WHAT IS MATHEMATICS AND HOW TO TEACH IT?

It is not exactly known what is mathematics. There is no proper definition. It is not exactly known, how to teach something that we can not define. Mathematics has been changing its form over the millennia of human existence. Today, however, what has been changing over the millennia, is changing in the blink of an eye with the development of computer technologies. Mathematics is a completely different field than it was before. Unfortunately, curriculum creators do not seem to notice that. There is a real problem with the teaching of mathematics in the new digital world. The problem is not only associated with archaic curricula, but also with students growing up in a technologically advanced world and teachers who do not keep up and their mutual relations.

Key words: definition of mathematics, computer technologies, teaching mathematics, curriculum

DEFINITION?

Unlike the natural sciences such as physics, chemistry, or biology it is virtually impossible to find a clear definition of mathematics. In many sources we can find all kinds of information. Mathematics is the study of topics such as quantity (numbers) (Oxford English Dictionary, 2014), structure (Keebone, 1963), space (Oxford English Dictionary, 2014), and change (LaTorre, Kenelly, Reed, Carpenter & Harris, 2011; Ramana, 2007; Schleicher & Lackmann, 2011). There is a range of views among mathematicians and philosophers as to the exact scope and definition of mathematics (Mura, 1993; Tobies, 2012). Mathematicians seek out patterns (Steen, 1988; Devlin, 2003) and use them to formulate new conjectures. Mathematicians resolve the truth or falsity of conjectures by mathematical proof.

Personally, I think the best definition of math, regardless of the specific features of a given language, or culture is:

Mathematics (from Lat. Mathematicus, from gr. Μαθηματικός mathēmatikós from μαθήμα-, μάθημα mathēmat-, mathēma, „knowledge, lesson, learning”, from μανθάνειν manθánein, „learn, get to know”) – science providing tools for obtaining exact conclusions from the assumptions (Encyklopedia PWN, 2014) therefore regarding the correctness of reasoning. Since the strict assumptions may concern various areas of human thought and are indispensable in science, technology, and even in the humanities, mathematics scope is wide and is still growing.

There is a common problem with a precise and unambiguous defining of mathematics. How to deal with something that we can not clearly define? How to teach the subject we can not define?
DO WE NEED MATHEMATICS?

People used math before they even could call it mathematics or define any clear and accurate mathematical concept as we know it now. People used mathematics before they could formally prove any theorem, even before anything could be called a theorem or an axiom, before they needed to use these terms.

Mathematics is a field of science that has been formed over many thousands of years. We do not know when exactly we can determine the timeline point and call it „the beginning of mathematics”. We know, however, that mathematics was created from the natural human needs. People tried to learn the rules that govern the world around him. The most basic mathematical concepts related to the amount and space are closely linked with the construction of our mind. Even animals have a sense of distance (Brożek & Hohol, 2014). Over the years, people began to develop and shape these concepts and began to notice recurring patterns.

This can be seen in „mathematics” of the ancient Egypt. It should be noted that the ancient Egyptians used to measure and count things with the parts of their body, which later were established into their units of measurement (Imhausen, 2006; Burton, 2005). The analogy to the present day imperial units is worth mentioning.

The Egyptians also used the decimal system, derived from their fingers (Burton, 2005). In the famous Rhind Mathematical Papyrus (Burton, 2005) in many calculations are fractions, the fractions were operated on numerators equal to one. The only exception was a fraction of two-thirds, for which was a separate symbol. All fractions were limited to the sum of partial fractions, i.e. the numerator equal to unity. Rhind Mathematical Papyrus also contains tables for the distributions to simple fractions for all the odd numbers from 5 to 331. It also contains a method for calculating the number π. There are publications stating that the Egyptians used the Pythagorean theorem, but of course we can not determine it that way. Egyptian mathematics was not based on proving which we know in modern mathematics (Kosteki, 2011). Tasks were solved on specific numbers, then made to verify the result. Until two thousand years later, the ancient Greeks and Pythagoras prove that all right triangles have some common characteristics. However Egyptians also „sensed” other mathematical concepts. In Moscow Mathematical Papyrus (Burton, 2005) we can find the formula for the volume of a truncated pyramid – the first trace of using „differential calculus” which proper development occurred only in the seventeenth century.

The crowning achievement of the aforementioned development was the work of English physicist and mathematician Isaac Newton and German mathematician and philosopher Gottfried Leibniz, which contained a systematic lecture of the theory and methods associated with the concept of integral and introduced the terminology and symbols similar to the contemporary (Kosteki, 2011).

