uptake in schools has been considerably slow. The current expansion of technology use took a new unconventional direction: a bottom-up, community-based collaborative development, catalysed by Internet-based communities and increasingly available community-developed software packages.

During the past decades it has been demonstrated that a large number of enthusiasts can alter conventional thinking and models of development and innovation. The success of open source projects like Linux, Firefox, Moodle, and Wikipedia shows that collaboration and sharing can produce valuable resources in a variety of areas of life. For this reason this process in education supports digital and mathematical competences by the students and pupils.

According the document of the European Union Recommendation of the European Parliament and of the Council of 18 December 2006 on key competences for lifelong learning (see Recommendation, 2006) mathematical competence is the ability to develop and apply mathematical thinking in order to solve a range of problems in everyday situations.

Building on a sound mastery of numeracy, the emphasis is on process and activity, as well as knowledge. Mathematical competence involves, to different degrees, the ability and willingness to use mathematical modes of thought (logical and spatial thinking) and presentation (formulas, models, constructs, graphs, charts).

Electronic examination supports digital competences by children. Many webpages and programs allows this kind of examination. One of these programs is Hot Potatoes (see Koreňová, 2015). Using ICT in education makes stronger constructionism approach. It enables the implementation of the process of teaching as a design, which is an entity of information elaboration developed into types of intelligent human thoughts, products and artifacts having mental, manual and expressive forms. The teaching process design is created by learning entities together with teaching entities - they play the roles of designers. These entities are protagonists in the active elaboration of information obtained from outside, and use the capacity to recognize and obtain relevant information and, at the same time, search for information on the teaching problem and the teaching topic. Experiments with selected mathematical syllabi, in combination with manipulation activities involving students, allow the subjects to change the perspective of viewing schoolwork - to also see (understand) it in other contexts (see Kostrub, 2017).

According Bianco, & Ulm (2010) ICT may improve mathematics education on different levels:

- ICT is supposed to improve students' understanding of mathematics. Dynamic constructions make mathematical processes visible: Configurations can be varied (nearly) continuously on the screen, functional relationships or invariants can be directly observed. It is possible in primary level combine these activities with manipulations with models (see Bayerl, & Žilková, 2016). With traditional media and static pictures the teacher can hope at best, that the student "sees" these mathematical processes in his mind's eye.

- ICT is seen as a tool to make mathematics education more authentic and realistic. Mathematics education often deals with very simplified, pseudo- realistic problems because data from real life are too complex to cope with by traditional media. However, the computer helps to tackle problems that require e.g. extensive numerical or algebraic calculations in secondary level.

- A further target area, which is often linked with digital media, concerns children's key competences. By working with ICT students are supposed to increase abilities of autonomous and cooperative learning. Digital media should foster communication and presentation competences as well as "computer literacy".

- Finally, digital media are supposed to serve as catalysts for innovations in mathematics education. By using ICT the way of teaching and learning mathematics should change in a substantial way. Mathematics education should become more inquiry- based, students should work in a self- organised way, self-responsibly and cooperatively. It supports communication and social competences developed by children (see Partová, 2011).

2. DATA AND METHODS

Between the years 2011 and 2014 there were about 350 000 students taking the K-6 examination in Poland. The data used in our analysis are taken from the research study „Diagnosis of mathematics" conducted in Poland between the years 2011 and 2014 (see Sakowicz, Mazur, Kusztelak, & Stańdo, 2012). The research involved 3,100 students from 120 Polish schools, which represented approximately 1% of the population of students in the years 2011 and 2014. The overall response rate was 40%.

In the study "Diagnosis of mathematics" students' scores in the mathematical tests as well as a personal questionnaire were analysed. All the tests were computer-based and took place at a given location at a specific time. A specially designed system checked for correct solutions. A similar e-exam took place in Poland in 2009 (see Stańdo, 2011). The mathematical part of the "Diagnosis of mathematics" exam lasted 80 minutes and consisted of both 15 close- and 7 open-ended questions.

The test assesses the following areas of knowledge:

1. Reading comprehension of mathematical texts.
2. Performing simple calculations.
3. Reading, presenting, interpreting data in a form of tables, diagrams, graphs.
4. Perceiving geometric figures and performing simple geometric calculations.

5. Describing and modelling by using algebraic expressions, equations and inequalities.

6. Putting forward hypotheses, justification, seeing similarities, recursion, etc.

Now we would like to present some examples of the exercises from the mathematical part of the "Diagnosis of mathematics" study. In exercise 17 (see Figure 1), students are asked to use the given equations as well as algebraic operations on digits in decimal system in order to find the unknown digits.

Exercise 17. (Category 1)

In each operation, the letters A, B, C, D, and E represent the same numbers. Fill in the appropriate ones and discover what numbers are hidden under them if

$A + C = D,\ A \cdot A = A + A,\ C \cdot C = C : C.$

$C + A = \ldots$ $\qquad D \cdot C = \ldots$

$$\begin{array}{r} ACA \\ +\ ABB \\ \hline E\ldots A \end{array}$$

$A = \ldots$ $\quad B = \ldots$ $\quad C = \ldots$ $\quad D = \ldots$ $\quad E = \ldots$

Figure 1. Exercise 17
Source: Own work

In exercise 19 (see Figure 2), one has to move points C and D so that the given figure becomes a square. Then, a student needs to calculate the area and perimeter of the figure.

Exercise 19. (Category 1)

Move with the points D and C so that the quadrilateral will be a square.

Calculate the area and perimeter of the square.

