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Introduction

One of the most important goals of modern education is to develop the dispositions and skills necessary for life-long independent learning. As pointed out by the European Council (2018), though learning by heart, memorizing facts or concepts is still an important skill, it is not sufficient to survive and thrive in modern knowledge-based societies. Much more crucial become these abilities which serve as tools for solving complex, interdisciplinary problems, such as: critical and creative thinking, formulating problems, predicting, drawing conclusions, computational thinking, planning and evaluating one's own learning, generating new ideas or sharing/discussing knowledge with others.

In the case of young children, the general learning dispositions might be perceived as inborn, granted. Young children are skillful observers, attentive listeners, tireless explorers, intrigued engineers and constructors, etc. (Simoncini, Lasen 2018). Driven by their natural innate instinct they tend to explore their environment with all the senses, trying to make sense of the world, understand how things work and why. Well before formal schooling begins, children have extensive conceptual knowledge that aligns with the scientific disciplines of biology, chemistry, physics and psychology, as well as emergent scientific reasoning skills (Brenneman 2011).

Unfortunately, many contemporary preschools and elementary schools, instead of taking care of the development of a child's intellectual dispositions, place too much emphasis on academic achievement. As Lilian Katz explains, "academic goals are those concerned with acquiring small discrete bits of disembedded information, usually related to preliteracy skills, that must be practiced in drills, and worksheets, and other kinds of exercises designed to prepare children for later literacy and numeracy learning. In an academic curriculum, the items learned and practiced require correct answers, rely heavily on memorization, on the application of formulae versus the search for understanding, and consist largely of giving the teacher the correct answers that the children know she awaits" (Katz 2010: 1–2). Intellectual learning, on the other hand, tries to engage and stimulate children's minds, inviting them to the quest for understanding. The concept of deep, intellectual learning emphasizes higher-order cognitive skills, such as: reasoning, hypothesizing, predicting, concluding, etc., as well as working collaboratively, thinking and interacting critically and actively with the content being learned (Warburton 2003). When young children investigate a scientific concept or process, they ask research questions, conduct experiments, draw conclusions and design solutions, being eagerly employed and intellectually challenged at the same time.

"Deep learning" perspective on science and math education underlines the following features:

- interdisciplinary vs. separate subjects learning (Warburton 2003): interdisciplinary problems involve various pieces of knowledge and skills resulting in holistic insight, and the ability to perceive the complex interconnections between the components of human life (social, environmental, economic),
- constructing knowledge vs. reproducing information (Marton, Saljo 1997): engaging in making/negotiating meanings with others, relating ideas to one's own previous knowledge and experience, discovering organizing principles to integrate ideas, examining the logic of arguments, etc.
- meaningful vs. theoretical context of learning: perceiving the direct connection between knowledge and everyday life reinforces learning, strengthens the pragmatic dimensions of new knowledge.

As a result, learning becomes strategic, deepens children's metacognitive abilities to reflect on one's own knowledge, as well as fosters a transfer of intellectual abilities into new contexts, new tasks, new challenges.

To summarize, as Katz points out "children should be helped to acquire academic skills in the service of their intellectual dispositions and not at their expense" (Katz 2010: 7). Ironically, such an idea is neither new, nor revolutionary. Popularized and elaborated in the 20th century by educational scientists and practitioners such as Maria Montessori, Célestin Freinet, John Dewey, etc., it dates back to the 17th-century epistemological reflection, such as the Galilean "Book of Nature."

We invite you to read, rethink and redefine the ideas of modern math and science education of a young child.

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THEMATIC ARTICLES

ARTYKUŁY TEMATYCZNE

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Iconic and Symbolic Representation in Early Mathematics Teaching

Reprezentacje ikoniczne i symboliczne w początkowym nauczaniu matematyki

KEYWORDS

early childhood education, mathematics methodology, symbolic representation, iconic representation

ABSTRACT

Mathematics is an abstract science, it uses a specific symbolic language, a kind of code that is difficult for children to comprehend. Using operation signs and numbers is not simple and obvious for them. The learning of mathematics by children cannot therefore be based on symbols alone. Action is needed first. However, since there is a large gap between an action and a symbol, it is necessary to support the teaching of mathematics with graphic means. Introducing a graphic element as a kind of methodological aid requires careful preparation, motivation and embedding it in previous physical activities performed by children. Otherwise, such an item, instead of facilitating the understanding of a concept, hinders that understanding and becomes an illusory aid. This paper describes the role and importance of pictorial representation in early mathematics teaching. Based on selected examples of tasks from textbooks, the difficulties of illustrating mathematical concepts are presented, and appropriate methodological solutions in this area are indicated.

SŁOWA KLUCZE

edukacja wczesnoszkolna, metodyka matematyki, reprezentacja symboliczna, ikoniczna

ABSTRAKT

Matematyka jest nauką abstrakcyjną, posługuje się specyficznym, symbolicznym językiem, rodzajem kodu, który jest trudny dla dzieci. Używanie znaków działań, cyfr nie jest dla nich proste i oczywiste. Uczenie się matematyki przez dzieci nie może więc się opierać jedynie na symbolach. Konieczne jest najpierw działanie. Ponieważ jednak pomiędzy działaniem a symbolem istnieje duża przepaść, to ucząc matematyki należy się posiłkować środkami graficznymi. Wprowadzenie środka graficznego jako swoistego ułatwienia metodycznego wymaga starannego przygotowania, umotywowania oraz osadzenia we wcześniejszych czynnościach fizycznych wykonywanych przez dziecko. W innym wypadku środek taki, zamiast ułatwić zrozumienie jakiegoś pojęcia, utrudnia to rozumienie i staje się ułatwieniem pozornym. W artykule opisano rolę i znaczenie schematów graficznych w początkowym nauczaniu matematyki. Bazując na wybranych przykładach zadań z podręczników, przedstawiono trudności związane z ilustrowaniem pojęć matematycznych oraz wskazano właściwe rozwiązania metodyczne w tym zakresie.

Introduction

Mathematics as an abstract science presents a specific way of looking at the world, and its hermetic language allows us to explain this world in an accurate, precise and unambiguous way. As Ewa Swoboda writes (2017: 27), "it is seen as a science that uses abstract concepts and relationships." And, as the cited author further notes,

> there is no way to experience with the senses what a particular detailed mathematical concept is, or what the relationships and relations between concepts are. These objects and relationships can only be represented through word, image, symbol, gesture. Each such representation carries a specific content, is a code for a certain meaning (Swoboda 2017: 27).

The Specificity of Math Education at the Early Childhood Stage

The specific characteristics of mathematics mean that it cannot be learned simply by observing the actions of others. In mathematics, individual experience is important but also cooperation and exchange of thoughts. It is also important to make mistakes, which are a natural phenomenon and should be skillfully used in the learning process (Turnau 1990: 79). And while this process is inherently based on reasoning and less on experience, the latter plays an important role in the school teaching of mathematics. It becomes particularly important in the case of elementary mathematics, in which concrete manipulation is the starting point in the formation of basic concepts. In teaching mathematics, logical-mathematical experiences are the beginning of a path that leads to higher-level reasoning. Collecting them allows qualitative changes in thinking and the formation of abstract concepts to take place.

Although mathematics is an abstract science that uses a specific symbolic language, teaching this subject to young children cannot be based on symbols alone. The intellectual capacity of early childhood education students limits the use of symbols and therefore makes it necessary to support teaching with practical (physical) actions and pictures. For what is available to adults is not available to 7- to 10-year-old children, and this must be taken into account in their math education. These issues are highlighted by Milan Hejny (1997: 17–18), who describes the cognitive mechanism related to the acquisition of mathematical knowledge. The emergence of a new piece of knowledge is conditioned by motivation and accumulated experiences. These experiences are isolated events at the beginning. Only then, when the child begins to notice the relationships between them, arranges and hierarchizes them, they become universal models. Then a new fragment of knowledge is discovered and this knowledge is understood on a higher, abstract level (Hejny 1997: 17).

In the early stages of children's education, action is the most understandable, because logical thinking, which becomes active at the turn of preschool and early school age, is firmly rooted in action. A shift away from visual perception to purely mental operations takes place later. The students are able to make certain transformations in their minds to conclude, for example, that despite the rearrangement, the lengths of the objects do not change. Action is therefore the beginning of the formation of abstract concepts that are presented symbolically in mathematics.

Since there is a large gap between action (concrete) and symbol (which for some students may be a difficult barrier to overcome), teaching mathematics should be supported by graphical means. Pictorial representations, as Zbigniew Semadeni points out, are

> an intermediate stage—between the concrete and the abstract … which can make it easier for a child to internalize, understand or assimilate certain mathematical notions. A schematic image can serve as a generalization of a specific situation and at the same time a generalization of a purely verbal formulation (Semadeni 1992: 116).

As the author further notes, the introduction of a graphic element as a kind of methodological aid, a bridge between action and symbol, requires very careful preparation, motivation, and embedding in previous physical activities performed by the child. However, if the graphic medium is to be detached from such experiences and introduced as "a finished, static creation, imposed on the child" (Semadeni 1992: 116), it is better not to use it, because instead of making the understanding easier, it will make it more difficult, it will become an illusory aid, a "didactic trick" that brings nothing (Pisarski 1996).

Jerome Seymour Bruner's Representation Theory as a Learning Model

Reflecting on the role of iconic and symbolic representation in teaching mathematics, it is impossible not to refer to the concept of Jerome Seymour Bruner. According to him, the process of internalization begins with a concrete action, which is summarized in the form of synthetic images to be finally described in the language of symbols. Burner links this transformation of concrete activities into abstract ones, through acting, drawing and telling, to three modes of representation: enactive, iconic, and symbolic defined as "a set of rules in terms of which an individual forms a concept of the constancy of the events he or she has encountered" (Bruner 1978: 530–531). The process of learning, according to Bruner, consists in "creating more economical or efficient ways of representing similar events … in a kind of translation of one mode of representation into another" (Bruner 1978: 531). These modes of representation appear in the child's life in a well-defined sequence (enactive, iconic, and symbolic), their development is interdependent and each remains virtually intact throughout life.

In younger students' learning of mathematics, performing an action using manipulatives plays an important role. Action, according to Bruner's theory, is an enactive representation and is the "representation of past events through an appropriate motor response" (Bruner 1978: 548), it is also the "knowledge of something contained in doing it" (Bruner 1978: 532). Iconic representation, on the other hand, is the knowledge contained in images and pictures. The rules that make up this mode, although they make it possible to grasp an object as a summary image, do not define it in a complete way, but only constitute a summary of what we know about it, and therefore present it approximately, selectively (Bruner 1978: 548). Symbolic representation means coding and decoding using a well-defined character system. Anything that makes up the essence of an individual's experience can be coded. The basic feature of symbolic representation is its detachment from the concrete, which means that we cannot do with it what we are able to do with a picture or a scheme of action, for the "symbolic system represents things through model features in a distant and arbitrary way. The word neither points directly, here and now, to its referent nor resembles it as an image" (Bruner 1978: 548).

Bruner's modes of representation underpin individual development and define a different way of dealing with incoming information. Each representation contains numerous variations because each represents an event selectively. What is important in this respect is the purpose which the representation is to serve (Bruner 1978: 530–531).

Bruner's learning model finds its application in the early years of learning mathematics. A student entering school is not only expected to be able to function at three levels of representation, but "must be able to move freely from one level of representation to another" (Gruszczyk-Kolczyńska 1994: 85) which means, according to the cited author the "ability to establish relationships between one's actions, graphic representation of things and events, and symbolic representation of them" (Gruszczyk-Kolczyńska 1994: 85). Not being able to function at an appropriate level in this area dooms some children to school failure at the very beginning of their education.

Graphic Representation of Arithmetic Operations in Early Childhood

For many years, various scientific studies in the field of early childhood math education have drawn attention to the various limitations and difficulties of children in understanding the meaning of more or less schematic illustrations or symbolic notations (Gruszczyk-Kolczyńska 1994: 83–102; Nawolska, Żądło 2010: 86–91; 2017: 108–120). With these arguments in mind, it is worth looking at some of the iconic and symbolic representations and their various combinations used in textbook problems for first- to third-grade students to see which of them actually help shape mathematical concepts and which are only an illusory aid (Pisarski 1996).

Most problems contained in early childhood education textbooks are supported by a variety of illustrations. At first, they are literal, but later, as children's experiences grow, they become more simplistic and schematic. Each illustration forming part of a problem (arithmetic or verbal) should support thinking, act on children's imagination so that the situation synthesized in a mathematical formula or described in a mathematical text is clear. Such an illustration in the case of arithmetic problems should help to understand the symbolic notation and be helpful in determining the result.

To illustrate children's potential difficulties in interpreting pictures, we will take a look at three selections that illustrate subtraction in the first grade (Figure 1, 2, 3).

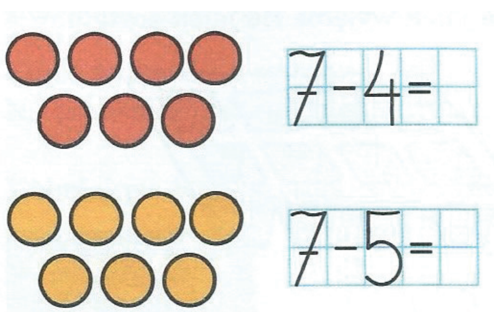
Figure 1. Illustrate subtraction

Source: Semadeni (2001: 54).

Figure 2. Illustrate subtraction

Source: Semadeni (2001: 55).

Figure 3. Illustrate subtraction

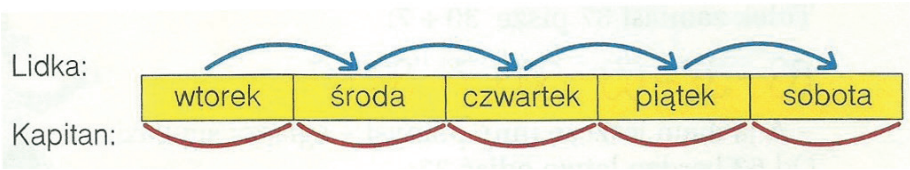


Source: Semadeni (2001: 70).

Subtraction is the inverse operation to addition and for that reason at least it is more difficult. It requires reversal action, which is not easy for students who do not yet reason operationally. In addition, it is difficult to convey the dynamics of the situation and the succession of time in the picture. This is well illustrated in Figure 1. This picture is preceded in the textbook by the *Make up a story. Create a question and answer it* instruction. There is also a blank space to write down the operation. To do this, one must first understand the convention of this static image and decode it according to the accepted way of illustrating subtraction (depletion as a result of: eating, smashing, pouring, ripping, etc.). An additional difficulty is the notation of the operation (7 – 2 = 5), which implies the need to return to the starting point and to imagine seven whole, unbroken cups. The next step is to imagine a change, i.e., breaking two cups. The process does not end there, as the result still needs to be determined. To do this, one needs to skip the subtrahend (2 broken cups) in the picture and focus on the difference, which is five whole cups. A slightly easier (cartoon-like) illustration of subtraction, is presented in Figure 2. There are two images here. The first shows the initial state (there were 5 acorns), while the second shows the final state (1 acorn left). The questions given serve as an aid to reasoning: *How many were there? How many are gone? How many are left?* Admittedly, this time one can see the initial number of acorns, but one still has to visualize the change based on the four acorn cups left. As in the problem in Figure 1, to indicate the difference, one has to omit the subtrahend (4 acorn cups left) and focus on the 1 whole acorn. The difficulty connecting these two illustrations of subtraction is that in both the first and the second picture the number of elements in the set does not change (there were 7 and there are 7, there were 5 and there are 5). Thus, to be able to correctly determine the result of subtraction in these tasks, it is necessary to understand the conventions of the picture, decode the information contained therein (broken, so they are not there, incomplete acorns so they are not there either). The subtraction presented in these two examples, and the difficulties that may arise in understanding the nature of the operation thus presented, justify the need for more frequent recourse to enactive representation in forming the concept of difference. Moving two broken cups (or sticks) out of the 7 cups (or sticks) placed on the desk will then cause no difficulty in determining the result. This is something children in kindergartens can handle. Moving too quickly (especially in case of subtraction, later also of division) to the iconic-symbolic level may not make an operation any easier or more familiar, but more difficult for children to comprehend. In situations such as those in Figures 1 and 2, students often do not see subtraction, and when asked to create stories on their own, these are often such stories as: *There were 5 whole cups and 2 broken cups. How many cups were there?* The next example (Figure 3) is a good illustration of subtraction, provided we properly prepare children to understand it. Such pictures can be introduced after a prior practical action. In order to determine e.g., how many discs will be left when 4 out of 7 are taken away, students should first manipulate (move) such discs, and then write down arithmetic formulas matching such practical activities. Then a picture in which the pushing operation is coded as crossing out can be used. The order of actions to be performed, this time on the picture, will be as follows: first I count the discs, then out of the 7 discs in the picture I separate 4 (because this is how many we are to subtract 7 – 4 =). The remaining discs that are not crossed out constitute the difference. In this case, we can hope that by creating an illustration to the action on their own, the students will remember the successive stages of that creation and the sequence of time. The picture, therefore, should be comprehensible, despite the fact that it is still static in the end, which is a fundamental difficulty in illustrating subtraction (Nawolska, Żądło-Treder 2017).