Also in the seventeenth century the analytic geometry was created by René Descartes and Pierre de Fermat as well as probability theory introduced by Pierre de Fermat and Blaise Pascal. The work of all these authors are marked by the clash of ancient Greeks geometrical ideas with arithmetic and algebraic ideas of Arabs (Kosteki, 2011). However, despite the lack of established language (which was formulated only in the eighteenth century), all these three theories became the foundation of modern mathematics (Kosteki, 2011).

The nineteenth century is characterized by a large increase of abstraction in mathematics, combined with the simultaneous emergence of new branches of mathematics. Evariste Galois and Niels Henrik Abel studied the solutions of equations of higher degree than the fourth, which led to the introduction and development of group theory and the theory of algebraic equations. Augustin Louis Cauchy and Karl Weierstrass created the definition of the limit of a function, and (together with Carl Friedrich Gauss) theory of analytic functions, that is differentiable functions of complex variables (Kosteki, 2011).

In geometry, Nikolai Lobachevsky and János Bolyai independently demonstrated that Euclid's
axiom V is independent of the others and that there are geometries that do not satisfy this condition. Consequence of their findings was the formulation of a new geometric theory by Bernhard Riemann (now called the Riemannian geometry), a much more general Euclidean geometry. This way modern European mathematics exceeded its roots also in geometry as Riemannian geometry was based on the theory of functions and differential geometry, areas very distant from the Euclidean study of rational proportions between line segments (Kostecki, 2011).

After citing only a short and rather selective parts of the history of mathematics, we can see an interesting phenomenon. Mathematics which had its origins in the immediate human environment and which originated from the natural needs to „organize” the world around him has become an abstract field of science. Average person who is not a professional mathematician no longer needs such mathematics. It is this „new” math that needs and will need people more and more.

**DOES MATHEMATICS NEED US?**

In the twentieth century mathematics has become a very extensive area of knowledge, often no longer comprehensible for a single mathematician. Due to the diversity and specialization of the latest knowledge it is almost impossible to briefly explain evolution of math to a bystander. Overall, however, we can say that the twentieth century was marked by a prominent development of abstract mathematics but also discovering relationships between different fields of mathematics, the detachment of new disciplines and specialization of study, as well as the creation of disciplines that examine the overall structure within which can exist mathematical objects (group theory, particularly category theory) (Kostecki, 2011).

Among the great mathematicians of the twentieth century two have to be mentioned: Srinivasa Ramanujan – a self-taught Indian genius (Kostecki, 2011) and Alexandre Grothendieck, who in the sixties revolutionized the vast expanse of modern mathematics (mainly algebraic topology and algebraic geometry) (Kostecki, 2011).

Over the years, mathematics changes its form. A so-called pure mathematics is being created, motivated by different goals than its practical application. It is distinguished by its strictness and abstract nature. As a separate branch of mathematics functioned since the nineteenth century. Sometimes it was also referred to as speculative mathematics (Simpson, 1740), and contrasted with the concept of mathematics created to improve other areas of science and technology, such as navigation, astronomy, physics and so on.

People do not need math, but mathematics in its pure form needs people who will determine its boundaries of existence, giving it shape and form, who will „pack” it in the formal structure of axioms, theorems and proofs. The issue that arises here are the boundaries. The boundaries of the existence of pure mathematics, which is not of use and is cultivated for the sake of practicing pure mathematics, which at the present time and with the current state of knowledge might not be applicable, but perhaps in the future it will. Although, will it still be pure mathematics, if we can find the practical application for it? And will people once again need math?

The twentieth as well as the twenty-first century has led to the creation of the new branch called applied mathematics as a sort of opposite of pure mathematics. And again the issue occurs because the interaction between the application of mathematics and the development of pure mathematics makes the area of applied mathematics not precisely defined. This includes actions to develop the mathematical use for other sciences, especially medicine, biology, computer science and technology.

**HAS COMPUTER TECHNOLOGY CONTRIBUTED TO THE END OF MATH?**

The introduction of computers for general everyday use changed everything. Computers have revolutionized, facilitated and accelerated certain processes.
Computers have revolutionized the approach to practicing mathematics. Today, computer programs such as Mathematica, Maple, Mathlab, Derive, MuPAD are generally based on areas related to the enormous progress in mathematics, such as computer algebra, and symbolic computations. In fact, everything that is taught in mathematics education in secondary school and higher education is available with a push of the button. Is math once again not needed?

What is the ability to use a compass and ruler for, when much more accurate, and even animated geometric proof mathematicians can create on a computer screen before quickly using the Internet to publish it? Furthermore – what is the knowledge of a complex theory for, if the result of practice that confirms this theory can be seen on a screen in a matter of seconds? Are people in the age of computers still in need of traditional chalkboard math? Previously the situation was simple. In the beginning people needed mathematics. Then it was the math that needed people. But what happens if we add computers to this relation?