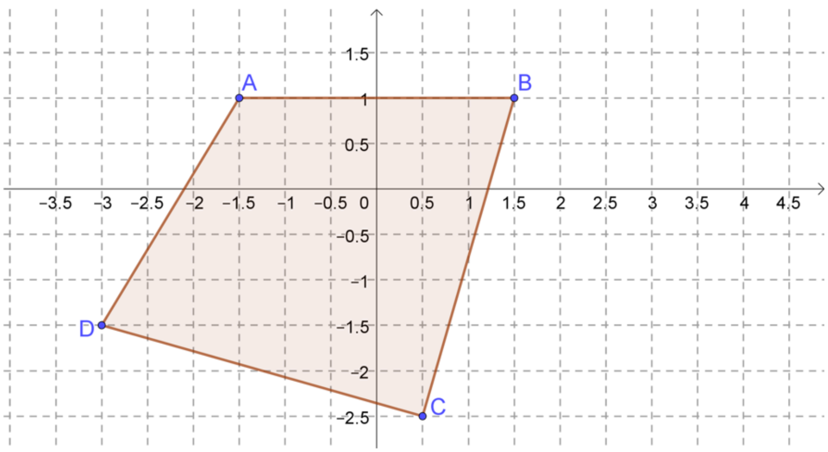
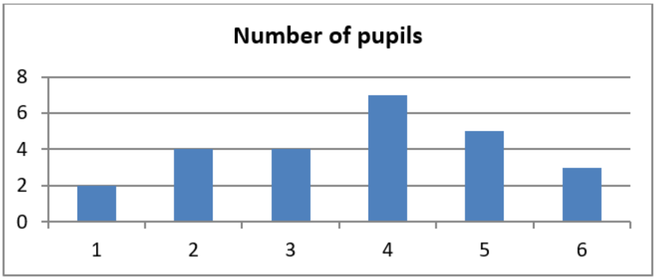


Figure 2. Exercise 19
Source: Own work

Exercise 22 (see Figure 3) presents a histogram of grades in mathematics. A student is asked to provide some statistics on the basis of the histogram, such as calculating the average or the percentage of the students with the best marks.

Exercise 22. (Category 1)

The following diagram presents the marks from the mathematics test in the first grade.



Give answers to following questions:

1. How many pupils wrote the test? ....
2. Which kind of mark have the biggest group of pupils? ...
3. Which percentage of the pupils obtain the mark “very good”? .... %
4. Is it possible, that more than one half of the pupils obtain the mark “good” or better? ...
5. The average value from the test is ...

Figure 3. Exercise 22

Source: Own work

Apart from the test scores, we analyse the following data collected from the questionnaire responses in the "Diagnosis of mathematics" study:

- the results of the examinations at the K-6 level,
- the birth order in the family,
- the marks in mathematics at the end of primary school represented on a 6-point scale.

On the basis of the report of the Ministry of National Education regarding the achievements of students graduating from primary school in Poland and the results of the students participating in the study, we get the following graph.

Next figure compares the general performance of the population of students in the final exam taken after the sixth grade with the results of K-6 examination reported in the questionnaire by the students participating in the "Diagnosis of mathematics" study (see Figure 4).

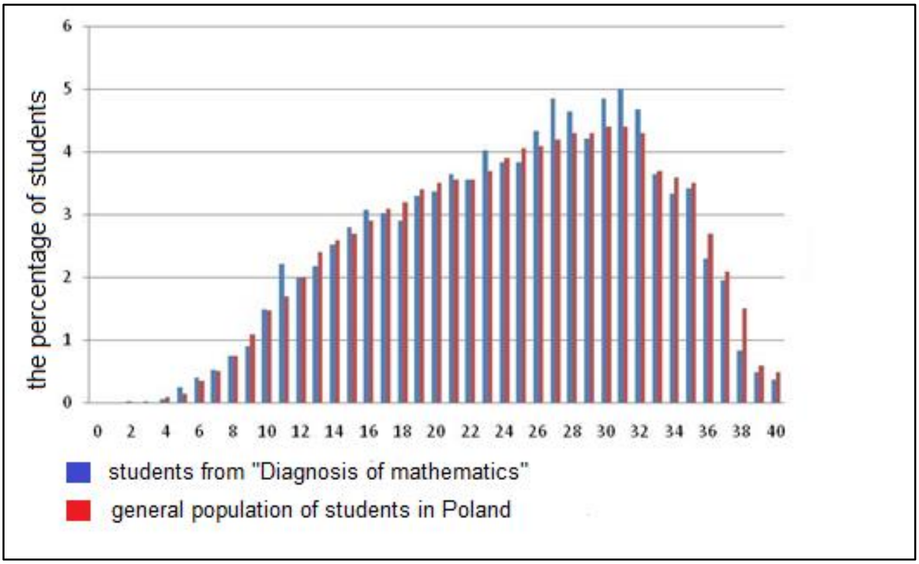


Figure 4. The number of points scored in the test taken at the end of the sixth grade

Source: Own research

The histograms in the figure above are very similar, which proves that the sample in the "Diagnosis of mathematics" study has been selected properly and can be a representative sample (see Figure 4).

3. STATISTICS ANALYSIS

3.1 Descriptive statistics

We have analysed a sample of 1,007 middle school students who obtained more than five points in the test and provided answers to the questions in the questionnaire. The students are divided into four groups according to the birth order in the family. The first subsample consists of 143 only children, the second one of 301 oldest children, the third of 194 middle children, and the last one of 369 youngest children. The last group of first born children is a union of only and the oldest children.