The use of illustrations in word problems is intended to help visualize the situation described in the problem and facilitate understanding and correct solution. A good example of such an illustration is Figure 4 corresponding to the following problem: *The ship entered the port on Tuesday before dawn, when it was still dark. It will depart on Saturday just before midnight. Help the captain calculate how many days the ship will be in the port.*

Figure 4. Illustration of the word problem

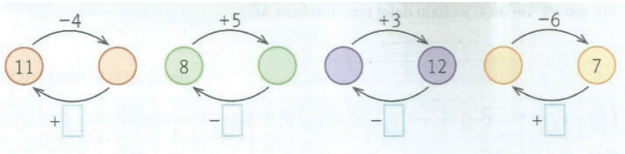


Source: Lankiewicz, Semadeni (1994: 78).

This word problem is about calendar calculations, specifically knowing the days of the week. It also checks the understanding of the term "day," which is not unambiguous and can be interpreted in different ways by children; it also refers to the problem of counting in "including" and "excluding" terms. The calculation of Lidka and the Captain shown in the illustration shows two possible methods. The Captain, reasoning practically (I entered before dawn on Tuesday and leave before midnight on Saturday), counts consecutive days in calendar terms. He will therefore spend 5 days in the port. Lidka, on the other hand, treats a day as a 24-hour segment and counts the passage of time, in which one day passes from Tuesday to Wednesday, another from Wednesday to Thursday, and so on until Saturday. Hence, according to her, the Captain will spend 4 days in the port. This apparent contradiction is very well explained by the proposed pictorial representation. However, this is not always the case. It happens that the pictures accompanying the problem serve a decorative purpose only and do not contribute anything significant to the process of solving them (Swoboda 2017: 36). These types of situations can even block one's understanding of the problem and make it more difficult, not easier, to solve.

In the math education of children, it is very important to discover general mechanisms on the basis of generalized ways of doing things, while it is a mistake to draw general conclusions on the basis of single, isolated facts. Often the pictorial representations presented to children in textbooks (trees, function tables, graphs), which are mixed iconic-symbolic creations, constitute ready products, introduced without any previous preparation. Students who are not adequately prepared to decode information contained in pictorial representations can rightly feel confused because they may not understand a problem coded in such a manner. It is therefore doubtful that at further stages of education the essence of the representation can be understood and used correctly (Gruszczyk-Kolczyńska 1994; Nawolska, Żądło 2010, 2017; Semadeni 1992). An example of a problem using an arrow graph to illustrate the relationship between addition and subtraction is shown in Figure 5.

Figure 5. Arrow graph

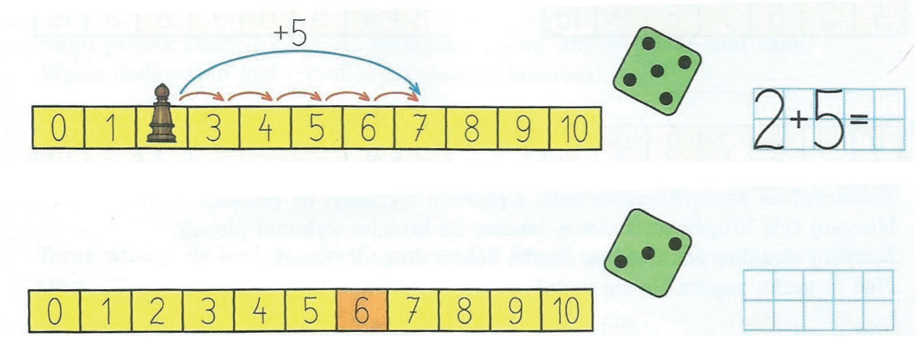


Source: Dobrowolska, Jucewicz, Szulc (2014: 49).

This problem, like most such problems in textbooks, is not preceded by any commentary, but only contains the *Complete the graphs* instruction. Unless the teacher comments on such a task, students will most often automatically fill in the missing numbers. They do so without giving any further thought to the meaning of these notations.

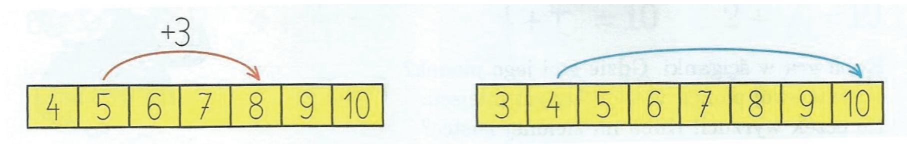
However, other examples exist in textbooks. Figures 6, 7, 8, 9, 10 illustrate the steps of introducing an arrow graph.

Figure 6. Step 1



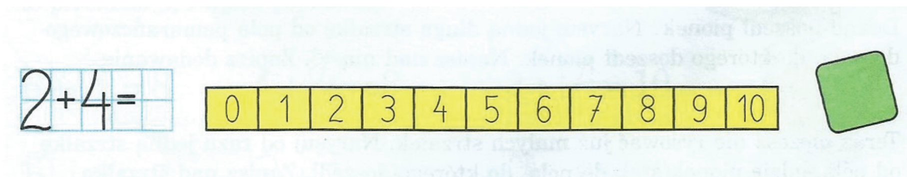
Source: Semadeni (2001: 37).

Figure 7. Step 2



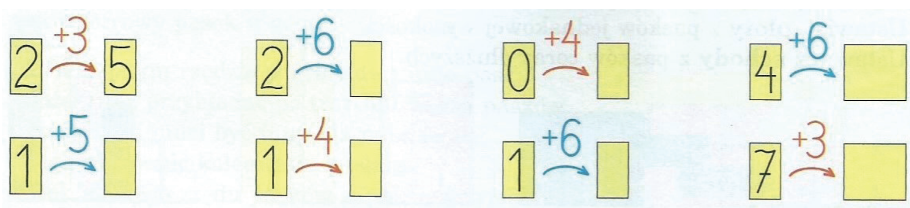
Source: Semadeni (2001: 37).

Figure 8. Step 3



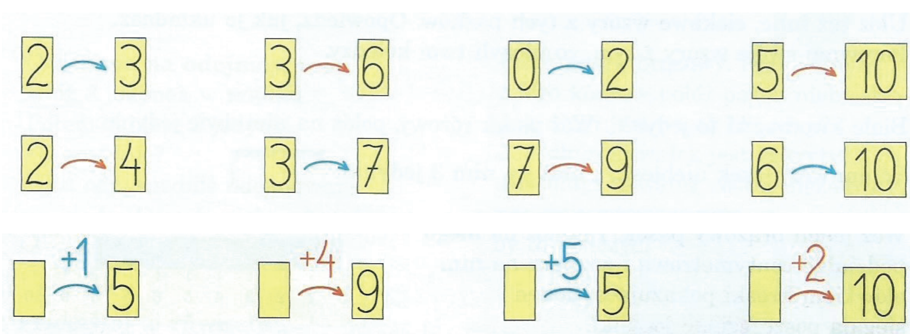
Source: Semadeni (2001: 38).

Figure 9. Step 4



Source: Semadeni (2001: 39).

Figure 10. Step 5



Source: Semadeni (2001: 39).

It all begins with a race game (using a row of squares with numbers) in which students play by rolling the dice and moving their pawns one square for each dot on the dice (Semadeni 1992: 114–119). At this stage, they can already begin to code the movements of their pawns along the row by drawing the appropriate arrows. In the next stage, this real-life game is transferred to the pages of the textbook. Students deal with hypothetical games played by the characters in a given problem. They should have no difficulties in identifying with them because they have played such games in the classroom. Thus, in Figure 6, they move one square to the right for each spot on the dice. In doing so, they first draw small arrows and complete the operation notation. Through direct experience, the formal notation 2 + 5 = 7 is clear and not difficult to relate to the pictorial representation. The number 2 is where the pawn stood, 5 is the number of dots thrown, and the plus sign and right arrow indicate the direction of the pawn's movement (right, add). The number 7 is the symbol of the square the pawn landed on after moving to the right. The tasks in Figures 7 and 8 deepen the understanding of this code (numbers, operation signs). The children's task is to determine, based on the illustration (Figure 7) or the written arithmetic formula (Figure 8), the number of dots thrown, the start and finish square. The problems presented in Figure 9 and Figure 10 contain a typical single-operation arrow graph. After such thorough preparation beforehand, it can hardly be called something imposed in advance, introduced without proper motivation. It provides an abbreviated record of the pawn's journey on the board. We have the square on which the pawn was standing, the arrow indicating the direction of the pawn's movement with the number of dots thrown and the square to which the pawn was moved. At this point, such a pictorial representation should not be something incomprehensible to children, for as Margaret Donaldson noted long ago "all normal children are able to demonstrate their abilities as thinking beings and users of language (...) provided, however, that they are confronted with meaningful life situations" (Donaldson 1986: 161).

The examples from the textbook show that the language of mathematics differs significantly from natural language. It is a difficult language, and as a result, children's use of pictorial representations or symbols such as operation signs, numbers, or arithmetic formula notation is not as obvious. Every single mathematical symbol (+, –, ·, :) that a child learns at an early stage of education is not only an abbreviated notation of a mathematical operation, but also a coded action, expressed with an appropriate verb (combine/add, take away/subtract, take "a few several times," "distribute equally," etc.). When we place these symbols between numbers, a mathematical formula is formed, which, again, is not a single symbolic notation. For a child who is just gathering logical-mathematical experiences in the course of various activities, the formula notation should be a synthesis of various experiences. For example, 10 : 2 = 5 is not only a notation of the relationship between the numbers 10, 2, and 5, nor only a notation of the specific quotient of the two numbers, but first of all an abbreviated (symbolic) notation of the action of dividing, for example, 10 candies into 2 equal portions and determining how many of them will be in such a portion, as well as a symbolic notation of dividing 10 candies into portions of 2 candies each and determining how many such portions will be formed. Furthermore, dividing ten candies into two equal portions is not the same for a child as pouring 10 liters of water into two buckets equally, or pouring 10 liters of water into vessels, two liters into each. The number 5 which is the solution to these two different problems represents in the first case the amount of water in one vessel, and in the next case the number of vessels needed. Formula 10 : 2 = 5 is a synthesis of the action of dividing relating to these different life situations (dividing candies, pouring water, and many other ones not mentioned here). This simple example shows that such a single symbolic notation contains a variety of children's experiences. Thus, it is difficult to expect such a notation to be immediately legible to all children because, as mentioned earlier, it represents a synthesis of diverse, sometimes extremely different children's experiences. On the other hand, however, it is precisely this variety of experiences (activities, actions), children's personal activity in this area, independence in constructing knowledge that contributes to increasing the operability of language and its construction at an ever-higher level. Hence, the introduction of symbolic notations (symbolic language) must be properly motivated and linked to the personal activity of the learner. Thus, it would be good for early childhood education teachers to be aware that for a certain group of children entering school, the symbolic level remains inaccessible for a long time (Gruszczyk-Kolczyńska 1994: 83–102). For them, the formal notation of a mathematical operation is sometimes incomprehensible, although they can answer how many candies each child will receive, or how candies each child will have (how much water will be in one container, and how many containers are needed). However, they are not yet aware that it is always the case that 10 : 2 = 5, regardless of whether we are pouring water or dividing candies.

To conclude the discussion of the language of mathematics as a kind of symbolic code, it is worth noting that in addition to the language of textbook problems, students still have to deal with the more or less formal language of the teacher. This language is also a code and it is worthwhile for a teacher to use it in a thoughtful way that allows children to understand it. The lack of ability to decode incoming information may cause disturbances in communication between the student and the teacher

> … distortions or disruptions may arise as a result of the student's inadequate decoding of the received information (the student creates a wrong idea about situations, processes, objects) and its translation into the internal language or vice versa—the lack of ability

to code their own thoughts and translate information from their own language into the language in which the student communicates with the teacher (Bugajska-Jaszczołt, Czajkowska 2013: 40).

Conclusion

The basic condition for limiting the spread of the phenomenon of the so-called "degenerate formalism"[1] is to create appropriate conditions for students to learn mathematics and properly develop their mathematical activity. Intellectual activity should take place on many levels and be based on student independence in pursuit of knowledge. The use of symbolic, mathematical language in this area is not straightforward because "like any sign, a mathematical symbol carries a specific meaning. It should be associated with various procedures, with typical uses. However, such associations are built over a long period of time, through the accumulation of experiences" (Swoboda 2017: 37). Good illustrations, pictorial representations properly constructed and grounded in children's experience can be helpful in building operational knowledge. Knowledge that will be owned by the learner, not something imposed and completely incomprehensible. In doing so, both the action and the illustration must not only precede the symbols, but also accompany them. The same is true of language. The symbolic one cannot be imposed on children too early, it should be preceded and supported by the colloquial one (Dąbrowski 2008: 142–143). Language skills, related to translating natural language into the symbolic language of mathematics, play an important role in interpreting mathematical problems. To be able to make such a translation one needs knowledge and understanding of the relationship between the two languages: natural and symbolic (Rodríguez-Hernández, Pruneda, Rodríguez-Díaz 2021: 3). It is important to remember that everyday language and the language of mathematics are two different worlds. Thus, for example, a circle that exists in the real world is just a shape of a real object, e.g., of a wheel in a bicycle or a car. In mathematics, a circle is an abstract concept, a product of our mind, defined in theory and not existing in the real world. The students in the lesson can at most use its model. However, when teachers use the term "circle," they do not mean a shape of a real object but an abstract object (Bugajska-Jaszczołt, Czajkowska 2013: 40).

Breaking with the "concrete" and realizing certain mathematical regularities (e.g., independence of numbers and numerical operations from the real world)

[1] The term introduced by Zofia Krygowska (in Polish: *formalizm zdegenerowany*). A manifestation of degenerate formalism is a lack of understanding of the meaning of terms, mathematical symbols, or chaos in the application of syntactic rules (Krygowska 1986: 27).

is a crucial moment in the development of mathematical knowledge. This moment, called by Hejny the elevation of abstraction (Hejny 1997: 17–18), allows the child to understand math at a higher level. It begins to understand symbols, rules, laws, relationships, procedures, etc. For this elevation of abstraction to take place and for a child to gain access to the abstract world of mathematics, prior experience is needed at all levels of representation—enactive, iconic, and symbolic according to Brunner's theory—and this is the basis for functioning well in the school setting.

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Inspiring Children's Mathematical Activity Through Contact With a Picture Book

Wyzwalanie aktywności matematycznej dzieci poprzez kontakt z książką obrazkową

KEYWORDS

picture book, mathematical narration, children, mathematical activity, kindergarten

ABSTRACT

Children's literature has a cognitive value and is a source of aesthetic experiences. Picture books with mathematical content are a special type of children's books. The study aims to show that picture books where mathematical text is combined with images in an aesthetic form provide impulses to create educational situations that inspire mathematical activity. Based on the classification of mathematical activity by Ewa Kozak-Czyżewska, we developed our methodological proposals for stimulating creative and imitative mathematical activity in children. These suggestions are presented on the basis of our work with two books: *Numbers* written by Jacek Cygan and *At our house* written by Isabel Minhós Martins and Madalena Matoso. For the purpose of this study, educational classes with the use of mathematical literary texts were conducted for six-year-old children in kindergarten. It has been shown that picture books can inspire creative and imitative mathematical activity in children. By providing positive experiences, these texts can support the processes of learning mathematics, awaken children's motivation to calculate and use mathematics in everyday life. The presented study may be used as a model of working with picture books with mathematical content in kindergarten.