The aforementioned relation can be seen in Figure 1.

In the Figure 1. we also see that mathematics is the basis for the computers, while computers are making a contribution to mathematics by automatic proving of theorems. It is a process in which the computer determines whether a theorem is provable in a given theory, often on the occasion generating a proof. This is a list of theorems proved by a computer along with a year (List of theorems proved with the help of computer programs, 2014):

- Four color theorem, 1976
- Connect Four, 1988 – a game
- Non-existence of a finite projective plane of order 10, 1989
- Robbins conjecture, 1996
- Kepler conjecture, 1998 – the problem of optimal sphere packing in a box.
The first type can be described as a traditionalist. It is a supporter of traditional lessons, mostly in the form of a lecture. Such teacher provides examples of tasks which he solves during this lesson. This is followed by similar tasks solved by the students. Traditionalists are reluctant to use information technology in teaching mathematics or do not apply them at all, explaining it with a lack of time or lack of access to technology often claiming that the traditional, proven over the years methods are the best.

The second type may be defined as a beginner experimenter. It is also a supporter of traditional lessons but with elements that use information technology in teaching mathematics. Most often these technologies are used as a support to describe a given issue or task. These measures do not, however, completely replace chalk and blackboard. The teacher is open to using new technologies, but do not trust them completely, and is not convinced that the technology can replace traditional teaching methods.

The third type can be described as a computer geek. It is usually a young teacher who recently graduated from college, although this is not always the case. Still full of verve, energy and enthusiasm to work with students. Not only is such teacher open to the use of new technologies in teaching, but also can not imagine any math class without them. Happily learns about new computer programs and is familiar with various technologies that enable multimedia presentations, simulations and experimentations during lessons. He is convinced that in the near future technology will be able to completely replace traditional teaching methods.

Second – the official requirements concerning education. After studying the documents in the form of ministerial Podstawa programowa kształcenia ogólnego dla szkół podstawowych (Basis of the general education curriculum for primary schools) (2008) and Podstawa programowa kształcenia ogólnego dla gimnazjów i szkół ponadgimnazjalnych, których ukończenie umożliwia uzyskanie świadectwa dojrzałości po zdaniu egzaminu maturalnego (Basis of the general education curriculum for middle
and high schools, graduating from which allows earning a certificate after passing the matriculation examination) (2008) it can not be concluded whether and how any new technologies should be used during mathematics classes in Poland.

Let's consider the first of the aforementioned documents i.e. *Podstawa programowa dla kształcenia ogólnego dla szkół podstawowych* (2008). Among general objectives we can find the record stating that „one of the most important skills acquired by a student in the course of general education in the primary school” is „the ability to use modern information and communication technologies, including for finding and using information.” We can also find the record saying that the „important task of primary school is to prepare students for life in the information society. Teachers should create conditions for students to acquire the ability to access, organize and use information from various sources, using ICT, during classes of different subjects.”

It should be noted that specific objectives of teaching mathematics do not state clearly whether or how teachers could or should use modern information technologies in the teaching of mathematics. We can only find information concerning the use of a calculator during mathematics lessons.

Let's see what the second document – *Podstawa programowa kształcenia ogólnego dla gimnazjów i szkół ponadgimnazjalnych, których ukończenie umożliwia uzyskanie świadectwa dojrzałości po zdaniu egzaminu maturalnego* (2008) – has to say. In general objectives, we can find a record about „skills to efficient use of modern information and communication technologies” as well as a record: „An important task of the school on the third and fourth stage of education is to prepare students for life in the information society. Teachers should create conditions for students to acquire the ability to access, organize and use information from various sources, using ICT, during classes of different subjects.” Also, just as in the previous document we can find the information concerning the use of a calculator during math classes.

It should be noted that none of the mentioned documents properly defines the way in which teachers should use modern information technologies in the teaching process of specific concepts or branches of mathematics. I do not want to claim that the Ministry should impose what teachers have to do and which computer program they should use. That is not the point. But it seems that the objectives contained in the cited documents are too general and actually do not mean anything.

Third – the equipment of computer labs in schools, which plays an important role. There are too few computers and too poorly equipped with appropriate programs. Often classrooms, which held the mathematics lessons are not adequately prepared to work with modern information technologies.