3.1.1 Descriptive statistics for the number of points obtained in the "Diagnosis of mathematics" study depending on birth order

Next table and figure show that the means and medians of points scored in the "Diagnosis of mathematics" exam by the only and oldest children are higher than the corresponding measures of central tendency in the groups of middle and youngest children (see Table 1 and Figure 5).

Table 1.

Descriptive statistics for mathematics exam in the "Diagnosis of mathematics" study

	no. of obs.	mean	median	mode	standard deviation	kurtosis	skewness
only child	143	21,59	22	25	6,74	-0,52	-0,11
oldest child	301	22,18	22	22	6,90	-0,43	-0,03
middle child	194	19,96	20	17	7,34	-0,45	0,26
youngest child	369	20,79	21	23	7,23	-0,52	0,11

Source: Own research

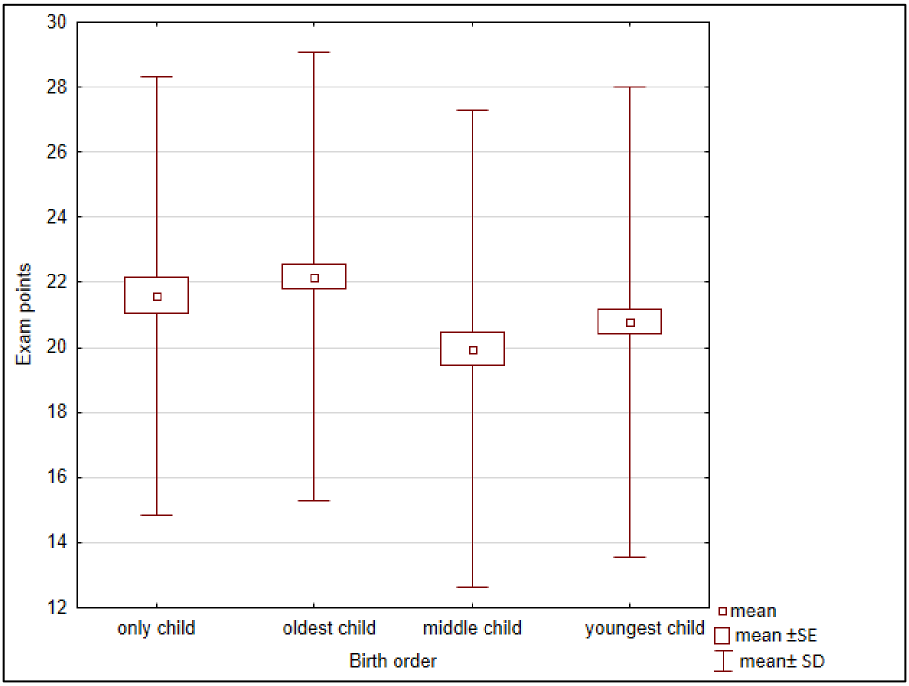


Figure 5. Descriptive statistics for mathematics exam in the "Diagnosis of mathematics" study

Source: Own research

In the group of oldest children all average measures of the exam points are equal to 22 and the distribution of point is symmetric. The distribution of the exam points from the samples of middle and youngest children have positive skewness, whereas for only children we have platykurtic distribution of the exam points.

3.1.2 Descriptive statistics for the number of points in the K-6 exam depending on birth order

Table 2.

Descriptive statistics for the K-6 exam

	no. of obs.	mean	median	mode	standard deviation	kurtosis	skewness
only child	143	26,30	27	26	7,00	-0,58	-0,51
oldest child	301	26,41	27	32	7,26	-0,33	-0,57
middle child	194	23,39	24	25	7,95	-0,76	-0,18
youngest child	369	24,83	26	26	7,41	-0,59	-0,39

Source: Own research

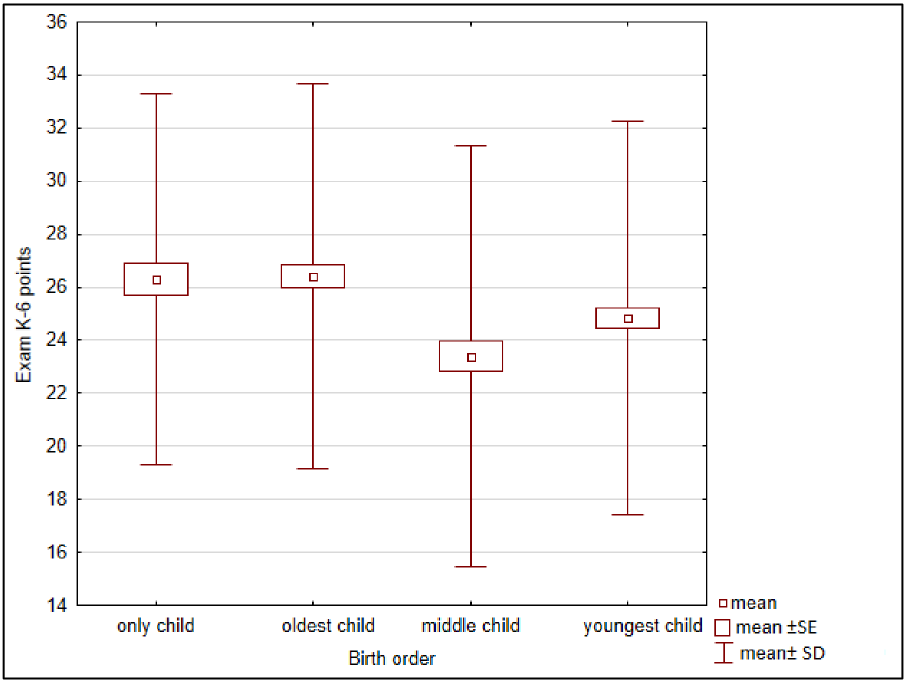


Figure 6. Descriptive statistics for mathematics exam in the "Diagnosis of mathematics" study

Source: Own research

The table and figure above show that the means of points obtained in the K-6 exam by firstborn children are significantly higher than the results of children who have older siblings (see Table 2 and Figure 6). It should also be noted that the medians for scores of the only and oldest children indicate that the firstborns achieved better results in the K-6 exam.