SŁOWA KLUCZE

książka obrazkowa, narracja matematyczna, dzieci, aktywność matematyczna, przedszkole

ABSTRAKT

Literatura dla dzieci ma wartość poznawczą i jest źródłem przeżyć estetycznych. Jej szczególnym rodzajem są książki obrazkowe z wątkami matematycznymi. Celem opracowania jest ukazanie, że książki obrazkowe, rozumiane jako te, w których tekst matematyczny łączy się z obrazem w estetyczną formę, dostarczają impulsów do kreowania sytuacji edukacyjnych wyzwalających aktywność matematyczną. Opierając się na klasyfikacji aktywności matematycznej w opracowaniu Ewy Kozak-Czyżewskiej, opracowano własne propozycje metodyczne pobudzania twórczej i odtwórczej aktywności matematycznej dzieci, co ukazano na przykładzie pracy z książkami: *Cyferki* (autor: Jacek Cygan) i *W naszym domu jest* (autorzy: Isabel Minhós Martins, Madalena Matoso). Zajęcia dydaktyczne z wykorzystaniem matematycznych tekstów literackich przeprowadzono dla dzieci sześcioletnich w przedszkolu. Wykazano, że książki obrazkowe mogą być inspiracją w wyzwalaniu twórczej i odtwórczej aktywności matematycznej. Poprzez dostarczanie pozytywnych przeżyć mogą wspierać procesy uczenia się matematyki, rozbudzać dziecięcą motywację do liczenia i używania matematyki w życiu codziennym. Opracowanie może stanowić model pracy z książką obrazkową z wątkami matematycznymi w przedszkolu.

Introduction

The spoken and written word have long been used for didactics and educational interaction, especially in kindergarten. Children's literature is a source of aesthetic experiences and rich language, it stimulates thinking, acting, learning in motion, and artistic creativity. A special type of children's literature contains mathematical content, also called a mathematical narrative. It comes in various forms such as poems, stories, fairy tales for children and about children, or texts created by children.

The article aims to show the possibility of using picture books with mathematical content to stimulate mathematical activity in children. The methodology described in this study refers to the research showing direct evidence for the motivational and activating benefits of providing children with a narrative in learning mathematics. Researchers in the field have shown that picture books and fairy tales are excellent materials for developing mathematical abilities (Ross, Dryden 2009) and mathematical cognition in children (Van den Heuvel-Panhuizen, Van den Boogard 2008). The process of learning with the use of picture books is more effective than the process of learning without them because the stories presented in the texts are meaningful to children. The story is the basic means of building meaning (Van den Heuvel-Panhuizen, Elia, Robitzsh 2016: 324). The stimulating influence of books and narratives can also be found in the use of narration in learning science, i.e., in STEM education

(Rostek 2019), effectively supporting the development of spatial thinking, especially spatial imagination, and the ability to perform mental rotations (Hong 1996; Jennings et al. 1992; Young-Loveridge 2004; Casey et al. 2002; Van den Heuvel-Panhuizen, Elia, Robitzsh 2015). In addition, it has been shown that the visual-spatial modeling of literary texts and stories helps children to understand the content and sequence of events in the story (actions) and to determine the relationship between characters, which is important when children solve mathematical problems (Dolya 2007: 82).

The main purpose of this study is to describe the possibility of using picture books and texts with math content in early education regarding triggering mathematical activity in children. The main research question is to what extent picture books and counting books with narrative poetry can be useful in mathematically activating children. The method of the study is a review and interpretation of children's literature with the aim to show the possibility of using mathematical books in preschool and early school practice.

A Mathematical Picture Book

The definition of a picture book in this study is taken from Van den Heuvel-Panhuizen, Elia, and Robitzsh (2016: 323). A picture book is understood as a book consisting of a text and illustrations "in which the story depends on the interaction between the written text and the image and where both have been created with the conscious aesthetic intention" (Arizpe, Styles 2003: 22). And while it might seem that reading picture books is not the best way to teach maths, the stories told in the books may contain mathematical content, so children have a chance to interact with mathematics. According to Van den Heuvel-Panhuizen, Elia, and Robitzsh (2016: 324), mathematical concepts children encounter in picture books must be broad. The book may be about numbers, measures, or geometry but also such issues as visible regularities, the pursuit of truth, and the search for causes, since they are all related to mathematics. A number of cognitive scientists consider "the story as a most natural package of organized knowledge in the cognitive system for acquiring and retaining information" (Casey, Andrews 2008: 276), and picture books can offer cognitive hooks to explore and construct mathematical concepts and skills (Van den Heuvel-Panhuizen, Elia, Robitzsh 2016: 324).

Among the respected Polish authors of texts with mathematical content are Jan Brzechwa (e.g., *A week*, *Caterpillar*, *7-mile shoes*), Danuta Wawiłow (*Listen to a new, rectangular and square fairy tale*, *Triangle Karolina, Triangle fairy tale: a fairy tale about 100 kings of Lules*) Wanda Chotomska (the poem *Ten snowmen*), Małgorzata Strzałkowska (poems *Week* and *Calendar*), Anna Łada-Grodzicka (a collection entitled: *ABC of counting: Mathematical poems*), Jacek Cygan (*Numbers*). New books also appear on the global market, published and translated into many languages, for example: *The war of the Numbers* by Darien Juan, *At our house* by Isabel Minhós Martins and Madalena Matoso, and *One hundred seeds that flew away* by Isabel Minhós Martins and Yary Kono. Many kindergartens also conduct didactic projects using and creating new, mathematical poetry for children (initiatives such as *Mathematics in poems*[1] and *Maths poems*[2]).

Mathematical Activity

Activity is the primary learning mechanism. Activity allows humans to regulate their relations with the environment, realize goals and aspirations, and reveal their abilities. According to Jan Strelau (1992: 65), activity is a temperamental trait that manifests itself in the number and scope of actions taken by an individual with a specific stimulating value. It is always based on a specific willingness to act, which is triggered by internal factors such as needs, and external factors such as tasks. The source of activity, apart from the human factor, is the material world, its phenomena, objects and tools. A child can learn about the world using sensory-experimental or mathematical-logical methods. In the first case, the learning material comprises colors, shapes, smells, tastes and sounds; in the second it comprises words and their meaning. For this reason, the written word can also provoke activity, and more specifically, mathematical activity.

"Mathematical activity is aimed at shaping mathematical concepts and reasoning, stimulated by abstract problems or theoretical problems concerning specific situations" (Filip, Rams 2000: 34). Gustaw Treliński (2005) describes students' mathematical activity as the entirety of their activity related to the formation of mathematical concepts and reasoning, stimulated by various situations and actions. It may include:

1. concrete activities aimed at creating or researching concepts and reasoning,
2. mental activities (imaginary and abstract) aimed at:
   a) creating concepts, researching them or using them,
   b) reasoning and shaping reasoning,
   c) formulating and solving theoretical and practical problems.

Activity manifests itself as external or internal actions. Thus, if someone does not do mathematical activities physically, it does not mean that they are not mathematically active. Ewa Kozak-Czyżewska (2008: 146) systematizes mathematical activity

[1] https://p118.przedszkola.net.pl/aktualnosci/konkurs-matematyka-w-wierszykach.html (accessed: 15.03.3021).

[2] https://psloneczko.szkolnastrona.pl/art,3038,4-wierszyki-matematyczne (accessed: 15.03.3021).

distinguishing its eighteen forms according to the type of operation influencing the type of activity (creative or imitative activity), the nature of the performed activities (manipulative and motor; verbal, manifested as audible or quiet speech; and cognitive), and the type of material constituting the basis of the performed activity (tangible, graphic, symbolic). This classification can be used as a framework for proposing methodological activities for children using texts with mathematical content.

Implications for Practice

The methodological suggestions for practice presented below were implemented in 2020 during classes with a kindergarten group of about 20 six-year-old children in a public kindergarten.[3] The classes were conducted by the author of the present study. Pedagogy students were also involved in the project to assist in didactic interventions. Many texts and books for children were used in the course of mathematics classes, two of which have been selected as methodological examples in this study: *Numbers* by Jacek Cygan and *At our house* by Isabel Minhós Martins and Madalena Matoso. *Numbers*[4] is written in Polish, while *At our house* has been published in Polish, English and Spanish. Each text was first presented to the children as a picture book to look at, then a story to listen to, and finally as an inspiration for mathematical activities proposed by the teacher.

Numbers in Motion: Experiencing and Taking Action on the Basis of the *Numbers* Picture Book

The content of *Numbers* by Jacek Cygan (2011) is presented below to help the readers understand the essence of the text-inspired activities better.

> Digits, one after another, were standing in a line, because the post office window was closed for an hour. The first was One, thin like a straw. Behind her was Two, a curve and a dash. Behind Two stood Three, two semi-circles. One, two, three, one, two, three. I can count already. How about you? Wiggle, wiggle, pretty line. Behind Three, Four, a chair upside down. And then Five, a noble digit but unlike anything else. Although a famous locksmith recently instructed me that two fives make up a keyhole. Of course, if they are inverted, my wife would add. My beloved Six stood behind Five, like... an upturned ram's horn. One, two, three, four, five, six. I can count now. Bye then! Seven stood stiff, like a stork's neck in a very elegant bow tie. Behind her was Eight, hugging

[3] In Poland (Lublin, Kindergarten no. 49).

[4] The full text with illustrations is available on the website: http://olaplocinska.com/wordpress/index.php/2016/02/13/numbers/ (accessed: 15.03.3021).

> herself affectionately. Such a cute snowman, made of two snowballs. After Eight, Nine stood calm, she looked like Six upside down. One, two, three, four, five, six, seven, eight, nine. What's next? I don't know. The numbers stood respectfully because they wanted to see themselves on fabulously colorful stamps. And suddenly Zero appeared. She was late, she didn't stop and the line broke. Nine fell over, Eight fell over, numbers grinned and all fell down. The racket was hellish, the numbers broke. Zero stood up slowly by the window and said, "One thing is true, I am a sister number to all of you. I am the most important, so I go first!" And they started arguing and flailing their arms, stomping, scratching, and screaming, "Don't count on it!" One, two, three, four, five, six, seven, eight, nine. And then what? I don't know. "It's a scandal, Zero can't rule us all! This is not fair, we all waited patiently." Ok, let's all agree that from now on there is no zero. Let's ask the postman where to get sixty cents. How to create ten pounds, one hundred, two hundred or a million when Zero is gone, and she was here a moment ago? "I'm leaving you numbers!" said Zero and she wanted to leave the line. The postman took the floor, "As you all know, the view changes depending on where you stand. What is it called? Ah, right, the standpoint! It is clear that without Zero Ten wouldn't stand, but without One in front, it wouldn't stand either! There's one conclusion, as Professor Numberton says, everyone has their place and everyone is needed. Everyone is equal, and whoever respects consent, I will present them with a beautiful stamp as a reward! The numbers all reconciled. They got their stamps, and when they saw them, they were on cloud nine. Why? Because looking at the postage stamps the numbers could all admire... themselves.[5]

After being presented with the content of the story and looking at the illustrations in *Numbers* (drawn by Aleksandra Woldańska-Płocińska[6]), the children were offered various mathematical activities. First, 11 children were selected to act out the story. Willing actors received cards with images of all the numbers. Their task was to play the role of the numbers from 0 to 9 and the postman. The teacher-narrator read the story out loud while the children illustrated its content with their bodies and gestures. Following the plot, the children had to line up in the correct order at the post office window. Then, with their bodies and gestures, every child showed the shape of their number and spoke their lines individually and together. Acting out quarrels and disputes between the numbers was recommended to be done silently, only with facial expressions, which was conducive to transmitting and reading messages and symbolic codes. The following activities were also performed actively and in motion. Among them were:

1. arranging numbers (child actors) in a row,
2. reading a series of numbers (one by one, backwards, every second number),
3. showing numbers with their fingers (what number are you?),

[5] Author's own translation.

[6] http://olaplocinska.com/wordpress/index.php/2016/02/13/numbers/ (accessed: 15.03.3021).

4. determining the place of a number in the series (e.g., what number is between 4 and 6, list all numbers lower than 9; what numbers go before 8, what numbers follow 6),
5. how many numbers (children) are between 4 and 9? These children step out of the line and call out their number.

Another interesting task inspired by the story was to create new vivid images of large numbers. At the beginning two-digit "live numbers" were created by combining numbers 1–9 and 0. Actors playing numbers from 1 to 9 lined up. The child playing zero was more dynamic. He/she was asked to approach each number in line. When it approached a number, e.g., 1 and stood on its right the children watching the activity would read the number as 10, etc. It was the viewers' job to read new numbers out loud.

Children were also asked to step out of the line in twos, symbolically hold each other's hands and show by means of cards what numbers can be made from them. For example, the teacher said, "The child who plays the number 3 and the child who plays the number 6 please come on the stage. What number can be made from these two numbers? Read it (36), then switch places. What number can you see now (63)? Then the children-numbers were picked in threes, fours, and more, and they formed new numbers.

The activities with numbers continued: designing postage stamps, role-playing and creating math fairy tales, solving problems with coins and banknotes that children would use to buy stamps, adding and subtracting numbers, looking for a number that is a sum component, or a number that is the result of a math operation. The table shows the activities proposed to children, relating them to Kozak-Czyżewska's framework (2008: 146).

Working with *Numbers* provided the children with a lot of joy and excitement. The whole group was involved in the proposed activities. The children especially liked role-playing numbers and creating "live numbers." The proposed various forms of activities allowed the teachers to activate the children with different cognitive and emotional needs and different temperaments. There were many methodological proposals inspired by the plot, which meant that the book content was the subject of children's activity for a long time, both in activities guided by the teacher and initiated by the children, i.e., play and physical and artistic activity.

Table 1. Mathematical activities inspired by *Numbers*

Nature of activity	**Type of activity**	**Material used**	**Examples and description of the activity**
imitative	manipulative and motor	tangible	– children act out different digits, use their body to form the shape of a digit – arranging plastic digit-shaped blocks in order from 0 to 9/10
		graphic	– arranging cards (pictures or postage stamps) with images of numbers from 1 to 9 or with a number of dots in a sequence
		symbolic	– recognizing the numbers read out loud by the teacher, searching for these numbers among pictures or among digit-shaped blocks – writing / tracing the shape of numbers on different materials (e.g., a tray with groats, a stick in the sand, etc.)
	verbal	tangible	– listing numbers in order from 1 to 10 and back from 10 to 1, searching the room for items that contain the shape of a number 1, 2, 3, etc. – using terms related to space: in front of, behind, between, previous, next, first, last, every second
		graphic	– choosing from among the graphic diagrams the one that shows the result of the operation, e.g., 4 + 2
		symbolic	– describing what the digit looks like – assigning coin and banknote symbols (PLN 1, PLN 2, PLN 5, PLN 10) to numbers or numbers on stamps and pictures

Nature of activity	Type of activity	Material used	Examples and description of the activity
creative	manipulative and motor	graphic	– creating live numbers according to children's own ideas, showing numbers with gestures
		symbolic	– building new two-, three- and multi-digit numbers out of cards
	verbal	tangible	– reading the created numbers out loud
		graphic	– designing postage stamps with images of numbers
		symbolic	– formulating the content of tasks for operations, e.g., 4 + 1 = 5
	cognitive	tangible	– discovering mathematical relationships: the place of numbers in a series, the role of 0
		graphic symbolic	– designing poems and narratives about digits and numbers – illustrating the created booklets

Source: Author's own materials.