Fourth – the students themselves. It should be noted that most of the students now belong to the generation of „digital natives”, their teachers however are still a generation of „digital immigrants”, which drew the attention of Mark Prensky, an American scholar of media and the Internet. In an article „Digital natives, digital immigrants” published in 2001 he used for the first time the terms „digital natives” and „digital Immigrants” to distinguish and draw attention to two different ways of functioning in contemporary world. Although several years has passed since the publication of this article, Prensky’s opinions are still valid. Today’s students belong to a generation that has used modern technologies since childhood. They grew up surrounded by video games, computers, mp3 players, digital cameras, mobile phones and other twenty-first century digital world inventions. We can safely conclude that technology is an important part of their lives, because this is the life they know and not any other and they can not imagine any other life. Generation described above Prensky (2001) called „digital natives”. In contrast, teachers mostly belonging to the generation which grew up not surrounded by information technology (perhaps with the exception of young teachers) are described as „digital immigrants”. Prensky (2001) also noticed that, as immigrants in the traditional sense try to
learn a foreign language – the digital immigrants try to learn a new digital media, which, however, they will never master.

Fifth – the education of teachers. Please note that in the digital world technological changes are occurring so rapidly that what future teachers manage to learn today can very quickly change its form or become completely obsolete tomorrow. People responsible for the training of teachers should pay attention to the preparation of future teachers to existence in a rapidly changing world, and to respond quickly to changes. Prospective teachers should be open not only to the acquisition of mathematical and didactic knowledge but also to learn new technologies and to be able to adapt to changes in the world of these technologies.

The cooperation of three groups is vital – those governing, making changes in education, including changes in curricula; those responsible for education of future teachers of mathematics; and the teachers themselves.

Sixth – the proper selection of teaching content. As already mentioned – the curricula practically have not changed their content from those of the nineteenth century. In previous paragraphs of this article I tried to show how mathematics has evolved over the centuries, or perhaps it would be better to write – over the millennia of human existence. Even the famous, world class mathematicians most probably can not imagine their work without computers. Using your computer, you can not only show, visualize or design you can also prove. The question is whether in the modern world, in which students are „computer natives”, mathematics education in its current form is still possible and necessary? What is the purpose of teaching children how to count in the era of fast computers and smartphones with calculators? Why teaching children to use a compass and ruler, if they can make a much more accurate drawing for example using GeoGebra and additionally create an animation to see something what they would never be able to see on paper or blackboard? Does anyone still need to learn multiplication tables?

In the pre-computer era teachers often referred to the so-called didactic triangle (Steinbring, 2005) describing sustainable relationship between the knowledge, the teacher and students. Now we can talk about a didactic tetrahedron (Steinbring, 2005) describing sustainable relationship between the knowledge, the teacher, students, and technology. This is shown in the figure below:

At this point we encounter another important issue – the role of technology in teaching. Roles can be various. Only on the teacher depends how technology will be used. We can find information about the different roles of technology in teaching, inter alia, in the works of Goos, Galbraith, Renshaw & Geiger (2003).
All these roles are described in the table below:

<table>
<thead>
<tr>
<th>The role of technology</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master</td>
<td>Teachers and students are subordinated to the technology. Their knowledge and skills are limited to simple operations.</td>
</tr>
<tr>
<td>Servant</td>
<td>Technology is a tool for drawing, counting but does not help in solving issues.</td>
</tr>
<tr>
<td>Partner</td>
<td>Technology facilitates the understanding and/or learning to see the tasks from different perspectives and solving them in different ways.</td>
</tr>
<tr>
<td>Extension of himself</td>
<td>The most sophisticated modus operandi. Technology does not only serve for calculating results but also for developing ways of thinking like a natural element of teaching/learning process.</td>
</tr>
</tbody>
</table>

The teacher should lead the learning process so that the technology would play the last of the roles described in the table.

**CONCLUSIONS:**

1. Comprehension and understanding of mathematics as a field of knowledge has evolved over the millennia. The fast evolution and development of mathematics as a scientific discipline is insufficiently appreciated, which does not remain indifferent to the so-called school mathematics.

2. Defining contemporary mathematics as a field of knowledge and as a subject in school is also problematic.

3. Important issue in the teaching of mathematics in the current „digital school” is a lack of cooperation between teachers, teacher training colleges and the people in power.

4. Problem also lies in the number of teachers who are not convinced to use digital technology during their classes.

5. Realizing and improving the relationship between students growing up in the digital world and the generation of teachers growing up in a completely different reality is important.

6. Another important aspect is not only convincing the teachers to use technology in an appropriate way so that the technology will not be a servant, a partner or a master but an extension of himself. The role of teacher is being aware of these roles and being able to distinguish them from each other.