3.1.3 Descriptive statistics for the marks in mathematics at the end of primary school depending on birth order

Table 3.

Descriptive statistics for marks in mathematics at the end of primary school

	no. of obs.	mean	median	mode	standard deviation	kurtosis	skewness
only child	143	3,70	4	3	1,13	-1,00	0,03
oldest child	301	3,66	4	3	1,14	-0,94	0,05
middle child	194	3,41	3	4	1,10	-1,03	0,18
youngest child	369	3,48	3	3	1,13	-0,91	0,22

Source: Own research

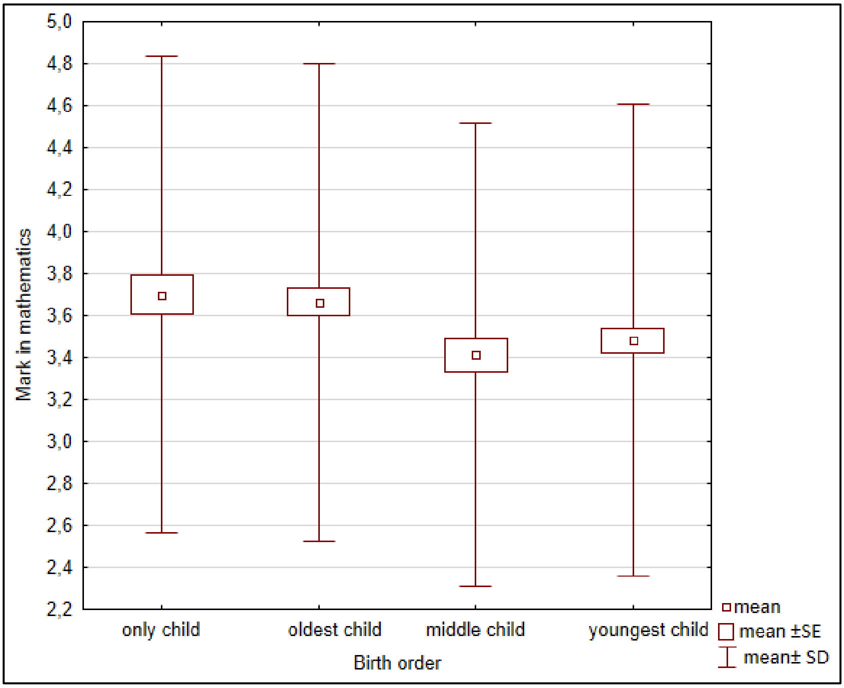


Figure 7. Box plot of marks in mathematics at the end of primary school

Source: Own research

As can be seen in Table 3 the medians of the points scored by firstborn children are equal to 4. This means that 50% of firstborn children obtained marks in mathematics greater than or equal to 4, while the medians of points scored by middle and youngest children are equal to 3. Figure 7 shows that the means of points of children who have older siblings are lower than the means of points of the firstborns.

3.2 Test results

The decision to reject the null hypothesis in hypothesis testing has a certain significance level determined by the investigator. We will denote it by α. Recall that α is the probability of rejecting the null hypothesis when it is true. For the purpose of our study we have assumed that α=0,05. The decisions taken at a lower level of significance are less susceptible to error and, therefore, are more reliable. In addition to the value of test statistics, the majority of statistical packages (including Statistica 10) calculate the value of the asymptotic significance, which is called the p-value (denoted by p). The interpretation of the test is as follows: if $p \leq \alpha$, then the reject the null hypothesis.

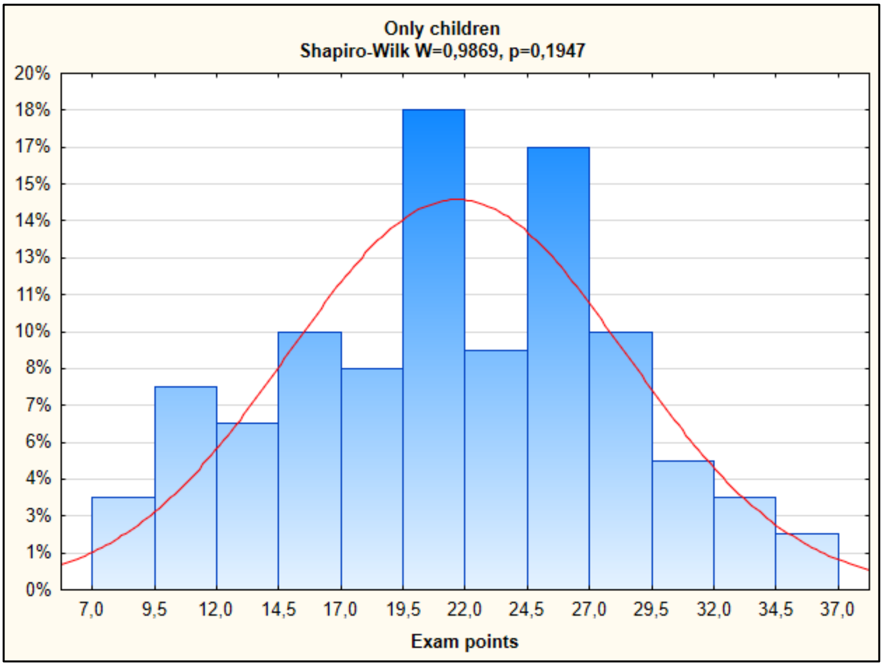


Figure 8. Histograms of mathematics exam in the "Diagnosis of mathematics" study for only children