At Our House There Are[7]

The story *At our house* is an example of a narrative for children describing reality using mathematics. The narrator describes their family using the language of mathematics, that is, comparing family members and elements describing their family numerically (e.g., body parts, diseases, activities, number of guests). The text of *At our house* by Isabel Minhós Martins and Madalena Matoso reads:

> There are ... 6 heads at our house. Every one of them thinks about their own affairs but sometimes they all think about the same thing. There are 78 fingers, 20 small fingers and 20 stubby fingers in our house. In total, that's 118 nails my mom cuts every Sunday. There are 6 bellies and approximately 40 meters of intestines at our house, both large and small. We stand in line to one bathroom every morning. There are 16 large and small boobs at our house. With the onset of spring, they all catch the sun on the porch. There are 3,560 freckles at our house. There would be a lot fewer if it wasn't for my dad's back… At our house there are 6 noses and 12 nostrils. During the pollen season, we all sneeze in the same direction. There are 1,351 bones at our house that are

[7] https://www.tmc.com.pl/pl/kategorie/40025-at-our-house-9781849760492.html (accessed: 15.03.3021).

> not always in the best shape. Doctor Zalewski said that we have a total of 1 scoliosis, 1 joint degeneration, and 2 discopathies. Besides that, thank you, we're fine. There are 800,000 hairs in our house that need to be washed, dryed, untangled and combed. When summer comes, we go to the hairdressers. There are 6 mouths, 6 tongues and 168 teeth at our house. My grandfather says we beat our gums like magpies, but eat more like dragons. There are 5 pairs of legs, 4 paws and 10 feet at our house. In other words, 10 shoes to take off and 10 socks to throw in the corner in the evening, and sometimes just 2 hands to deal with all that. There are 6 of us at our house, but when we throw a party, suddenly there are 16 of us. The bell rings and there are 27 of us. A few more cousins come and we become 32. Hm... let's count. Well, at home we now have 32 heads, 618 fingers, over 2 kilometers of intestines, 72 boobs (large and small) 32 noses, 60 legs, 8 paws, 6822 bones, over a million hairs and 924 teeth that chew and grind continuously.[8]

The content and form of the book is an example of communicating in mathematical language, and the creative tasks inspired by this publication were aimed at developing the ability to use numbers in everyday life and improve the ability to describe reality using mathematical language.

The book *At our house* aroused the children's curiosity and sparked their interest in human anatomy. The content and illustrations encouraged the study of the human body, viewing albums, illustrations, and x-rays. After these activities, children were particularly eager to describe their body structure in the language of mathematics and make posters describing their group in terms of quantity. A lot of narratives and mathematical stories were created.

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[8] Author's own translation.

Table 2. Mathematical activities inspired by *At our house*

<table>
<tr><th>Nature of activity</th><th>Type of activity</th><th>Material used</th><th>Examples and description of the activity</th></tr>
<tr><td rowspan="6">imitative</td><td rowspan="2">manipulative and motor</td><td>tangible</td><td>– studying the human body, e.g., counting and pointing to children's heads, legs, hands, feet, fingers, nostrils, etc.</td></tr>
<tr><td>graphic
symbolic</td><td>– viewing albums, illustrations, x-rays of the structure of the human body
– arranging the images of the numbers mentioned in the book, e.g., 6 heads, 78, 20 etc., using plastic digit-shaped blocks or cards illustrating the numbers and arranging them in order from the lowest to the highest number</td></tr>
<tr><td rowspan="3">verbal</td><td>tangible
graphic
symbolic</td><td>– finding numbers in the text, recognizing them, reading them and writing them on one's own</td></tr>
<tr><td>graphic</td><td>– using dashes to write the number of units, tens, hundreds, and thousands of a given number mentioned in the text, e.g., 78 fingers, etc. depending on children's needs and competencies<table><tr><td>tens</td><td>units</td></tr><tr><td>IIIIIII</td><td>IIIIIIII</td></tr></table></td></tr>
<tr><td>symbolic</td><td>– symbolic drawing of body parts and other things mentioned in the narrative (head, fingers, small fingers, stubby fingers, nails, etc.) and matching them to numbers on the cards (6, 78, 20, 118, etc.) Guessing how many body parts there were: what symbol it is and what number matches it</td></tr>
</table>

Nature of activity	Type of activity	Material used	Examples and description of the activity
creative	manipulative and motor	tangible graphic symbolic	– drawing or creating an anatomical model of the human body, putting sticky notes with a coded number specifying e.g., the number of heads in a selected group e.g., in the family or in a group of friends
	verbal	tangible graphic symbolic	– creating a similar narrative, poster, illustration, e.g. “In our group, there are...,” “in our family, there are…”
	cognitive	tangible graphic symbolic	a) solving problems based on the narrative: – If there are 6 family members and suddenly there are 16 of them, what do you think happened. Who visited the family, how many people/animals. Draw or suggest a solution. – Who can 32 heads belong to? How many hands do they have? Legs? Design a solution. Draw. Create a schema based on the plot. – How many noses have 12 nostrils? – Who can 60 legs belong to? If it were people. What if they were animals? – We have 618 fingers. How many hands are there? – Can you count hairs? 1,000,000 hairs, how many are these? b) solving similar tasks, e.g., how many fingers do 2 pairs of gloves have? Etc. c) creating new tasks by children for their mathematical narratives

Source: Author’s own materials.

Results and Conclusion

The aim of the study was to show that books with mathematical content in the form of narrative poetry or mathematical fairy tales may be used to create educational situations to inspire mathematical activity, both imitative and creative.

Research shows that children’s literature used as an educational tool affects many spheres of child development. The appearance of beautifully illustrated picture books with mathematical content creates new opportunities for using children’s literature in education. The conducted analysis suggests that mathematical books and rhymed mathematical texts provide children with a lot of joy, not only in terms of learning new content, but also the possibility of experiencing the content multiple times in various types of expression. Stories with mathematical content affect not only the cognitive sphere but also the emotional, social and moral sphere. By providing positive experiences, they support the learning processes, awaken children's motivation and the joy of discovering mathematical patterns.

The possibilities of stimulating mathematical activity presented above, both imitative (closed tasks) and creative (open tasks such as drama or drawing), inspired by a mathematical plot, are a means of gathering new mathematical experiences. Such activities and the accompanying experiences allow children not only to consolidate their knowledge but also to acquire and improve mathematical skills. They spark curiosity and interest in mathematics, which allows them to build new knowledge. Due to the specificity of the texts used in the study, this knowledge relates mainly to the concept of the numbers, built in relation to many of its aspects (cardinal, ordinal, code, arithmetic, and its contractual value) and efficiency related to counting. Contact with the literature with mathematical content can also be a way to improve existing mathematical skills and abilities (e.g., converting, counting in tens, hundreds, and coding information). A mathematical book triggers new activities supporting mathematical education, e.g., artistic and construction activities. In that way, children may develop mathematical interests, perceptive skills, attention, memory, learn symbolization, develop imagination and enrich mathematical language. Contact with a picture book encourages to mathematize reality and look at the world with "mathematical eyes." Introducing poetry and mathematical narratives into preschool education appropriately to the children's age, cognitive, and emotional needs can also be a new diagnostic space where the researcher carefully looks at the impact of literature or even consciously tests this impact on child development.

The use of picture books with mathematical content in preschool education is currently perceived as an experimental activity, also because there is not enough research on its effectiveness in early mathematical education. Nevertheless, it has been shown that mathematical books have a great educational potential for being the basis of multifaceted and expressive mathematical activities for children. Both the content of the mathematical books and their form allow the teacher to create interesting and varied mathematical activities with the active involvement of the group. The described activities may encourage a deliberate search and creation of teachers' own repertoire of valuable books, narratives, and poems. Teachers looking for mathematically saturated texts for their methodological experiments can make teaching and learning more interesting and individualized. Reviewing and working with mathematical stories also brings to mind the idea of encouraging children to create and illustrate their own texts, then act them out, and design new tasks for their colleagues.

Picture books and counting books should be available to every preschooler and pupil and every teacher should have a series of mathematical books helpful in the educational process. The teacher may select texts from native or foreign poetry on purpose in order to organize new mathematical activities, both imitative and creative. Therefore, it is worth using picture books with mathematical plots and narrative poetry to a greater extent in early education.

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Unusual Word Problems and the Development of Critical Thinking in Early School Students

Nietypowe zadania tekstowe a rozwijanie krytycznego myślenia uczniów edukacji wczesnoszkolnej

KEYWORDS

critical thinking, mathematical word problems, unusual problems

ABSTRACT

Nowadays, it is increasingly difficult for people to make their way in a rapidly changing world. Critical thinkers are able to function well in such a changing environment and their education should begin in early childhood.

This paper presents the results of an experimental study on the development of critical thinking of third grade elementary school students. Unusual word problems with missing or contradictory data, an ambiguous solution, or with unrealistic content (meaningless in real life) served as a tool for developing this type of thinking. These problems provoked the students to think, to critically analyze both the content and data of word problems. This, in turn, helped the students become more reflective, notice missing or contradictory data, ambiguity of a solution or lack of realism, fill in missing data, correct contradictory information and make unrealistic data realistic, as well as seek all possibilities for a solution. Thus, their critical thinking skills developed.

SŁOWA KLUCZE

myślenie krytyczne, matematyczne zadania tekstowe, zadania nietypowe

ABSTRAKT

Współcześnie coraz trudniej jest ludziom się odnaleźć w szybko zmieniającej się rzeczywistości. W tak zmiennych warunkach dobrze mogą funkcjonować ludzie myślący krytycznie, a ich kształcenie należy rozpocząć już na etapie wczesnoszkolnym.

W artykule zostały zaprezentowane wyniki eksperymentalnych badań nad rozwijaniem krytycznego myślenia uczniów III klasy szkoły podstawowej. Narzędziem służącym rozwijaniu tego myślenia były nietypowe zadania tekstowe z deficytem lub sprzecznością danych, z niejednoznacznym rozwiązaniem lub o treści nierealistycznej (bezsensowne życiowo). Zadania te prowokowały uczniów do myślenia, do krytycznej analizy treść zadań oraz danych. Dzięki temu uczniowie stali się bardziej refleksyjni, dostrzegali: niedobór lub sprzeczność danych, niejednoznaczność rozwiązania bądź brak realizmu, uzupełniali brakujące dane, korygowali sprzeczne i urealniali nierzeczywiste dane oraz poszukiwali wszelkich możliwości rozwiązania. Tym samym rozwinęła się ich umiejętność krytycznego myślenia.

Introduction

The modern world is changing so rapidly that we sometimes struggle to keep up with these changes. This intensity of changes should be taken into account in children's education, from its very beginning. It is difficult to predict what the world will be like in a decade or so, what skills will be needed in the adult lives of today's early school students. We therefore need to prepare them for life in a dynamic and complex reality, taking into account their needs, abilities and interests. We are supposed to educate people to become independent, capable of both adapting to changes in their environment and introducing necessary and desirable changes in it.

The core curriculum of 14 February 2017 states that "Primary school education is the foundation of education. The school's task is to gently introduce the child to the world of knowledge, to prepare the child to perform the duties of a student, and to implement self-development" (Podstawa programowa 2017: 11). And the purpose of this education is "to develop competences such as creativity, innovation and entrepreneurship; to develop c r i t i c a l [emphasis mine] and logical thinking, reasoning, argumentation and inference skills … to equip students with a body of knowledge and to develop skills that enable them to understand the world in a more mature and structured way" (Podstawa programowa 2017: 11).

The educational goals listed above can be achieved through children's math education. In math lessons, students develop comprehensively, they gather logical and mathematical experience, acquire knowledge and skills specified in the curriculum, practice memorizing skills, precision, perseverance, responsibility, reading comprehension. While solving problems, they learn to analyze facts, synthesize events, estimate risks, make rational decisions, they perfect abstract thinking, and learn to reason and infer correctly not only in familiar situations but also in new, both simple and complex, usual and unusual ones (Podstawa programowa 2017: 26). Learning mathematics develops logical and critical thinking, which is exactly what we need most nowadays and what will be useful to us in the yet unknown future. In problematic situations, we cannot make rational life and work decisions or take a particular stand without it. It helps us in many aspects of our lives. In dealing with a multitude of media information and advertisements, it allows us to make a critical selection and evaluation of their content and identify the relevant pieces thereof. This prevents us from succumbing to manipulation, demagogic tricks of politicians and allows us to make a realistic assessment of their activities. If we do not think logically and critically, we become unreflective. We accept other people's explanations without inquiring into the truth. We make rash and irrational decisions and allow ourselves to be taken advantage of. Therefore, critical thinking is a necessary skill to avoid being manipulated and to be an independent person.

Critical Thinking

Critical thinking[1] is not a clear-cut concept. Various definitions thereof are formulated and interpreted differently depending on the needs. Sometimes it is easier to define what it is not. "Critical thinking is not the same as criticizing, expressing dissent, or the art of argumentation. It is rather an intellectual process through which, by verifying information and combining facts through objective and measurable analysis, we arrive at the truth" (Wichura 2016). Critical thinking is thus the processing of information in a conscious and complex cognitive and metacognitive act.

A person who thinks critically:

- is able to analyze any situation (problem, phenomenon, experience) from many points of view and select from the mass of information the relevant pieces thereof, evaluating it accurately,
- is able to make judgments and assessments based on clear and justified criteria,
- is able to select arguments for and against a thesis and draw conclusions on this basis, predicting their practical consequences,

[1] The words "critical," "criticism" derive from the Greek word *kritikos*. Critical means "based on analysis, examination of the features of an object; analyzing and evaluating a phenomenon, work, etc.; applying the method of scientific criticism" (see entry in dictionary: *Słownik języka polskiego PWN*, 1978: 1065). Therefore, criticism means, among others, the ability to make judgments, see differences and make decisions.

- knows how to arrive at truth using logical inference with true premises,
- seeks to discover and correct both their own and others' weaknesses in judgments, reasoning, and procedures.

Critical thinking is not a skill that arises spontaneously—its acquisition and development involves practice. It therefore requires both effort and training. Exercises in critical thinking can and should be introduced at an early age, for example during math lessons, with word problems as a tool. Word problems are a valuable teaching tool because they are a special case of a problem situation. Therefore, the ability to solve them can also have a practical dimension, being a model (paradigm) of action in any (problematic) situation.

However, not every word problem or the way it is used is a good tool for developing critical thinking. Too many school word problems are convergent in nature, which can and does create the false suggestion that there is always a solution and that there is only one correct solution to a problem situation. In addition, many of these problems, which are intended to illustrate the applications of mathematics, have unrealistic content and show the world in a distorting mirror[2] (Nawolska, Żądło-Treder 2017a; 2017b). When confronted with solving such problems, children start to perceive school as an institution detached from life, and mathematics as a collection of numbers, laws, theorems and formulas without any purpose or use. "Moreover, students cease to notice logical relationships in mathematics and they increasingly often tend to think that it consists of many unrelated arithmetic techniques, each assigned to a specific topic" (Klus-Stańska, Kalinowska 2004: 13). Accustomed to the importance of computations following a predetermined pattern in solving school tasks, they notice the differences between school mathematics and the mathematics they encounter in everyday life. They begin to take math lessons less seriously, perceiving them as a conventional game, a kind of theatre. No wonder, then, that upon entering the classroom, students shut down their common sense, which allows them to function efficiently in the real world, see their own and others' mistakes and judge them properly. They uncritically assume e.g., seven groszy coins [there is no such a coin in the Polish monetary system] or a girl 245 cm tall.[3] In such a situation we can

[2] The articles Nawolska, Żądło-Treder (2017a, 2017b) contain examples of problems, the content of which is in contradiction with children's knowledge and life experience, which causes difficulties in children's understanding of the world or even shapes a distorted image of it. Such problems make children stop paying attention to the content of the problem, they recognize that it is only a pretext for computations, so they focus on extracting numbers from the text and performing computations. This leads to a lack of problem-solving skills often manifested by inadequate computations.