**REFERENCES**


Prensky%20-%20Digital%20Natives,%20Digital%20Immigrants%20-%202012-08-04县委
PRESCHOOL EDUCATION AND SCHOOL ACHIEVEMENTS OF STUDENTS AT THE AGE OF 10

The article is dedicated to the importance of preschool education for later school achievements of students. Early education and care are identified as one of the key factors that determine not only the adaptation of a child to the school situation and his or her readiness for learning, but also deferred effects in the form of school achievements at later stages (Bauchmüller, Görtz & Rasmussen, 2014). In the literature of the subject, there are also raised issues related to the significance of the quality of the preschool education for the social and emotional development of a child. Other factors pointed out include the availability of a kindergarten, the qualifications of the personnel and the quality of programmes implemented in a given institution (c.f. Yoshikawa et al., 2013). This article presents the results of analyses performed on a representative all-Polish group of grade 4 students. They solved a test covering numeracy and literacy skills. What was checked was the extent to which early education, measured by the number of years which a student spent in a kindergarten, is correlated with the results obtained by the students. It was found out that every year in a kindergarten translates to an improvement in the performance measured at the age of 10. There were also indicated limitations in the interpretation of that result connected to the socio-economic status of the families from which the children came.

Key words: Early care and education, kindergarten, school achievements, cognitive development

1. EFFECTS OF PRESCHOOL EDUCATION – REVIEW OF SURVEYS

The importance of early education for later functioning of a child, both in cognitive, and social and emotional terms, has been the subject of many studies and analyses performed in Europe and worldwide (Brzezińska, Czub, Czub, 2012). Many schemes carried out to popularise access to preschool education and improve its quality are based on the assumption that it has a significant impact on later achievements and success in coping with the challenges faced at later stages of education (Brzezińska, Czub, 2012).

Children who entered the education system at the age of 3 or 4 obtain better results at the end of education even in the third grade (IBE, 2011). The effect is more apparent in the case of boys than girls, but what is the condition is attending a kindergarten for at least three years. In this context, the data coming from the Early Childhood Longitudinal Study (Loeb et al., 2007) should be brought up. It considered the effects of early care and education.
in the context of later performance (measured at the start of school), taking into account the moment when a child starts to participate in various forms of care delivered outside of home and the number of hours which he or she spends in the institution per week. The best effects in the form of better school achievements were obtained by the children who started to participate in various programmes of preschool care at the age of 2-3. On the other hand, as regards children who were younger, under two years of age, when they started attending an institution, there were observed disadvantageous effects in the form of appearance of behavioural problems (externalisation problems). When the number of hours spent in an institution by a child was included in the analyses, it turned out that, for children from families with a low socio-economic status, a higher number of hours gives benefits in the scope of literacy and numeracy skills, and has just a slight adverse impact on social functioning. As regards children from wealthy families with a high socio-economic status, they benefit most in the scope of academic performance (literacy and numeracy) when they spend relatively little time in the institution (15 to 30 hours per week). Spending more time, that is above the average, brings no additional gains in the scope of the level of skills, while there has been noted a deterioration in the scope of social and emotional functioning.

The results of the international studies PIRLS (Progress in International Reading Literacy Study) and TIMSS (Trends in International Mathematics and Science Study) (Konarzewski, 2012, p. 83), in which also Polish third-graders participated, revealed that the length of preschool education was of no significance for their later performance. As the author of the report remarks, the kindergarten undoubtedly is important for the level of school achievements of children who start learning in the first grade, but the effect disappears when the performance of children aged ten who are finishing the first stage of education is measured (the study was carried out in May 2011, with the participation of students of primary school grade three).

A similar problem is emphasised by Yoshikawa et al. (2013), who pose a question concerning the cause of the weakening or even disappearing relations between early education and school performance indicators. The authors underline that what we deal with here is the phenomenon of diminishing differences between children who have participated in preschool education and those who have not. Then, the authors of the report on the study PISA (2011) indicate that early preschool education is important for performance at the age of 15. The effect, however, was observed in many countries, where preschool care is more widespread, where kindergartens are available during most of the months in a year and where appropriate funds were available for maintaining a high quality of work of the institutions (Melhuish, Barnes 2012). Studies performed in Western Europe identify the positive effect of attending a preschool by a child, which is perceptible with respect to various areas of social, emotional and intellectual functioning. However, it does not need to be relevant to systematic differences between children in the scope of school performance. It results from the analyses of studies carried out by A. Brzezińska and her team (2012) that the long-term effects concerned particularly children from disadvantaged groups and were related to the quality of the institution.

The surveys performed within the Study of Early Child Care and Youth Development NICHD (National Institute of Child Health and Human Development; the study commenced in 1991) revealed that a higher quality of care of a child during infancy and early childhood moderated the links between the socio-economic status of a family and the child’s performance in the scope of literacy and numeracy, measured over the years from the start of compulsory education until the age of 11. Low income of a family was a worse predictor of school failures of children, who attended institutions, where the quality of care was high. Children, who, between the ages of 6 and 54 months, had at least three episodes of care in institutions classified as characterised by a high quality of work, obtained
results similar to the results of children from high income families. Thus, it can be stated that children from families with a low socio-economic status benefited more from being in such institutions (Dearing et al., 2009). The authors (op. cit.) emphasise that the results are consistent with the hypothesis that high quality of care over a child promotes and helps him or her to achieve better performance and is related to higher school readiness and, therefore, enables him or her to achieve better long-term performance at school.