Source: Own research

Figures from Figure 8 to Figure 15 show the histograms of the points scored in the mathematical exam in the "Diagnosis of mathematics" study and in the K-6 exam results for four groups of students as well as the results of a Shapiro-Wilk normality test.

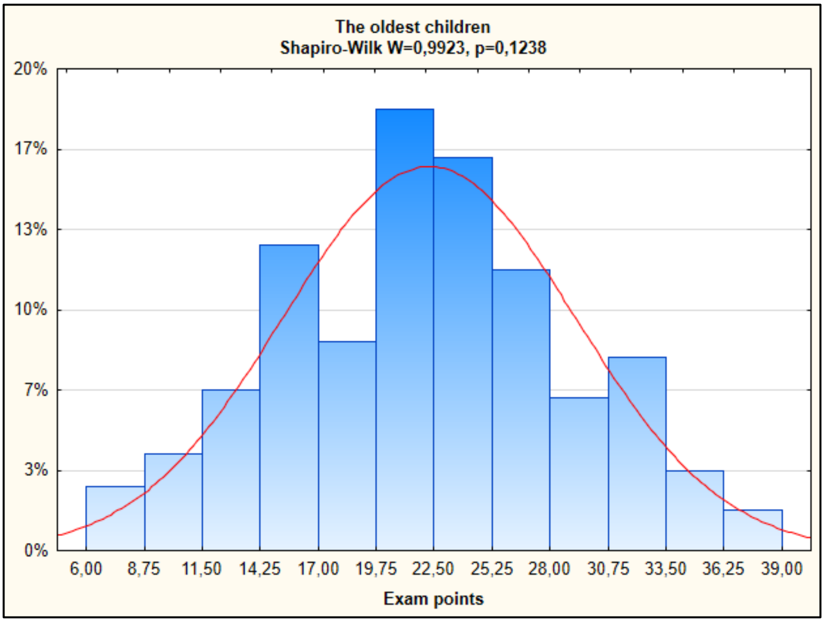


Figure 9. Histograms of mathematics exam in the "Diagnosis of mathematics" study for the oldest children

Source: Own research

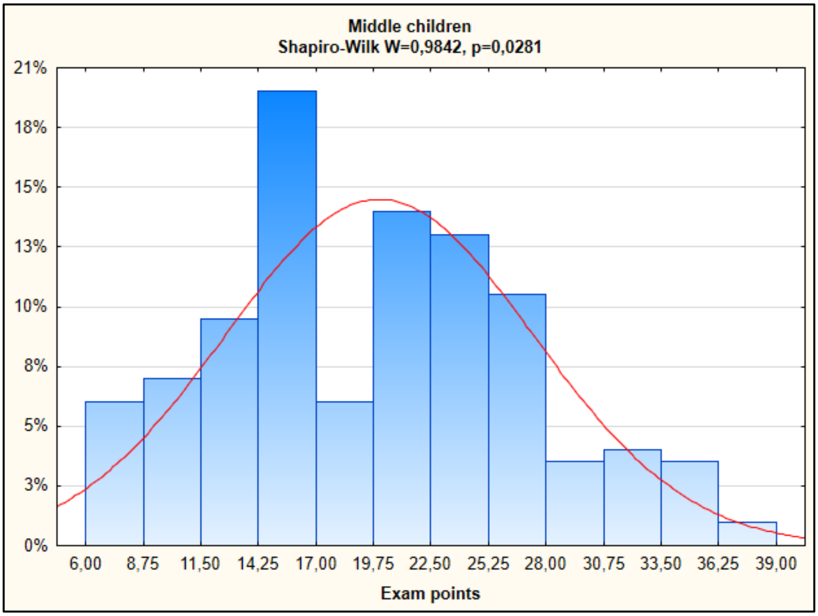


Figure 10. Histograms of mathematics exam in the "Diagnosis of mathematics" study for middle children