[3] In 2006, 116 third graders were to solve the following problem: *There are 6 coins in Agatha's piggy bank, a total of 42 groszy. What kind of coins might these be?* As many as 12 students performed the 42 : 6 = 7 division and answered: *These are the seven groszy coins* (Nawolska, Żądło 2007). In 2014, 114 students were to solve the following problem: *Kasia is 10 years old and 145 cm tall. She grew 10 cm over the past year.*

speak of "a peculiar disease of thoughtlessness that the students were infected with, even though it was the last thing that both they and their teachers would wish for" (Klus-Stańska, Kalinowska 2004: 18).

In view of the above, the school's work appears to be a Sisyphean task. It intends to develop in the child what it will need later in adult life in the real world, and at the same time consciously, with great care, does everything to deprive it of contact with this world, keeps it isolated from social life, not giving it the opportunity to experience life's problems (Dewey 1913: 135). "Teachers, being aware … of the difficulties of learning mathematics, try to bring their students closer to the understanding of the concepts, trying to explain everything to them. They also want to protect them from mistakes for fear of fixing them in children's minds" (Kalinowska 2010: 8–9). For fear of these mistakes, they control the student's every step (Kalinowska 2010: 8–9). And yet only active participation in life, solving problems arising from realistic situations can well prepare children for the tasks ahead. Therefore, according to constructivism, in working with children we should abandon teaching and focus on organizing an environment that fosters the activeness of students and thus supports their learning process (Klus-Stańska 2018: 111–130).

In math education, unusual word problems are a good tool for developing students' competence. Solving them contributes to developing the habit of critical thinking, which facilitates the evaluation of various situations, verifying whether there are grounds for adopting a certain thesis, and thus enables the pursuit of truth.

Developing Critical Thinking in Third Grade Students

In the 2018/2019 school year, a pedagogical experiment was conducted in one of Krakow's elementary schools over January and February. The goal was to develop critical thinking in early childhood education students. The study involved only 14 third grade students. The diagnostic tool was a set of 4 unusual word problems. In the preliminary study, the subjects were to solve problems with missing data (1*a*), ambiguous problems—with multiple possible solutions (2*a*), with the content meaningless in real life—unrealistic (3*a*) and with contradictory data (4*a*). Next, an experimental factor—the independent variable—was introduced in the form of specially organized classes aimed at developing critical thinking. In these classes (12 lesson units), the students not only had the opportunity to solve tasks with different types of unusualness, but most importantly they had the opportunity to discuss what they were doing

How tall will she be at age 20? As many as 59 students failed to notice the lack of realism of the situation presented in the problem, made an inadequate mathematization of the content of the problem and gave the result of 245 cm as Kasia's height (Nawolska 2014).

and why they were doing it in the given way. To think of possible and impossible solutions. Whether the information (data) in the sentence is sufficient to solve it, or whether something is missing and if so, how to get the missing data. Whether data gaps can be filled in freely, or whether there are any restrictions, and if so, which ones. How it relates to solving life's problems. They evaluated their ideas, checked their correctness, discussed solutions and wording of the problems, and corrected the incorrect ones.

After a series of experimental classes, a final study was conducted in which the students were again asked to solve 4 unusual problems (1*b*, 2*b*, 3*b*, 4*b*)—different from the preliminary study but with the structure and type of unusualness analogous to the tasks from the preliminary study.

Third grade students' critical thinking skills served as the dependent variable (in both the preliminary and final study), assessed based on:

- the ability to spot missing data and fill them appropriately,
- the ability to see the ambiguity of a solution and to find all possible solutions,
- the ability to recognize a lack of realism and to adjust the content of the task in such a way as to make the task situation meaningful to life,
- the ability to spot contradictory data and to remove such a contradiction.

The students could score 7 points for solving each task in both *a* and *b* versions. Points were awarded for critical and logical thinking skills and this number was not diminished by arithmetic mistakes, lack of written answer (when solved correctly), or shortened presentation (the answer only, from memory). The students could seek a solution in any way they wished as long as it was relevant to the problem situation. Aggregate, score-based summary of the results of preliminary and final study results is presented in Table 1.

Table 1. Score-based summary of preliminary (ps) and final (fs) study results

No.	**First name**	**Number of points for solving the problem**								**Total**		**Difference fs-ps**
		1*a*	**1*b***	**2*a***	**2*b***	**3*a***	**3*b***	**4*a***	**4*b***	**Σ ps**	**Σ fs**	
		ps	**fs**	**ps**	**fs**	**ps**	**fs**	**ps**	**fs**			
1.	Mikołaj	3	7	0	7	0	5	0	7	3	26	23
2.	Sofya	3	7	0	7	0	7	3	7	6	28	22
3.	Zosia	1	7	0	7	0	7	3	7	4	28	24
4.	Mateusz	3	7	0	7	0	7	0	7	3	28	25
5.	Artur	3	7	0	7	0	7	3	7	6	28	22

6.	Przemek	3	7	0	7	0	7	3	7	6	28	22
7.	Alex	3	7	0	7	0	5	0	7	3	26	23
8.	Ania	0	7	0	0	0	5	0	7	0	19	19
9.	Tomek S.	1	5	0	7	0	7	0	7	1	26	25
10.	Tomek St.	3	7	0	7	0	7	3	7	6	28	22
11.	Iza	0	7	0	7	0	5	0	7	0	26	26
12.	Tomek T.	7	7	0	7	0	7	0	7	7	28	21
13.	Maja	1	7	0	7	0	5	0	7	1	26	25
14.	Bartek	0	5	0	0	0	3	0	0	0	8	8
Total		31	94	0	84	0	84	15	91	46	353	307
Arithmetic mean		2.21	6.71	0	6.00	0	6.00	1.07	6.5	2.28	25.21	×

Source: Author's own research.

From the data presented in Table 1, it can be seen that the students did not demonstrate critical thinking skills in the preliminary study (ps). In total, all the students scored only 46 points for solving all the problems in the preliminary study. In the final study (fs), the results were significantly better, as the total score of the entire group was 353. These are just figures. How did the students perform in solving the preliminary and final study tasks? The results obtained are presented in pairs: a problem from the preliminary study and an analogue from the final study.

The Ability to Spot Missing Data and Fill Them Appropriately

In the preliminary study, the students were given the following missing data problem:

Problem 1*a* Piotrek, Paweł and Janek were collecting postcards. Piotrek collected 16 more postcards than Paweł, and Janek collected 14 more postcards than Piotrek. How many postcards did each of them collect?

For the problem to be solvable, we would need to know the number of postcards collected by one of the boys: either Paweł, Janek or Piotr.[4] The problem can also be solved when the total number of postcards of all boys is known.[5]

Only one of the participants (Tomek T.) noticed the missing data: *I did not know how many postcards Paweł had* and filled in this gap by assuming that Paweł had 0 postcards, which made the problem solvable. Thus, filling the data gap, he determined the number of Piotrek's postcards (16) and calculated the number of Janek's postcards (0 + 16 + 14 = 30).

Seven students noticed the missing data and indicated it by writing e.g., *it is not given how many postcards Paweł has*, but they finished their work without filling in the gap. They scored 3 points each.

Three students indicated that it is impossible to solve this problem, but they did not explain why. They scored 1 point each. Another three children wrote that they could not solve the problem because it was too difficult for them. They scored zero points.

In the final study, the students were to solve, analogously to the preliminary study, the following missing data problem:

Problem 1*b* Tomek, Antek and Krzyś enjoy reading adventure books. Tomek read 16 pages more than Antek in a day and Antek read 12 pages more than Krzyś. How many pages each of them read during the day?

As in the case of problem 1*a*, it is not possible to solve problem 1*b* without completing the missing data: the number of pages read by one (any) of the boys or the total number of pages read by all the boys.

All the students noticed that the problem is impossible to solve due to missing data and filled it bringing the problem to a solvable format (to a usual problem). They added one of the numbers: 1, 10, 11, 13, 18, 19, 20 or 30 as the number of pages read by Krzyś. They thus created the easiest variant of the solvable problem. Twelve of them, after filling the missing data, correctly solved the problem scoring the maximum number of 7 points. For example, Ania assumed that Krzyś read 20 pages and calculated the number of pages read by Antek and by Tomek.

---

[4] If the number of Paweł's postcards (p) is given, then the number of Piotrek's postcards can be determined as the sum of $p + 16$, and the number of Janek's postcards as the sum of $p + 16 + 14$. If the number of Janek's postcards (j) is given, then the number of Piotrek's postcards can be determined as the difference of $j - 14$, and the number of Paweł's postcards as the difference of $j - 14 - 16$. If the number of Piotrek's postcards (r) is given, then the number of Janek's postcards can be determined as the sum of $r + 14$, and the number of Paweł's postcards as the difference of $r - 16$.

[5] If the total number of postcards of the three boys (s) is given, then the number of Paweł's postcards can be calculated as a third of the difference of $s - 16 - (16 + 14)$. The number of postcards of the other boys is to be calculated as described in footnote number 4.

Two students (Tomek S. and Bartek) mixed up the relationships while solving the problem with the data filled by them and performed only part of the calculations correctly, so they did not score the maximum number of points.

The Ability to See the Ambiguity of a Solution and Explore All Possibilities

In the preliminary study, the students were to solve the following problem with an ambiguous solution:

Problem 2*a* Piotrek is to send a package to his friend. He was told that stamps worth a total of PLN 45 should be affixed to the package. Piotrek has 20-zloty and 5-zloty stamps. How many stamps of each type should he affix?

None of the subjects recognized that there were three possible stamps configurations making up a total value of PLN 45 and that all of them should be included in the answer.

Ten subjects gave exactly one correct way to select stamps. They all included two 20-zloty stamps one 5-zloty stamp.

The remaining students did not give any correct possibility. For example, Bartek determined the sum of all numerical data (45 zł + 20 zł + 5 zł = 70) and at the same time wrote the equation incorrectly (no denomination in the result) and presented the numerical result as the number of stamps.

In the final study, the following problem served as the one with an ambiguous solution:

Problem 2*b* Małgosia loves art activities. She always buys the crayons and paints she needs from the same art supply store. The store's price for the box of crayons is PLN 10, and PLN 15 for the box of paints. During her recent shopping trip Małgosia spent PLN 70 in the store. How many boxes of crayons and how many boxes of paints could Małgosia buy with this amount?

As in problem 2*a*, there are three possibilities of buying crayons and paints for 70 PLN and all of them should be included in the solution.

Twelve students recognized the ambiguity of the solution, listed all the possibilities, and gave the correct answer.

Two students (Ania and Bartek) presented only one possibility. Although Ania initially wrote down three possible solutions to this problem (one of which was incorrect), she backed out by crossing out two of them, including the correct one. In the end, she pointed to buying two boxes of paint and four boxes of crayons as her only solution. Bartek first corrected the data: he changed the price for the box of crayons from 10 PLN to 20 PLN, and the price for a box of paints from 15 PLN to 10 PLN.

Perhaps he liked the very ability to decide on the data, or perhaps his intention was to make the data more realistic according to the boy's experience, or it was an attempt to make computations easier. After changing the data, there were 4 shopping possibilities, but Bartek indicated mathematically only one of them. Bartek and Ania scored zero points for their "solutions."

The Ability to Recognize a Lack of Realism and to Adjust the Content of the Problem in Such a Way as to Make the Problem Situation Meaningful to Life

The following problem served as meaningless in real life in the preliminary study:

Problem 3*a* On the first day Maciek ate 26 chocolate bars and on the second day he ate 5 more than on the first day. How many chocolate bars does he have left to eat if he had 65 of them at the beginning?

Trying to eat as many chocolate bars as outlined in the problem would have to end badly. The content of the problem is unrealistic but none of the students commented on it critically. All the subjects took the problem "seriously" and performed various calculations. Two of them performed correct computations: 65 – 26 = 39, 26 + 5 = 31, 39 – 31 = 8.

Other students were even not able to cope with the arithmetic relationships. Most of them (10 subjects) gave the number 34 in their answer. These students determined the number of chocolate bars eaten on the second day as 26 + 5 = 31 and determined the difference as 65 – 31 = 34 with complete disregard for the number of chocolate bars eaten on the first day.

Ania's work reveals behaviour typical of children who do not analyze problems, but perform computations only. Ania determined the sum of all the figures (65 + 26 + 5 = 96) and gave the answer "Maciek has 96 chocolate bars," that is unrelated to the question.

In the final study, the following problem served as the unrealistic one:

Problem 3*b* A runner has 1.200 km to run. On the first day he ran 480 km, and on the second, 30 km more than the first day. How many kilometers is left for the runner to complete the run?

All the students recognized the lack of realism. They knew that it was impossible to run 480 km in one day, so they revised the problem bringing it to the usual problem format. They changed the unrealistic data value to a more realistic one. Instead of 480, they entered, for example, 15, 17, 20, 48, 50. In addition, they made other changes to the problem, although they were not needed.

Eight of them not only accurately corrected the data, but also correctly solved the problem they created. They scored 7 points each.

As many as five students, when solving the problem using self-corrected data, did not include in their calculations the number of kilometers covered by the runner on the first day. They only calculated the distance covered on the second day and the difference in the length of the entire route and that distance from the second day. They scored 5 points each.

One student, Bartek, made the numerical values so "realistic" that he obtained a contradictory data problem. If he had solved the problem correctly, he would have recognized his mistake. He, however, performed computations inadequate for the content: he determined the sum of all the data and included it in the answer. He scored 3 points for noticing the lack of realism and for correcting the problem.

Ability to Spot and Resolve Data Contradictions

In the preliminary study, the students were to solve the following contradictory data problem:

Problem 4*a* Kasia has 3 ribbons: a pink, a blue and a white one. The pink ribbon is 30 cm long, the blue ribbon is 16 cm shorter than the pink ribbon, and the white ribbon is 17 cm shorter than the blue ribbon. How many cm long is the white ribbon?

The data in the task is contradictory, because with the values given, the white ribbon would have to have a negative length. Data correction could be done in several ways:

- by increasing the length of the pink ribbon,
- by reducing the length difference between the blue and the pink ribbon,
- by reducing the length difference between the white and the blue ribbon,
- by changing one (or both) of the length relationships between ribbons from "shorter" to "longer."

Only five students noted the contradiction in the data. They expressed their observations in different ways. For example, they wrote, that it is impossible to subtract 17 from 14, or they indicated that it is impossible to solve this problem because the white ribbon would be less than 0 cm.

Zosia wrote that "it is impossible to solve this problem because the blue ribbon is shorter than the white one," and Przemek even stated that "Kasia does not have a white ribbon." These students scored 3 points each.

The remaining students (nine subjects) did not notice the data contradiction. In the case of eight of them, this may have been due to arithmetic errors. One of them

(Alex) started the computations, but apparently did not trust his skills, because he did not finish the problem and wrote that "the problem is too difficult for me."

In the final study, the students were to solve the following contradictory data problem:

Problem 4*b* The following flowers were delivered to the florist: tulips, roses and sunflowers. There were 25 tulips, 10 fewer roses than tulips, and 20 fewer sunflowers than roses. How many sunflowers were delivered to the florist?

Thirteen students noted that it is impossible to solve the problem due to contradictory data. Each of them corrected the data bringing the problem to a usual format and correctly solved the corrected problem scoring maximum points. For example, Artur increased the number of tulips to 50 and increased the difference between the number of tulips and roses to 20, although the latter was unnecessary.

One student (Bartek) most likely confused the phrase "10 fewer" with "10 more" and instead of subtracting 10 from the number of tulips (25), he added 10, so he did not notice the contradiction in the data and did not correct it. He scored zero points for his solution.

Conclusion

The data given above show that the students did not demonstrate critical thinking skills in the preliminary study. They did not analyze problem content or data. They were rather unreflective. When solving unusual problems, they tended to select ready arithmetic schemes that were known to them and effective in solving usual problems, although in these cases they were not applicable. They lacked control over their operations and were content with one answer, even though multiple solutions were possible. Does it mean that they are thoughtless? Rather not. This is more a result of the selection of problems in textbooks or the style of the early childhood education teacher. It is sometimes the case at schools that as soon as the content of the problem, a usual one most often, is given, one of the students (the one who functions better in the school system and calculates faster) gives a mathematical formula (operation) as the solution to the problem and the answer, and thus the whole process of solving is finished—those who had too little time to think, understand, try to find a solution, stand no chance, because the teacher gives another task to solve and the situation repeats itself. Again, a few will find the "solution" (operation), and the rest of the students will rewrite it in their notebooks with no time to think about it. In this way, children's potential, their abilities are not being used. Critical thinking is then unavailable to children. In addition, in order to be able to solve problems/tasks, one needs to practice that skill and not every student gets that chance. All it takes is to give children unusual problems to solve and trust them, sow doubts in them and allow them to think, discuss, question and act; the success is then guaranteed. The results of the final study demonstrate that critical thinking is available to early childhood education students. They only need to be allowed to engage in it.