The studies discussed above (the Study of Early Child Care and Youth Development) also yielded analyses concerning the deferred effects of early care delivered by people not related to a child, including institutional care (Vandell et al., 2010). A repeated analysis of the same group was performed when the subjects were 15 years of age and it revealed that the quality of care in the institutions was a significant predictor of the cognitive development measured in the context of performance in the fields of mathematics, reading, vocabulary and solving verbal analogies. The quality of care was also a negative predictor of externalisation problems manifested at the age of 15 ($B = -1.89$). The dependences between the quality of care and cognitive achievements were important both for the linear connection ($B = 2.62$) and the square connection ($B = 3.35$). The time spent in the institution (the number of hours) was a predictor of impulsiveness and risky behaviours. There were also verified the mediation effects of earlier school performance measured at the age of 4 and a half and in the first, third and fifth grades. The quality of care was an important predictor of performance at the age of 4 and a half, and the achievements at specific stages of education were mediators of the relation between the quality of early preschool care and performance measured at the age of 15. As regards emotional and behavioural functioning, the number of ours spent in an institution was an important predictor. Children who spent more hours in institutions were more likely to manifest externalisation problems and risky behaviours, as well as they had a higher level of impulsiveness at the age of 15. The externalisation problems measured at specific stages of education were mediators of the relation between the number of hours spent in the institution and the externalisation problems measured at the age of 15. On the other hand, the quality of care was a negative predictor of externalisation problems at the age of 15.

The analyses discussed above confirm the role of early institutionalised care and education. What is the main factor is the quality of functioning of those institutions, which has a bearing on deferred effects in the form of the level of performance, as well as for social and emotional functioning. It also turned out that the incidence of behavioural problems among children who spent more time in an institution as assessed by teachers was significantly higher. This confirms the already mentioned effects observed with regard to younger children – the measurement made at the beginning of primary school (Loeb et al., 2007).

Many reports, in which the positive effects of early care and education are described in the context of later academic achievements and social and emotional functioning, concern special programmes prepared for and focused on the improvement of the children’s functioning. They are aimed at reducing the differences between children from disadvantaged groups and middle class children. However, when we look at the results of studies concerning whole populations and children participating in normal forms of early care delivered outside of home, we see somewhat different arrangements of the relations and higher variation in the described effects. In those programmes, the quality of early care outside of school was high and strictly controlled. On the other hand, in studies of whole populations within general early care and education systems, the quality varies and remains the key predictor for later academic performance (Melhuish, Barnes 2012). A slightly different opinion on who benefits the most from preschool education is held by Yoshikawa et al. (2013). According to them, not only children from disadvantaged or minority groups

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benefit from high-quality preschool care, it also pertains to children from middle class families.

When conducting analyses concerning the relations between early care and education before school with school achievements and later functioning one must remember that majority of the results concerning general populations of children come from research in which subjects were not sampled randomly, while experimental design is hardly ever encountered in this field. It is noted that the results are more likely to reflect the processes of selection of children resulting from family, social, and economic conditions. Lack of control over those variables may lead to the consequence that the observed differences, rather than resulting from the impact of preschool education, are the result of other processes responsible for whether and how long a child attends an institution and what type of institution the parents chose (Melhuish, Barnes 2012).

METHOD

For the purposes of the article, data coming from a study carried out at the Institute of Educational Research1 on a representative sample of N=5547 of primary school students were analysed. At the first stage of the study, in the school year 2010/2011, when students attended the third grade of primary school, data coming from parents or legal guardians of the children were collected. The study utilised questions from a parent questionnaire concerning socio-demographic variables, the socio-economic status of the family and data concerning participation in the system of preschool care and education. Measurements of school performance were carried out by means of standardised tests of school achievements in the scope of reading, language skills and mathematical skills, and was administered at the beginning of grade 4 in the school year 2011/2012. A broader description of the tools used, including their psychometric characteristics and procedures can be found in the study report (Czy szkoła ma znaczenie, 2014) and in the publications (Jasińska, Modzelewski 2012, 2013).

RESULTS

In the examined sample of 10-year-old children, there was taken into account (in parent questionnaires) a variable concerning the history of a child in the preschool, described in categories of “the child attended a kindergarten for”, “one year”, “two years” to “three or more years”. It should be noted that the statement “the child did not attend a kindergarten” shall be understood as identification of the situation, in which a child did the compulsory, one-year-long school preparation (the so called “zero grade”), but beside it did not previously attend a kindergarten. Table 1 presents the numbers of subjects by category.