Source: Own research

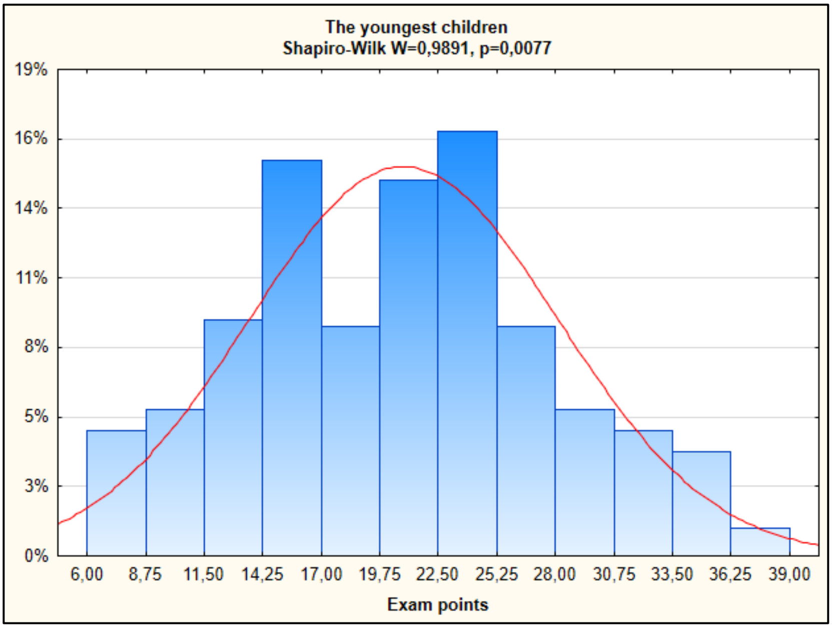


Figure 11. Histograms of mathematics exam in the "Diagnosis of mathematics" study for the youngest children