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"Book of Nature": How to Teach Children to Read It?

„Księga Natury". Jak uczyć dzieci ją czytać?

KEYWORDS

early mathematical education, "Book of Nature," emotional and volitional competencies, instrumental competencies, measurement

ABSTRACT

Modern science and technology are founded on the belief in the rationality and mathematical structure of the world. Learning about it, the progress and quality of our lives are related to the popularization of thinking about mathematical education as equipping students with the competencies necessary to read the Galilean "Book of Nature." The article presents the idea of a mathematical understanding of reality and the leading emotional-volitional and instrumental competencies that should be provided to students of elementary education in order to shape their beliefs about the effectiveness of this way of cognition and support them in acquiring appropriate knowledge and skills.

In terms of field-specific and social competencies, it is about: awakening cognitive curiosity, building the attitude of epistemic and ethical optimism, belief in the inevitability and cognitive value of error, developing the ability to cooperate and compete in small groups, and to shape the attitude of researcher reliability.

In terms of instrumental competencies, these would be: the ability to model phenomena at the level of substitutes (simulations), knowledge of numbers, decimal positional system and four arithmetic operations, the understanding of measurement and practical knowledge of measures, the ability to problematize phenomena from the natural world, having elementary knowledge of heuristics, a certain level of calculation efficiency and knowledge of basic geometric figures.

SŁOWA KLUCZE

wczesnoszkolna edukacja matematyczna, „Księga Natury", kompetencje emocjonalno-wolicjonalne, kompetencje narzędziowe, pomiar

ABSTRAKT

Współczesna nauka i technologia ufundowane są na przekonaniu o racjonalności i matematycznej strukturze świata. Jego poznawanie, postęp i jakość naszego życia są związane z upowszechnieniem myślenia o edukacji matematycznej jako wyposażaniu uczniów w kompetencje konieczne do odczytywania Galileuszowej „Księgi Natury". W artykule przybliżono ideę matematycznego rozumienia rzeczywistości oraz wiodące kompetencje emocjonalno-wolicjonalne i narzędziowe, w które należałoby wyposażyć uczniów edukacji elementarnej, by ukształtować ich przekonania odnośnie do efektywności tej drogi poznania oraz wesprzeć w pozyskaniu stosownej wiedzy i umiejętności.

W zakresie kompetencji kierunkowych i społecznych chodzi o: rozbudzanie ciekawości poznawczej, budowanie postawy optymizmu epistemicznego i etycznego, przekonanie o nieuniknioności i wartości poznawczej błędu, rozwijanie umiejętności współdziałania i rywalizacji w małych grupach oraz o kształtowanie postawy rzetelności badacza.

W zakresie kompetencji narzędziowych byłyby to: umiejętność modelowania zjawisk na poziomie zastępników (symulacji), znajomość liczb, dziesiątkowego systemu pozycyjnego i czterech działań arytmetycznych, rozumienie pomiaru i praktyczna znajomość miar, umiejętność problematyzacji zjawisk ze świata natury, posiadanie elementarnej wiedzy z zakresu heurystyki, pewien poziom sprawności kalkulacyjnej oraz znajomość podstawowych figur geometrycznych.

> Philosophy of nature is written in this enormous book which is continuously open before our eyes, but it cannot be understood unless one first understands the language and recognizes the characters with which it is written. And this book is written in the language of mathematics.
> Galileo Galilei, *Il saggiatore* (after: Van Doren 1991: 200).

Introduction

Mathematical education is an obvious and necessary element of general education, but its place and rank have always depended on the general concept of this education resulting from the general trend of civilization and the arrangement of social life.

For example, ancient Greece produced many outstanding mathematicians who mainly dealt with cognitively interesting, but practically unimportant dilemmas such as: squaring a circle or the so-called "Delian problem" (doubling the cube). Rome did not make a great contribution to the development of mathematics, but using its achievements, created a network of roads and aqueducts, as well as impressive buildings, many of which have survived and are admired by contemporary engineers (Merzbach, Boye 2011).

As it seems, the trend of modern Roman-oriented mathematical education towards the acquisition of competencies by learners in the field of the so-called "applied mathematics" (Hardy 2018: 124), nowadays observed as a good mastery of the formal aspects of mathematics, is far from sufficient without the skillful application of them in various fields of science and industry, which is necessary for the progress of civilization. As Mogens Niss writes, "mathematical competence is the ability to understand, judge, do, and use mathematics in a variety of intra- and extra-mathematical contexts. Necessary, but certainly not sufficient, prerequisites for mathematical competence are extensive factual knowledge and technical skills" (Niss 2003: 218).

Such an exposition of "applied mathematics" is not only a civilizational necessity, but also a chance to popularize mathematics itself as a vital competence worthy of attention, useful and manageable in life, unlike the so-called "pure mathematics," the level of which for over two centuries has exceeded the cognitive abilities of the vast majority of people.[1]

The article is devoted to the presentation of the conditions that should be met by effective mathematical education of younger school-age children aimed at developing competencies in the field of "applied mathematics."

What Does Galileo Teach Us?

From the earliest times to the present day, there has been a vivid view that the world is rational and has a mathematical structure, and mathematics itself is not so much a human invention as the result of discovering what God or nature wrote down in the "Book of Nature." Euclid already noted that "the laws of nature are only the mathematical thoughts of God," Johann Kepler wrote simply that "God is a mathematician," and today Godfrey H. Hardy claims that "mathematical reality lies outside us," and "our function is to discover or o b s e r v e it" (Hardy 2018: 123).

The breakthrough in thinking about the world was brought about by the achievements of Galileo and Newton, who proved its mathematical structure, presenting

1 As Lynn Arthur Steen writes: "Less than 1% of the US population is acquiring elements of mathematics that are beyond the [mathematical knowledge] of the late eighteenth century" (Steen 1983: 15).

equations as the best and surest way to describe and understand reality. In Pierre S. Laplace's mental experiment, a man armed with Newton's mathematical laws of mechanics and augmented but still human capabilities (the so-called "demon"), "could summarize in one equation the motion of the largest bodies in the universe as well as the tiniest atoms; for such a mind nothing would be uncertain, and the future, just like the past, would be before his eyes" (after: Gaarder 1995: 250). Thus, it points to the surprising fact that such equations can also have predictive power, revealing the possibility of empirically confirmed phenomena even after decades.[2]

Assuming that nature is William Paley's "clockmaker" and not Niels Bohr's "gambler," at least as important as obtaining the facts is interpreting them, making them meaningful. They are themselves like a type case with compartments full of types that do not mean anything on their own, and whose meaning is given only by the intention and the thought of those who arrange words and sentences out of them.

"To Want" and "Can." Competencies Necessary to Read the "Book of Nature"

Every action understood as a conscious and purposeful act is anchored in the will.[3] It is also a part of learning about the phenomena of the world, but this will must be equipped with certain intellectual and manipulative tools and the ability to use them effectively. They are complementary goods, and their shape and harmonious combination determine the goals of educational activities that will prepare children to read "The Book of Nature."

Metaphorically speaking, getting to know the night sky requires the possession of a telescope and the ability to use it, and at least elementary knowledge of stellar constellations. Nevertheless, cognitive curiosity combined with the need to spend sleepless nights in silence and solitude is at least equally necessary for this. One needs patience and fortitude to endure inconveniences, failures, adversities of weather and fate.

[2] For example, the existence of a neutrino was empirically confirmed after a quarter of a century and more recently, after half a century, the Higgs boson was discovered.

[3] Action is a specifically human activity "which can be judged morally because of its conscious and purposeful character (*actus humanus*)" (Podsiad 2001: 203).

Emotional and Volitional Competencies

1. Curiosity about the world and persistent inquisitiveness in exploring it

Curiosity about the world is a natural quality of children's minds, but it has at least two perplexing properties. Firstly, they develop a process of habituation to stimuli,[4] a kind of cognitive "anesthesia," which makes them take the phenomena around the world for granted in order to not to be surprised by them or to think about them (Nowak 2010: 12–13; 2016: 71).

Secondly, children's interests are as intense as they are short-lived, and they are not resistant to failure. When asking, children are often satisfied with any answer or, in a rush of amazement, shift their interests to other issues, without waiting for explanations of the previous ones (Ligęza 2006: 235). Such lability and short duration of children's interests are not conducive to acquiring good knowledge and skills, and the teacher should become the children's perseverance, inquisitiveness and will.

I believe that the science learned by children should be more of a story of reaching knowledge, also through mistakes and errors, than just a catalog of their transient successes. More a story of the stubbornness of constant dropping which wears away a stone than of good luck. The story of Maria Skłodowska-Curie's diligence in shifting tons of pitchblende rather than Alexander Fleming's nonchalance and good luck.

2. Epistemic and ethical optimism

We live in the world of a special triumph of science, but also of a crisis of trust in it and world-view revaluations. Significantly, this crisis of trust affects a wide audience as well as scientists, so that even a specific term "ironic science" was coined for this circumstance.[5]

Since students do not live in a social vacuum, they have access to various types of information, whether they like it or not, it is advisable to build students' conviction about the value of scientific cognition and progress made by not avoiding difficult issues.

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[4] Jerzy Siuta defines "habituation" as: "an adaptive phenomenon consisting in the reduction of the strength of the reaction and its disappearance when the stimulus causing it continues or when it repeats itself" (Siuta 2010: 98).

[5] "Ironic science resembles literary criticism because it presents points of view, views that are at best interesting and provoking further commentary. It does not, however, lead to the truth. In this way, it is impossible to achieve empirically verifiable surprises, forcing us to make a significant revision of the basic description of reality" (Horgan 1999: 18–19).

The experiences of the last century and the almost daily media reports draw attention to another aspect of the case. In the context of scientific discoveries, more and more questions about the real progress of civilization and the good of changes appear. I believe that we should adopt here the attitude of Maria Skłodowska-Curie, who, when receiving the Nobel Prize, raised this topic saying: "one should wonder whether learning about the secrets of Nature brings benefits to mankind or, on the contrary, this knowledge is harmful to it. … I am one of those who … believe that humanity will learn more good than evil from new discoveries" (Rahoza 2011: 4).

Since human life also has a spiritual dimension, it must be remembered that science does not know and rather will not know the answers to existential questions bothering man also in childhood, and certainly in adolescence. Questions about the purpose and meaning of life, transcendence, good, evil, beauty, etc., fall outside the remit of science.

3. Belief in the inevitability and cognitive value of errors

If "to err is human," then the history of science, which is a catalog of lost ideas, errors and mistakes, is an outstanding example of this maxim. Even ignoring the historical significance of coincidence in the discoveries and the so-called "beatus error," it is worth recalling that the conscious error significantly broadens our knowledge, limiting the scope of ignorance.

Making children aware of this issue is not only a tribute to historical truth, but can also improve the psychological situation of a child who experiments with the world, wanders and becomes easily discouraged, who is situated in a good company of the strongest intellects, which can be comfort in failures and an encouragement to continue cognitive effort.

It is therefore necessary to patiently give students the right to make mistakes and a chance to correct their mistakes, so that they are their mistakes and their "discoveries" as much as possible, despite the fact that, in the face of their redundancy,[6] the teacher, like the divine demiurge, knows the result of experience, and in the face of children's helplessness would like to make use of his competencies.

4. Ability to cooperate and compete in small groups

Research work has long been a team activity. The research is carried out by competing groups of people who inspire and complement each other. In these circumstances,

[6] In the methodology of sciences, in this context, one speaks of subjective and objective research problems, i.e., those to which the answer is unknown only to the researcher (here: a student) and problems to which the answer is unknown to science as such (Cackowski 1964: 105).

one of the important areas of preparation for current and future cognitive activities should be the acquisition of positive experiences related to cooperation and competition by children.

An excellent school of such cooperation, and at the same time—dialectically—of group competition, are various experiences and experiments, which, on the one hand, stimulate more effective effort and, on the other, give a chance to discover synergy.[7] In the course of such activities, students get to know themselves and each other, their strengths and weaknesses, learn to share work and responsibility. They learn to lead others and submit to leadership based on the epistemic authority (subject-related competence) of their classmates and solidarity, indicating that in effective team activities, their coordination and leadership is necessary and beneficial for all.[8]

5. Researcher reliability

Even the brightest ideas and thoughts need to be implemented to become something useful. Researcher reliability, as I understand it, is a competency on the border of field-specific and instrumental dispositions. It requires responsibility, precision in measurements, patience, reliability and regularity in observations.

Instrumental competencies

Effective reading of the "Book of Nature" also requires a number of instrumental competencies; knowledge and skills, which I believe include:

1. The ability to model phenomena at the level of simulation (substitutes)

Mathematical cognition of the world consists in modeling its phenomena in numbers and formulas, but when working with children, it is good to model them using tokens, and then using graphical representations and diagrams. The advantage of such modeling is that it meets the specific thinking of students, but directs their attention towards quantitative phenomena, disregarding the features and physical properties of the modeled phenomena (Treliński 2016: 77–79).

[7] It is about the effect also described as 2 + 2 = 5, where the synchronized joint effort gives a greater effect than the simple sum of the effects of the work of individual team members (Nęcka 1994: 83).

[8] By epistemic authority, I mean authority based on its subjects' belief in the substantive competence of the person who is bestowed with it or who claims it. By deontic authority—one that is related to the performance by the holder of some function, or a person fulfilling some social role. There is always some form of the ability to enforce obedience behind it. Solidarity authority is a deontic authority in which the common goals are pursued both by the one who has authority and those who obey him (Bocheński 1994: 24–26).

2. Knowledge of numbers, decimal positional system and knowledge of the four arithmetic operations and the ability to formalize them

Reading the "Book of Nature" is related to the knowledge of numbers and the actions on them, which are its letters and sentences. From this point of view, it should be noted that the numerical competence of children is much more than knowing, even correctly, a sequence of numerals, and knowledge of actions is more than retrieving verbal and graphical engrams from memory (Gruszczyk-Kolczyńska 2014: 65–70). Having the concept of a number and mathematical operation and a decimal positional system can be compared to a box with a name tag affixed to it, but inside which there is a rich and, above all, diverse and orderly arranged set of experiences, ideas and associations, memory of activities, etc., related to the gradual climbing the steps of enactive, iconic and finally symbolic representations (Dąbrowski 2007: 11). Those who have acquired the concept in such way can use this box by taking out the contents appropriate to the situation, but also create and add new ones to it, which will mean (connotation) and signify (denotation).

3. Understanding measurement and actual knowledge of standard measures as well as relationships and dependencies between them

The places where the created world and the world of numbers meet are the measures. If the numbers are letters, then the measures seem to be the words of the language in which the world is described. The primary issue is therefore the acquisition by students of good concepts, measured, understood and skillfully applied, avoiding degenerate formalism (Hejny 1997: 19). By adhering to the metaphor of "book," it is about a kind of functional illiteracy,[9] reading measures like words in an unknown language without understanding, which, even if fluent, carries no factual information. This is dangerous because it creates the formal appearance of having appropriate competencies by the students, and thus makes it difficult to recognize the deficiencies and correct them.

It is a situation analogous to the situation when someone reads a thermometer with the Fahrenheit scale (°F) without difficulty, makes appropriate calculations regarding the increase and decrease of temperature, not knowing what this temperature actually means for him, for his well-being.