Table 1. Sizes of categories describing children in terms of their participation in preschool education.

<table>
<thead>
<tr>
<th>Category of preschool attendance</th>
<th>N</th>
<th>%</th>
</tr>
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<tbody>
<tr>
<td>without preschool education</td>
<td>1661</td>
<td>29.9</td>
</tr>
<tr>
<td>one year in a kindergarten</td>
<td>1007</td>
<td>18.2</td>
</tr>
<tr>
<td>two years in a kindergarten</td>
<td>1063</td>
<td>19.2</td>
</tr>
<tr>
<td>three or more years in a kindergarten</td>
<td>1816</td>
<td>32.7</td>
</tr>
<tr>
<td>Total</td>
<td>5547</td>
<td>100</td>
</tr>
</tbody>
</table>

Division by gender does not differentiate the numbers of years of attending a kindergarten. There are no significant differences in terms of the time of attending a kindergarten by boys and girls.

An analysis of the size of locality where the children lived revealed a significant (chi²(6, N=5515)=318.03; p<0.001) differentiation of the number of years in preschool education. In cities with a population over 5 thousand, most children had gone through at least two to three years of pre-

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1 The “Study of the quality and effectiveness of education and institutionalisation of the research infrastructure” implemented by the Educational Research Institute and co-financed from the European Social Fund (Operational Programme Human Capital 2007–2013, Priority III: High quality of the education system).
school education, while there were fewer children who had never attended a kindergarten. As regards rural areas, the categories of children attending a kindergarten for two years or more were much less populous. In rural areas, there dominated children who had never attended a preschool programme.

The highest professional status of the parents (HISEI, c.f. Education at a Glance 2009: OECD Indicators 2009) is significantly, linearly connected to participation of a child in preschool education. The higher the professional status, the longer the duration of participation of a child in preschool education (F(3.5341)=405.04; p<0.001; eta²=0.18).

It should be noted that the HISEI variable has the strongest connection to the number of years of participation of a child in preschool education of all the analysed contextual variables.

Also the parents’ education is significantly related to the number of years of preschool education of a child. Better educated parents more frequently and/or earlier send their children to a kindergarten. The dependence is relevant both for the education level of the father (F(3.5508)=9.43; p<0.001; eta²=0.05) and the mother (F(3.4345)=20.21; p<0.001; eta²=0.14). The dependence is stronger here for the mother’s education level.

**Fig. 1.** Level of achievements on the scale of mathematics, reading and writing of 10-year-olds depending on the number of years of participation in preschool education. Scale of achievements with a mean of 100 and standard deviation of 15.

Analysing the index of household resources, we can observe a similar trend. More opulent households are also those that form which children participate in preschool education more frequently and longer. The relation is strong and statistically significant (F(3.5546)=220.44; p<0.001; eta²=0.11).

To sum up, it can be stated that, at the time of the study, children participating in preschool education were mostly children of parents with a high professional status, coming from wealthy families, from big cities, having well-educated parents. Children not attending a kindergarten were, in turn, most frequently children from rural areas, from families with a lower professional status and a lower level of education, from less affluent communities.

An analysis of the performance of students depending on their participation in preschool education, carried out for the whole studied sample, clearly indicates that children attending a kindergarten are characterised by a higher level of competence in the scope of reading, writing and mathematics (student performance was measured by means of three tests prepared for the purposes of the study and standardised, c.f. Czy szkoła ma znaczenie, 2014). The data are represented in Figure 1.
However, the variables related to participation in preschool education, which describe the socio-economic status of the family and the size of the place of residence should not be forgotten. The factors may also be significantly correlated with the school performance of children. Therefore, an analysis concerned the relation between participation in preschool education and school performance at the age of 10, with simultaneous control of the contextual variables describing the socio-economic status of the child’s family. Having incorporated into the model contextual variables, such as the child’s intelligence, the child’s age, early start or postponement of the course of learning, education of the child’s parents, professional status of the child’s parents, and the household resources index, one may notice that the impact of the number of years of participation in preschool education on school performance at the age of 10 remained significant, but the strength of the relation fell markedly for performance in the scope of reading and writing skills, and the relation became insignificant for numeracy skills. Thus, there is observed a strong relation between the number of years of preschool education and the performance of 10-year-olds on the scales of reading \( F(3.4698) = 4.16; p < 0.01; \text{eta}^2 = 0.003 \) and writing \( F(3.4698) = 4.44; p < 0.01; \text{eta}^2 = 0.003 \), and a relation below the statistical significance threshold for the results on the mathematics scale \( F(3.4596) = 1.97; p = \text{ni}; \text{eta}^2 = 0.001 \). The strength of the relations measured by the eta-squared coefficient for the relation between the participation in preschool education and later school achievements is presented in Table 2. The coefficients were calculated in two variants – for direct results on the reading, writing and mathematics scales and for results incorporating variance resulting from the aforementioned contextual variables (family socio-economic status and individual variables).