Source: Own research

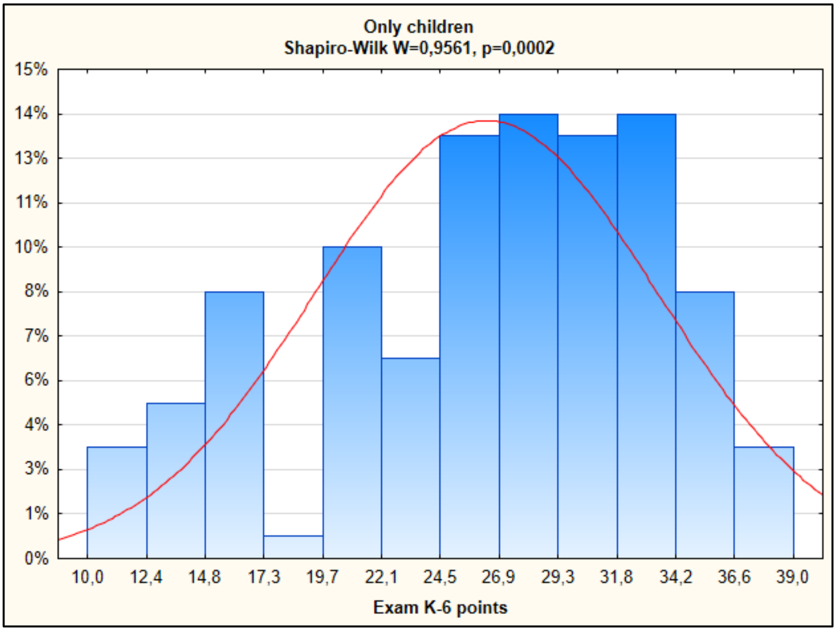


Figure 12. Histograms of the results in K-6 exam for only children

Source: Own research

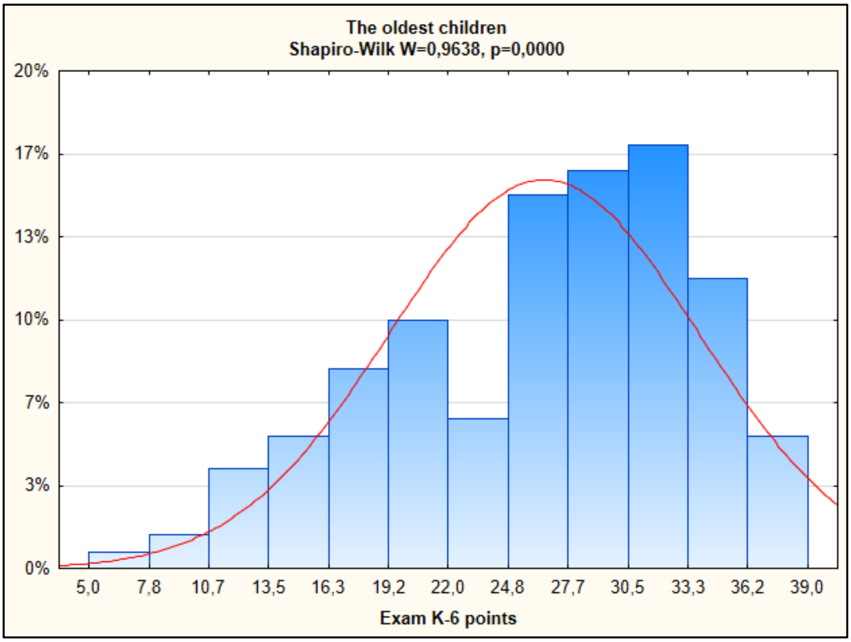


Figure 13. Histograms of the results in K-6 exam the oldest children

Source: Own research

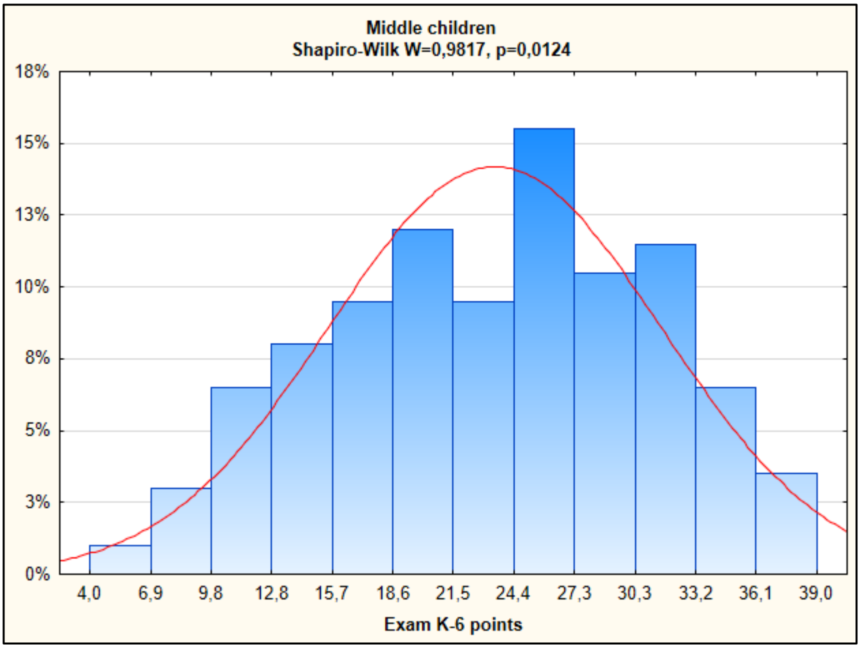


Figure 14. Histograms of the results in K-6 exam for middle children

Source: Own research

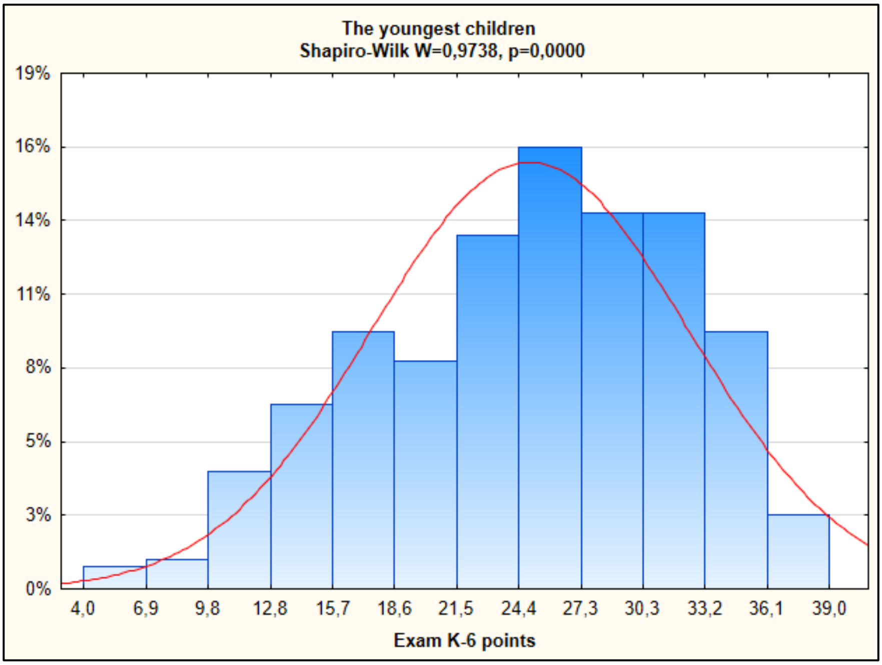


Figure 15. Histograms of the results in K-6 exam for the youngest children

Source: Own research

In Shapiro-Wilk test, the null hypothesis assumes the normality of probability distribution. Analysing the results of these tests at a significance level of 0,05, we reject the null hypothesis for the scores of the middle and youngest children in the "Diagnosis of mathematics" study. As for the K-6 exam, we reject the null hypothesis in all groups of students. At the end, we use the Shapiro-Wilk goodness of fit test. The result of goodness of fit test has shown that in order to check the relationship between the birth order and the achievements in mathematics we cannot use a parametric test.

Consequently, we use non-parametric statistical methods to check whether the distribution of the exam results in the "Diagnosis of mathematics" survey, the K-6 test results and the marks in mathematics of four populations of students coincide. To this end, we do not require any assumptions of probability distribution, the assumption of normality in particular. We apply the Kruskal-Wallis one-way analysis of variance by ranks to detect the differences between the populations (see page 645 in Aczel, & Sonderpandian, 2009, page 595 in Sheskin, 2000). The only requirement for the Kruskal-Wallis test is that the samples are random and the observations are independently drawn from the populations. The null hypothesis says that in all populations the analysed variables have the same distributions. Note that the nonparametric tests compare probability distributions, all their parameters in particular, i.e. the mean and the median. We confirm the Kruskal-Wallis test results use the median test (see page 67 in Aczel, & Sonderpandian, 2009), where the null hypothesis says that all populations have the same median.

We investigate the following hypotheses:

1. The birth order of children in the family has a significant impact on the results of the exam "Diagnosis of mathematics".

2. The number of points scored in the K-6 examination varies among the populations of the oldest, only, middle and youngest children.

3. The birth order of children in the family has a significant impact on the marks in mathematics at the end of primary school.

In the case of the rejection of null hypothesis based on the Kruskal-Wallis test we do not know which populations differ from other. In order to recognise the differences between the populations, we use multiple comparison test (also known as post-hoc tests). To this end, we use the Scheffe test (see page 376 in Aczel, & Sonderpandian, 2009). This test is the most conservative one. This means that we use it when we are less likely to reject the hypothesis of equality of means. The Scheffe test is recommended for the pairwise comparison method, where the sizes of samples are not equal in all of the groups.

Below we present the tests results and statistical analysis of all these hypotheses.