A realistic understanding of concepts must therefore be built on observations and experiences, on muscle memory, images and imaginations, going through the stages of (I) spontaneous accumulation of knowledge about the physical aspects of the world

[9] Dorota Klus-Stańska, analogically, speaks about the mathematical illiteracy (Klus-Stańska, Nowicka 2005: 107).

by the child in the course of their own activity, (II) intentional, teacher-guided perception and qualitative comparison of items in terms of quantitative characteristics, (III) the child's realization of the necessity of indirect measurement and its essence, (IV) learning the standardized units by the child, (V) performing calculations with the use of nominated numbers, (VI) learning derived units (greater and smaller) than the initial one, their mutual relations and binomial expressions and the ability to convert from measures in larger units to smaller ones, (VII) the creation of a locally ordered system of measures, including measures of extension, surface area, volume and mass as well as the rules for creating derivative units and their names (Nowak 2009: 157–163).

4. The ability to problematize phenomena from the world of nature and the social world

Noticing the phenomena of the world, being curious and surprised by them must be combined with a number of skills that will allow you to problematize this surprise and curiosity. If we assume that the "Book of Nature" is an inexhaustible set of tasks with content, then it would be about the ability to solve tasks and having the necessary competencies:

a) the ability to analyze and assess the initial situation from the point of view of the quantity and quality of information,
b) the ability to generate ideas for a solution and check them, with the ability to move between different levels of representation, and to verify them internally (assessment of the reasonableness and probability of the accuracy of ideas),
c) reflectivity, which makes it possible to evaluate the effectiveness of actions, and above all, in the process of generalizing individual solutions, it leads to their paradigmatization, thus allowing the accumulation of knowledge and skills (Polya 1975: 266–287).

5. Elements of knowledge and skills in the field of heuristic problem-solving techniques

The school, as it seems, rightly aims to equip students with reliable competencies, confirmed as to their effectiveness. However, discovering the secrets of the world, even through play, is a pioneering journey into the unknown and forging one's path, so that those who want to embark on this journey must also be equipped with tools and unusual skills, different from those taken on a school trip. This is the nature of heuristic problem-solving procedures, the knowledge and skillful application of which optimizes the cognitive process, significantly increasing the chances of its success.

There is already a wide selection of literature on the possibility of using heuristics in school, so I would like to highlight only some generalities. Edward Nęcka, an expert on the subject, gives them the form of the following principles:

1. The principle of diversity; there is no one best procedure for reaching knowledge, the more you know, the bigger the chance of success grows.
2. The principle of deferred evaluation, separating in time the usually co-occurring processes of generating ideas and their immediate evaluation, which stifles creativity in favor of common-sense and cautious activities (self-censorship).
3. The principle of rational irrationality; conscious and critical use of intuition, emotions, luck in the cognitive process, etc.
4. Principle of competent incompetence; an intentionally critical approach to recognized epistemic knowledge and authority.
5. The principle of play; the spontaneous and playful nature of the cognitive activities undertaken.
6. The principle of validity; concentration of all cognitive forces on the problem currently being solved (Nęcka 2005:15–18).

As can be seen, the rules are largely paradoxical, which makes them new, surprising and attractive to children.

6. Some level of calculation proficiency and/or skill in using a calculator

It is not a central and intellectually most demanding skill, but it is certainly as necessary as the others. It has the character of an instrumental efficiency that allows for effective (i.e., fast and error-free) testing of ideas and reaching final results.

Without denying that creative anxiety, curiosity and invention are the essence and spring of cognition, let us remember that only turning an idea into numerical data gives information about its truthfulness and possible usefulness.

Under the influence of rapidly developing information technology, calculation efficiency as the goal of education is subject to far-reaching reinterpretation and reduction, but if we treat the process of exploring the world as a creative act, it seems that just like a piece of creation often evolving from its original intention and improving in the course of its implementation, calculation may turn out to be a more creative act than we thought so far.

7. Knowledge of simple geometric figures and their relationship with material reality

Galileo's proposition and the history of mathematics indicate that the beginnings of scientific exploration of the world were geometrical, and that for two millennia

Euclid's *Elements* were an imitated but unattainable example of scientific accuracy and clarity.

The world of civilized man is a geometric world, it is a space of circles, triangles and rectangles, cubes and spheres. It is delineated according to parallel and perpendicular lines, it is built according to levels and verticals, and as a result it is impossible to understand the world without knowing even the elements of geometry.

Apart from that, as Urszula and Gustaw Treliński point out, for the student geometric education may additionally be:

1. the way to the ability to mathematize the relations of the surrounding world,
2. a "bridge" between the natural language and the language of mathematics,
3. a factor conducive to the development of mathematical imagination and intuition,
4. an important element of shaping an active attitude towards tasks and problems (Treliński, Trelińska 1996: 7–8).

In order to avoid degenerate formalism, also in this area, one should strive to discover the properties of figures and objects having their shape, and not focus on unnecessary, incomprehensible, and sometimes simply misleading definitions (Gruszczyk-Kolczyńska 2009: 371–376).

Conclusion

Reading and understanding the "Book of Nature," like any other book, requires appropriate development of both core and instrumental competencies. Developed enough for the students to be able not only to apply them in new situations, but using a kind of "generative grammar" to create such situations themselves, ask questions about them and formulate hypotheses to solve them.

Among the field-specific and social competences, attention should be paid in particular to the importance of:

1. curiosity and cognitive inquisitiveness,
2. optimism about your own cognitive abilities and the good that comes from it,
3. conceptions about the inevitability of making mistakes and their cognitive value,
4. skills of effective cooperation within a small group and competition with others,
5. research reliability and precision of measurements.

Instrumental competences, necessary in rational cognition of the world, should include:

1. the ability to model phenomena at the simulation level,
2. knowledge of natural numbers, understanding the decimal system of counting and arithmetic operations,
3. understanding the essence of measurement and practical knowledge of standard measures,
4. the ability to problematize phenomena from the world of nature and social life,
5. knowledge and practical ability to use simple heuristic techniques,
6. good calculation efficiency at the level appropriate for a given class,
7. knowledge of simple geometric figures and the ability to interpret world phenomena in their categories.

Shaping the cognitive attitudes of children taking into account these elements may seem to be a chance for more effective understanding, because they are based on practical activities, in learning mathematics through them. Building their sense of self-agency in this regard, and in the future, they will undertake more frequent studies and work in disciplines where the knowledge of "applied mathematics" is one of the basic competences. These are disciplines that determine the further development of our civilization and the quality of our life.

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Montessori Approach to Science Education: Cosmic Vision as a Unique Area of Pupils' Studies

Montessoriańskie podejście do poznawania środowiska społeczno-przyrodniczego. Kosmiczna edukacja jako wyjątkowy obszar uczniowskiego poznania

KEYWORDS

Maria Montessori, Montessori pedagogy, Cosmic Education, Science Education

ABSTRACT

The paper aims at recalling Maria Montessori's essential assumptions about the child development and organization of the educational process as a basic issue considering the concept of science education. In the Montessori pedagogy, it is characterized by the form of the so-called Cosmic Education. Cosmic Education is a unique approach to work with children aged 6 to 12. Thus, the idea of Cosmic Education, the relationship between the child's needs and the science education curriculum is elucidated. The essence of the Great and Key Lessons as centers of children's exploration and research is discussed. The Montessorian way of learning about fundamental human needs is presented as an inspiration for school practice. The basis for collecting empirical material is the analysis of the content aiming at the current achievements within the selected topic characterization.

SŁOWA KLUCZE

Maria Montessori, pedagogika Montessori, kosmiczna edukacja, poznawanie środowiska społeczno-przyrodniczego

ABSTRAKT

Celem niniejszego artykułu jest przypomnienie głównych założeń, jakie sformułowała Maria Montessori na temat rozwoju dziecka i organizacji procesu edukacyjnego, jako punktów krytycznych w rozważaniach nad koncepcją kształcenia w zakresie poznawania środowiska społeczno-przyrodniczego. W pedagogice Montessori wskazana koncepcja przybiera postać tzw. Kosmicznej Edukacji. Kosmiczna Edukacja jest unikatowym podejściem w pracy z dziećmi w wieku od 6 do 12 lat. W artykule wyjaśniono ideę Edukacji Kosmicznej, wskazano związek między potrzebami dziecka a programem poznawania środowiska społeczno-przyrodniczego. Opisano istotę Wielkich i Kluczowych Lekcji, jako ośrodków dziecięcych badań i dociekań. Zaprezentowano także rekomendowany przez Montessori sposób poznawania przez dzieci fundamentalnych potrzeb człowieka, będący inspiracją dla praktyki szkolnej. Podstawą do zebrania materiału empirycznego była analiza treści przeprowadzona w celu scharakteryzowania aktualnych osiągnięć w ramach wybranego tematu.

Introduction

Albert Einstein defined education as a type of human intellectual activity, the task of which is to establish the fullest possible interdependencies between the phenomena taking place in the world around man which are available to the senses (Butryn 2011: 352). The process of establishing combinations and dependencies takes place through systematic and planned thinking. That is why, paraphrasing Einstein, first of all, man should acquire the ability to think critically and independently and attain general intellectual and practical skills. These skills are much more important than specialist subject knowledge which is not capable of meeting needs emerging in the diverse and complicated conditions of human life (Butryn 2011: 350). According to Einstein, the essence of education is not to acquire factual knowledge but, firstly, to exercise the mind so that it is able to seek and build knowledge independently and, secondly, to foster the belief that study is not a duty but "an enviable opportunity to learn to know the liberating influence of beauty in the realm of the spirit" (Einstein as cited in Butryn 2011: 350).

This objective of the paper is to recall Montessori's assumptions about the child's development and organization of the educational process as a crucial issue considering the concept of science education. The basis for collecting empirical material is the analysis of the content aiming at the current achievements within the selected topic characterization. The critical content analysis leads to systematic and reliable indication of what topics were mentioned and how they were discussed in the collected research material (Szczepaniak 2012: 84–86). It is widely accepted that the purpose of the method of analysis and criticism of the text content is primarily the characteristics of the current achievements within the selected thematic area. This is accompanied by the components of interpretation and conceptualization. The researcher's conduct is guided by the methodological rules related to the need to ensure the efficiency, credibility and cognitive value of work results (Cisek 2010: 277–280).

Organization of Children's Education for the Development of Independent Thinking Skills

Maria Montessori developed an original concept of child education based on the search for replies to fundamental questions about the sense of life and human growth. The idea developed from the understanding of human nature enabled Montessori to work out an original concept of school and education. At the beginning of the 20th century she elaborated the universal laws governing the development of children. That resulted in the preparation of a school environment that would correspond to the disclosed needs of a child (Bednarczuk 2016: 9). Montessori stated that education can be used as a kind of help for a child in developing his individual life potential and gaining independence. The source of the child's independence becomes his or her spontaneous activity which results in his or her specific developmental achievements. This should be stimulated and controlled by the school environment, the so-called p r e p a r e d e n v i r o n m e n t. According to Montessori, activity and independence are inseparably connected and the sentence: "Help me do it myself" illustrates their relations perfectly. Thus, freedom proves to be the basic condition of the mental set transformation. This is freedom to choose where, when, how long and with whom the child would like to work, learn or play. Nico van Ewijk states "Education of this type has been a piece of research, a scientific experiment to investigate the possibilities inherent in the scholar, and to offer him means, stimuli, which might awaken what energy was left to him and employ it in permanent fashion, augmenting it with and coordinating it by individual exercises" (Van Ewijk 2014: 49).

At the beginning of the children developmental path, they explore the world through their senses. They are sensual explorers, so primarily they need sensory and manipulative materials, practical life exercises suitable for multi-sensory cognition. Practical life exercises facilitate the development and improvement of small motor skills. Their repetition supports building harmony and coordination of movements. They develop a sense of responsibility for a workplace shared with others. Sensory materials were designed in such a way that children can advance their physical perception and acquire the skills of organizing information. Working with hands-on materials designed by Montessori supports building universal mental strategies (e.g., ordering, classification, defining categories, etc.) and guides how to control the correctness of task performance. In this way, a set of materials as well as a set of examined and effective rules of behavior in the school environment induce individual work and cooperation (Bednarczuk 2016: 148–149). Teamwork comes naturally in the cases when it is suitable or necessary. At the same time, the child must learn to make use of the potential he possesses: "To get stronger by himself before he can join the group because the stronger the child is, the more he can get involved and the better he can integrate with the group" (Dattke 2009: 102). Thus, education primarily means providing care and love, supporting the development of the organism, its well-being and safety, fostering health as well as moral development (Kunowski 2000: 254).

Then the time comes when children begin to acquire and organize knowledge about the world consciously. The period between 6 and 12 years of age is a time of mental acuity, moral sensitivity and a period of social interests' development. Due to the discussed characteristics, children go to the outside world, "beyond" their inner world, they open up to reality and people. They want to know more, show extraordinary willingness to learn; that is why they seem to be constantly interested: what, where, why, how? Hence this is the so-called "period of special sensitivity" for culture (Montessori 1989a, 1992). Children aged 6 to 9 penetrate their surroundings, get to know social reality available for them (their own social group) in order to understand the principles of its functioning, they are more interested in the world of things than in the world of ideas and concepts. Their orientation in reality is based on the direct action, the contact with objects the child gets to know. The 9- to 12-year-old children become the explorers of reality because this is a period of transition from the specific mental representations to abstract thinking. The reversibility of mental processes is the most essential achievement associated with the form of specific thinking which contributes greatly to the development of flexible thinking, being an important step in gaining independence from objects manipulation (Rękosiewicz, Jankowski 2014: 33).

They become critical explorers; therefore, the learning environment responds to the need for independent cognitive activity implementing qualitatively diverse developmental materials (academic materials). In this stage there is nothing more fascinating for the child than discovering the world. Thus, educational materials should enable studies in diverse areas of culture and stimulate all paths of learning, including the expressive strategy highlighted by Montessori. The student has the opportunity to discover or to explore the content hidden in the Montessori materials. The curriculum integrates the idea of cosmic education. This is an area of the program characterized by the principles of coexistence and interdependence in the material world. This unique approach supports students in constructing their knowledge by focusing on finding the answer to the question about their place in the world

(Bednarczuk 2016: 149–149). In this case education is formation of subjective consciousness of the pupil while learning about reality (Kunowski 2000: 254).

The Idea of Cosmic Education

The term *cosmos* is of Greek origin and means order, the world in the form of the harmoniously organized whole, the reverse of chaos (Kopaliński 2003: 279). The concept of Cosmic Education used in the Montessori pedagogy refers to such organization of studying the world by the child that he or she can discover the order of the surrounding world, its universal plan consisting, according to Montessori, in the fact that all elements of animated and unanimated nature are combined. Cosmic Education is an educational philosophy which supports Montessori's beliefs about interrelations in the Universe, joint responsibility, cooperation and stability of all the inhabitants. "Cosmic tasks" attributed to being are results of their mutual relations. The cosmic task consists in doing the attributed work by each being to satisfy their own needs, which at the same time creates the conditions for the development of others and thus the world. "But there is a purpose more important than the protection of the offspring or the preservation of the species. It is somewhat beyond mere growing according to a pattern or living according to instincts. This more significant purpose is to conform to a master plan towards which all things are moving" (Montessori 1989b: 2) The example given by Montessori was a mollusk. It takes calcium carbonate from the sea to build a protective coating building its own house, but at the same time the amount of this substance diminishes in the sea-water. If its level was high, the life on Earth would be poisoned (Montessori 1989a).

The task set for the man depends on the place of his dwelling in the course of his or her life. The child's task is creation of a person, constructing of a man "who will build peace, a man who is adapted to the world in which he lives. (…) the greatest work ever accomplished during any lifetime is that which takes the human being from the helpless state of the newborn baby to the child who, not only manifests the characteristics of the species, but clearly belongs to his own human group and is also his own and individual self" (Grazzini 2013: 111). In turn, the adult gifted with free will and intelligence is to perform a great task of Earth transformation and accomplish the function of transforming nature. He builds culture "to construct a new world full of marvels which surpasses and overrules the wonders of nature. This is a man who creates civilization. This work is unlimited and it is the aim of his physical limbs" (Montessori 1989a: 69). The adult's cosmic task is one of those "contributing to the upkeep and development of the Earth, of creation, modifying and transforming the environment." Building the civilization "which is in *constant evolution* and which *involves* a *continual modification* and *enrichment* of *their* spiritual territory (Grazzini 2013: 111).