Table 2. The strengths of the effect of preschool education (eta-squared) for deferred achievements on the scales of mathematics, reading and writing, directly and with control of contextual variables.

<table>
<thead>
<tr>
<th></th>
<th>effect of preschool education</th>
<th>effect of preschool education with control of socio-economic status</th>
</tr>
</thead>
<tbody>
<tr>
<td>mathematics</td>
<td>0.034</td>
<td>0.001 (ni.)</td>
</tr>
<tr>
<td>reading</td>
<td>0.031</td>
<td>0.003</td>
</tr>
<tr>
<td>writing</td>
<td>0.034</td>
<td>0.003</td>
</tr>
</tbody>
</table>

As Table 2 illustrates, introduction of the contextual variables to the analysis of the strength of the effect resulted in significant weakening of the obtained dependences. The level of explained variance in the case of reading and writing dropped tenfold, and in the case of mathematics the model with covariants is statistically insignificant. Yet one should note that, for each of the above three scales, an analysis of contrasts, which tests the hypothesis concerning the curvilinear dependence between the number of years of participation in preschool education and later performance, showed significant \( p < 0.05 \) adjustment to the square function with maximum values for the group not participating in preschool education and the group participating for at least three years.

Does the obtained pattern of results mean that it is best not to send children to kindergartens? No! As can be seen in Figure 1, children attending kindergartens obtain better results in tests of achievements even with a measurement deferred by a few years. How should one interpret the obtained results then? The results present school performance of children with various numbers of years of using preschool education, analysed taking into account the social and material status and individual variables. The results may be interpreted in the following way: they signify how effective a child’s use of his or her educational environment was. And thus – children who did not attend a kindergarten (as described at the beginning of the chapter) tend to remain in
a poor educational environment – the obtained result shows that they used it with remarkable efficiency. Carers (usually mothers, grandmothers) influenced the development of their competences as well, as possible. As regards children who did attend a kindergarten (as described at the beginning of the chapter – they were most often children coming from wealthy communities with high opportunities) did not benefit from those opportunities as much as their peers from less privileged communities, yet there was observed a significant, linear, positive impact of the preschool environment, cumulative with each year of utilising the preschool care and education. The effects might be much more efficiently analysed if the studies carried out incorporated variables that describe the quality of the preschool environment. The pedagogical approach applied in the kindergarten, the atmosphere in the kindergarten, management of the institution – these are variables which have an enormous impact on the effects of preschool education, including deferred effects. Without control of the characteristics of the institutions it is extremely difficult to describe (taken their high differentiation) their general, deferred effects.

CONCLUSIONS

An analysis of the data indicates a clearly positive effects of early education. Children attending preschool programmes increase their cognitive capital from year to year, which yields deferred effects in the form of increased level of competence in the scope of reading, writing and mathematics at the end of the first educational stage (primary school grade three). Activities aimed at improving the accessibility of preschool care and education should be directed in particular at children living in rural areas and children from less educated families, from disadvantaged communities, worse-off. Such activities may significantly help in building the cognitive capital of children with lower educational opportunities and shall bring not only direct, but also deferred effects over many years. The effect has been observed in many longitudinal and large-scale studies, to which we referred in the first part of the article. Children from families with a lower socio-economic status benefit the most thanks to attending a kindergarten (c.f. Loeb et al., 2007; Dearing et al., 2009). Early start of education brings the effects in the form of better school performance at least until primary school grade 4.

What is a key factor which was taken into account in the discussed studies was the quality of preschool education. It was shown that it was not the number of years spent in an institution by a child alone what should be considered, but most of all the ways of organising care and education. An analysis performed on a population of more than 30,000 Danish students revealed that a greater number of employees in a kindergarten per one child and a greater number of men employed in a kindergarten were important predictors of the students’ academic performance. What was just as important was the education and preparation of teachers: it was significant that they should have formal education and training in the scope of preschool education (Bauchmüller, Görtz Rasmussen, 2014). Thus, it is beyond doubt that the answer to the question concerning the importance of preschool education for later performance, the studies which considered the quality of education and care in the kindergarten which a student attended are necessary. It is no less important to extend the analyses also onto measures of adaptation, including the quality of life and well-being of children, as well as indicators of emotional and social development, treated as equal in importance to the measures of school achievements. Such an arrangement of the examined dependences would offer an opportunity to provide a relatively comprehensive answer to the question concerning the importance of early education and care for later functioning of students.
BIBLIOGRAPHY