3.2.1 The test results of the number of points scored in the mathematical exam in "Diagnosis of mathematics" and the independent variable (grouping) of the birth order

Table 4.

Test of hypothesis results of mathematics exam in the "Diagnosis of mathematics"

Kruskal-Wallis test: $KW = 14{,}1572, p = 0{,}0027$

Median test: $general\ median = 21,\ \chi^2 = 11{,}3441, p = 0{,}0100$

Scheffe test (p-value for multiple comparisons test):

	only child	oldest child	middle child	youngest child
only child		0,884136	0,223418	0,723594
oldest child	0,884136		0,009355	0,097327
middle child	0,223418	0,009355		0,624905
youngest child	0,723594	0,097327	0,624905	

Source: Own research

The p-value of Kruskal-Walis test is equal to 0,0027. This means that we reject the null hypothesis about the distribution of the exam points for the population of only, oldest, middle and youngest children taken from the "Diagnosis of mathematics" study as they are identical. We show that the mean value of points scored in the mathematical exam in "Diagnosis of mathematics" depends on the birth order. The multiple comparison test shows that the largest difference occurs between the oldest and the middle children (p=0,009355).

3.2.2 The test results of the number of points obtained in the K-6 exam and the independent variable (grouping) of the birth order

Table 5.

Test results for the numbers of points in the K-6 exam

Kruskal-Wallis test: $KW = 22{,}38506, p = 0{,}0001$

Median test: $general\ median = 26,\ \chi^2 = 20{,}54580, p = 0{,}0001$

Scheffe test (p-value for multiple comparisons test):

	only child	oldest child	middle child	youngest child
only child		0,998987	0,005622	0,257806
oldest child	0,998987		0,000219	0,056056
middle child	0,005622	0,000219		0,188313
youngest child	0,257806	0,056056	0,188313	

Source: Own research

We reject the null hypothesis at the significance level of 0,05. A post-hoc test shows that there is a difference between the K-6 exam results of the only and middle children (p=0,005622) and the results of the oldest and middle children (p=0,000219).

3.2.3 The test results of the marks in mathematics at the end of primary school and the independent variable (grouping) of the birth order in the family

The p-value in the Kruskal-Wallis test is lower than 0,05. Therefore, we reject the null hypothesis. In the median test, the asymptotic significance is equal to 0,0525. Therefore, we reject the null hypothesis at a significance level of 0,1 (see Table 6).

We conclude that the distribution of marks in mathematics at the end of primary school for the populations of only, oldest, middle and youngest children is not the same.

Table 6.

Test results for marks in mathematics

Kruskal-Wallis test: $KW = 9{,}4892, p = 0{,}0234$

Median test: $general\ median = 4,\ \chi^2 = 7{,}7055, p = 0{,}0525$

Scheffe test (p-value for multiple comparisons test):

	only child	oldest child	middle child	youngest child
only child		0,992681	0,149092	0,281869
oldest child	0,992681		0,116831	0,228463
middle child	0,149092	0,116831		0,920761
youngest child	0,281869	0,228463	0,920761	

Source: Own research

However, the post-hoc Scheffe test has not shown any statistically significant differences between the birth order and the results in mathematics. This situation usually happens when the p-value is close to 0,05. It should also be noted that the K-6 and "Diagnosis of mathematics" exams have a uniform assessment for all of the students, in contrast to the marks in mathematics at the end of the sixth grade, which are given by each teacher individually and using their own criteria of evaluation.

4. DISCUSSION

The interaction between the pupil and the teacher has according to Hejný, et al. (2006) an influence on the educational process during mathematics lessons. If the teacher uses an authoritative style, then he don't respect the individuality of the pupil and his/her family situation. If the teacher uses a dialogical style, then he is able to make a deep investigation of possible reasons for the student's results during the mathematics lessons, in an empathetic way. Our research shows that birth order has an influence on pupils' results during the educational process. It leads mathematics teachers to make deeper diagnostics during their lessons. The class teacher can use results of this kind of research for more effective cooperation with parents of pupils in the class. Another application is to create groups of pupils in the class in the way that pupils in one group have a different birth order. The pupils in these groups can help each other not only in the process of obtaining new knowledge, but also in the process of socialisation.

CONCLUSION

This study has shown that there exists a clear correlation between the performance in mathematics and birth order. All three hypotheses posed in this study have been proven. The results of our research have shown that people who were born as the first child are often more successful in mathematics.

We have also shown that only and oldest children score significantly more points in mathematical exams and have better final marks in mathematics than middle and youngest children. It is also worth noting that there are no significant differences in mathematics achievement between the only and the oldest child. A genetic predisposition can have a major impact on the lack of differences between only and oldest children.

These findings must be respected by teachers in the educational process. If the teacher knows the birth order of a concrete pupil, he can adapt his approach in the educational process with this pupil. Some groups of these pupils need more time in the process of gaining knowledge or more attention on the part of the teacher. It is important to support the practice in families that older siblings teach and help younger siblings.

The tasks in tests can be given to children in electronic form, which allows for doing research in bigger samples. Testing and e-testing are new way of research in the development of mathematics key competences and abilities. This testing has importance for educational diagnostics.

We expect, that in future it will be possible to carry out research about dialogical or authoritative styles of teaching in mathematics education. Another possibility is studying pupils' learning styles. The important role has the successive and gestalt style of teaching (see Hejný, Novotná, & Stehlíková, 2004). Testing and e-testing is a useful tool for the diagnostic aspect of mathematics education.

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