The first assumption of the Cosmic Education is helping pupils to discover and understand the laws of the Universe treated, as already mentioned, as a network of relations. Secondly, it includes the support in recognition of one's own cosmic task as the species and individual. "It is only against the background of our place in the universe, our relationship to other living organisms, and our understanding of human unity within cultural diversity, that we can attempt to answer the question 'who am I?'" (Duffy, Duffy 2002: 6). To do this, the broad interpretative context is necessary. Getting to know the Universe includes many issues. It combines the knowledge of biology, botany, zoology and history contents as well as those of mineralogy, astronomy, geography, geology, chemistry and physics. These fields of study are given names but not divided into separated subjects. Each of them develops the interest in the world which is a unity. Each of them reveals facts and phenomena as a part of the common whole (Bednarczuk 2007: 31; Healy Walls 2008: 41–49). "When a child learns about trees, the teacher should not forget to tell how conditions as well as vegetation and animals affects their growth. On the other hand, trees should create such conditions that provide comfortable life for plants, animals and people" (Stein 2003: 133–134). Starting with the whole is aimed at creating representation of cosmic order. Cosmic education is also a way to visualize the social code of "giving and taking," a life and educational philosophy—a close relationship between man and the environment which is developed towards environmental education, education for peace, sustainable education (Bednarczuk 2007: 31; Healy Walls 2008: 41–49).

The Child's Needs and the Cosmic Education Curriculum

Cosmic Education is a unique area of learning developed by Montessori as a tool for educating particularly 6- to 12-year-old children. She defines that period of life as "the time of culture" during which the human spirit is organized. However, the contents of the area under consideration appear as early as in the kindergarten. Grazzini (2013: 112) states that "Cosmic Education helps the children to acquire a cosmic vision of the world, a vision of the unity and finality of the world, a vision which gives a sense of meaning and purpose. Cosmic Education gives the children the opportunity and the freedom to explore, study, and acquire knowledge of the universe not only in its globality, but also in its complexity." Individual and team studies support the development of potential of the child (Montessori 1989a). Children learn to appreciate how various cosmic forces work and interact. They discover nature of scientific laws.

As early as in the first period of development (0–6 years) a child is brought into the world of nature through experiencing it and working with sensory material. Experiencing nature leads to improvement of the senses. Sensory cognition is a source of processing and understanding the world accessible to a child at that time. In the course of her London lectures Montessori (2015) pointed out to the importance of elementary materials in the context of indirect preparation for Cosmic Education. Absorbed image impressions and experiencing structures organized owing to the manual activity ("seeing with the hand") are the foundation for "constructing the power of imagination" (Montessori 2015: lecture 5). The curriculum for 0- to 6-year-old children, bringing into the cosmic plan, is very detailed and carefully prepared (Montessori 2015; Elsner 2003). Among the original materials intended for manipulation there are botanical and zoological cards as well as aids in the field of physical geography.

The Cosmic Education curriculum for the 6- to 12-year-old children is different, which results from different developmental regularities. Children are interested in what is unusual, in the things that constitute a cognitive challenge. Therefore, the idea of presenting the vision of the universe corresponds to the child's needs. It satisfies the hunger for knowledge; it is a breeding ground for natural curiosity and emerging interests. It enables the child to search for an answer to the question: who am I?

The children aged 6–12 reach a new standard of moral development. In this period moral principles are still external and the source of motivation to adhere to them are the closest people. However, the child is able to observe accurately what behaviors are socially acceptable in his or her school group, in the family and in the peer group. He/she becomes convinced that what is good is that what is recognized as good by the family, class, group of friends. Considering morality from the perspective of the social system, the child sees the sense of preserving it. He or she becomes aware that the needs of the individual are not more important than those of the entire social group (Rękosiewicz, Jankowski 2014: 29). From the perspective of socio-moral development, Cosmic Education patterns, models, ideas for children looking for moral awareness through stories about the universe, heroes, rulers, significant figures (Healy Walls 2008; Helfrich 2011: 42).

Children are interested in establishing various social relationships. They begin to become gradually independent of their loved ones and are able to participate in a wider social context. They meet the world of a new class where they meet students from different age groups (mixed-age group) which results in increasing the number of contacts and acquiring new social skills. They learn and master the principles and rules of teamwork being able to follow new rules. Children work willingly in a group, derive joy and satisfaction from the opportunity to learn with others so Cosmic Education is a study of shared responsibility and cooperation. It enables learning in cooperation, in mutual relationships/interactions, both in the classroom and outside it.

Cosmic Education meets one more characteristic of the child's developing potential. The explosion of imagination characterizing the 6- to 12-year-old children provides the opportunities of obtaining information and motivates them to learn. Owing to their imagination children can come into contact with the content that they are not able to experience directly. This is how imagination "enables us to see those things that are in front of our eyes" (Montessori 2015: 173). The power of imagination and the emerging ability to abstract mean that there are no limits to the children's search—the universe itself is the limit. Therefore, Montessori wrote (1989a) that we should give children a vision of the Universe because by presenting it we can help the child with learning and organizing knowledge processes.

The frequently repeated phrase—"the vision of the Universe"—is the distinguishing feature of the Cosmic Education curriculum. Strictly speaking, this is not an educational curriculum in the sense of the traditional scope and sequence. This is rather a holistic, inviolable, inseparable and rich-in-detail set of stories about the formation of the universe, the solar system, the Earth, life on earth and human inventions that inspire students to seek, deduce, argue, explain, reason logically, investigate and build knowledge. Getting familiar with such complex issues is possible due to exploration. The child gains an understanding of the world through experience and exploration. As Charlotte Poussin, Hadrien Roche and Nadia Hamidi (2019: 63) state, children notice that the more they delve into a given topic, the more they can see and understand. Presenting the universe as a dynamic creation, in which all its elements have a task to do, encourages children to contribute to its development. "Montessori looks at the world, sees the world on a very grand scale, that is, at the level of the universe with all of its interrelationships. There is the inorganic world which is ecologically linked in innumerable ways with the biosphere which, in turn, is linked with human beings or the psycho-sphere" (Grazzini 2013: 108). Montessori offered students a vast panorama of the history of the universe and mankind in the form of six Great Lessons, accompanied by more detailed Key Lessons (Lillard 1996).

Great Lessons as a Center for Children's Research

In the Montessorian approach the child is supposed to learn and explore the laws of nature, human achievements resulting from understanding the idea of working for the common good, from noticing the knots of interdependence. Discovery of the laws of the Universe proceeds from general to the detailed being based on the analysis, observation and reflection on the content of the Great Lessons.

1. The First Great Lesson is the History of the Universe. The story of how the world, the sun, the stars, the moon, the earth and water, etc. were formed. It presents the world at the dawn of time, characterized by earthquakes and volcanic eruptions. The slow shaping of the earth's crust took place in response to the natural laws of nature. "The Sun (the prime source of energy), the Land

(also the rocks and the earth or soil), the Water and the Air, all of which act and 'work' according to the cosmic laws of their being, that is, according to their inherent nature" (Grazzini 2013: 109). The story of creation, the bringing into being of what did not exist before, this is one aspect of cosmic education and then there is, as it were, the "house-keeping" or maintenance of that creation (Hayes 2005: 3).

2. The Second Great Lesson is about Coming of Life, about how life appeared in the sea and spread over land. This is the tale of various cosmic tasks of living beings. "We see how Life appears to save and preserve the order and harmony of the world since, left to themselves, the non-living agents cannot maintain cosmic order and threaten to bring about chaos" (Grazzini 2013: 110).
3. The Third Great Lesson: In Coming of Humans child gets to know the evolution of a man, starting with *homo erectus* and *homo habilis*, going to *homo sapiens*.
4. The Fourth one—The Story of Writing—presents the human need to communicate with the help of signs and methods improving communication tools.
5. The Fifth Great Lesson—The Story of Numbers—introduces students into the world of simple signs and counting on bones and sticks, to Roman numerals and the introduction of zero.
6. There is also the Sixth Lesson, called the River of Life, devoted to the work of the human body (Lillard 1996; Duffy, Duffy 2002; Healy Walls 2008; Poussin, Roche, Hamidi 2019; Clarkson, Clarkson 2009).

The goal of each lesson is to wake up the children's astonishment so that they are inspired to continue searching, asking questions, and investigating. Lessons are not designed to teach facts presented in the story. Story and study are the essence of the Great Lessons (Duffy, Duffy 2002: 34).

Storytelling is an indispensable element of Cosmic Education. "Events, reflections, results, facts, hypotheses, research, natural disasters, mysteries of nature and everything that can be experienced are told in their own words here" (Elsner 2003: 2). This is how students are inspired to carry out research and make projects. Therefore, it is essential for the story, as Healy Walls writes (2008: 52–53), to follow a few basic principles. Firstly, the story must be presented in an inspiring way. Secondly, it must start with philosophical notions hidden behind the cosmic plan. Thirdly, the indicated theoretical and logical approach must be presented in an appropriate scientific language, adjusted to the child's interest and mental possibilities. Fourthly, all presented information should be correct and sufficient as a starting point for their own scientific research. Finally, the story should specify the means by which the child can continue researching the data.

As Lillard (1996: 71) emphasizes, in the days after the Great Lesson, the teacher's goal is to get groups of children to search for the answers to their questions as well to provide studies and do their work together. The Great Lesson alone cannot accomplish this aim. Its purpose is to indicate the general area of study. Key Lessons make the exploration possible because they provide additional and detailed information in a particular field. The key lessons are not given to every child or in any particular time frame. The teacher chooses lessons on the basis of the observation of the child's interests (Lillard 1996: 71–72). To paraphrase Montessori's words: "One plan and many patterns" (Montessori 1989b: 82).

In this way, the Cosmic Education curriculum goes beyond the limits of linear and systematic acquisition of knowledge, for example successive representatives of the plant and animal kingdoms, in isolation from the broad cognitive context. The Montessori curriculum includes monumental stories about the origin and evolution of life on Earth, which stimulate children to undertake individual or group thematic studies. Therefore, if in the first period of development (0–6 years) the Montessorian materials evoke deliberate and orderly activities of the child, they constitute the scaffolding of children development and in the mid-school age the materials become of secondary importance. It is essential that the child should build the context (the whole) of systemic thinking necessary to understand himself and his place in the universe. The interests generated by the Great Lesson become the most important. The materials available in the classroom have to maintain children's curiosity and enable research (Duffy, Duffy 2002; Healy Walls 2008; Poussin, Roche, Hamidi 2019). This provides a structure within which the inspiration will stay alive and grow into further learning (Healy Walls 2008: 53). It is important that children should have time to accomplish their projects. This is a huge challenge for the teacher. The curriculum is created bottom-up. This means that it is inspired by the child, so it is born in action. Clare Healy Walls recommends that "it is preferable to inspire the children to plan for themselves by presenting them with the wider curriculum that they must cover, helping them to understand gradually all the existing topics that must be covered over the next month/year. This encourages them to seek lessons and inspiration on topics as they develop responsibility for managing their own curriculum" (Healy Walls 2008: 47). In this way recognizing children's interest areas is a source of the curriculum.

Great Lessons provide children with the opportunity to examine the outside world carefully. They develop, perform and present their own or group projects. The teacher guides the child to make contact with experts and sources of knowledge that help further research and creation. Children are set free to explore and establish their own paths through the complex maze of knowledge on the Earth. They discover many kinds of interrelationships existing in the world and thus explaining how the Earth functions (Grazzini 2013; Stephenson 2015).

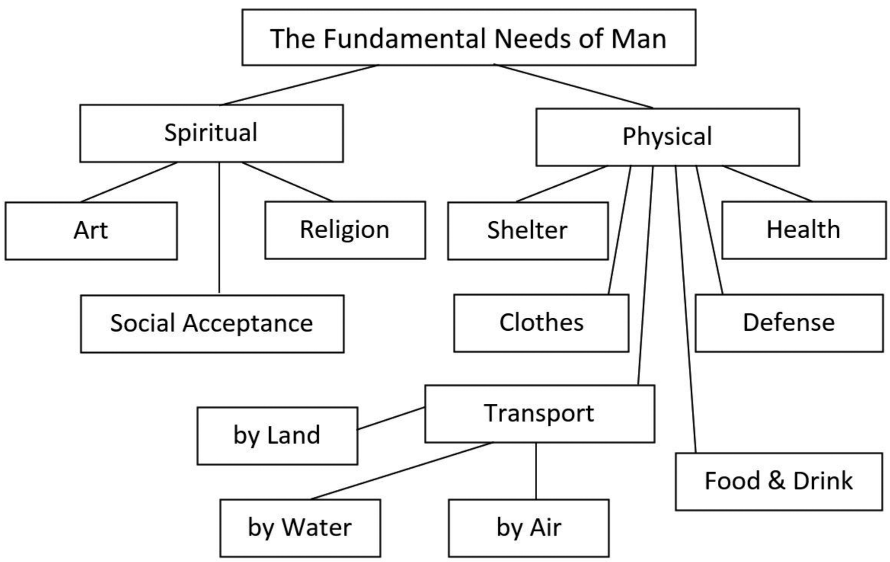
In summary, Cosmic Education encourages the child at an early school age to learn about the natural laws of the world of nature, interdependencies and mutual links between organisms and basic needs shared by all people via stories, presentations and experiments. Thus, we are approaching the Montessori concept of history. In order to develop the concept of history, it is necessary to examine different ways in which people meet their needs.

Fundamental Human Needs as an Area of the Child's Investigation

The Third Great Lesson, the Coming of Man is accompanied by Key Lessons concerning fundamental human needs (Lillard 1996: 72). Children start to learn about fundamental human needs at about the age of six and continue throughout the period of education. Children talk about the needs and about satisfying their own needs, about how they are satisfied by people living today in the civilizations and cultures they have learned about (the scope of knowledge depends on the age of the students). This is a key to the history for the children as well as the "concept" of history (Hayes 2005: 7). The Montessorian approach to history focuses on the search for an answer to the question: How do people satisfy their needs? Montessori was fascinated by the fact that significant progress of civilization was connected with changing ways to satisfy the universal needs of people (Poussin, Roche, Hamidi 2019: 177).

The Fundamental Needs of People develop the paradigm that all people share the same needs and the only difference between various groups of humans is how they satisfy those needs. The differences are representative of geographical location, time period and social economic status. Therefore, humanity "is more alike than different" (Cunningham 2017). How is this topic presented to children? Marianne and John Clarkson (2009) propose a special Key Lesson about a boy living in Stone Age who strayed from the tribal group, got lost and had to look for shelter, food, clothes, satisfy the need for security. He missed his family and expressed his emotions by means of free expression. In the intention of the authors this story is to initiate children's studies on fundamental human needs: "Og looked up. The sun was going down and it was starting to get dark. (…) I need somewhere to shelter for the night. (…) He could not sleep; he was so thirsty. He found an icicle dripping. He made a cup with his hands, and drank. (…) He heard the noise. The noise seemed to be coming closer. (…) He tied the flint to the top of the stick with a piece of skin from the bear. Now Og had something to defend or protect himself with. Og prayed to the Great Spirit of his tribe (religion)" (Clarkson, Clarkson 2009: 63–64). It is worth comparing Og's needs and the way of meeting them with the needs of contemporary children. According to the classic Montessori methodology, children are proposed a discussion on what they would do if they were on a desert island and had to survive on it (Duffy, Duffy 2002; Motz 2001), or a conversation referring to their everyday life, for example about the clothes in which they came to school, about the means of transport they have taken to get to school, about what they have eaten for breakfast, about the appearance of their homes, spending free time in the museum or cinema (Poussin, Roche, Hamidi 2019: 188). It makes them discover fundamental needs of all people (Fig. 1): physical ones (nutrition, clothes, shelter, defense and transport) and spiritual (art and religion).

Fig. 1. Fundamental needs of people



Source: Clarkson, Clarkson (2009: 75).

Learning history leads to discovering and finding different ways of meeting the needs of man across time and space. Across time means finding out how humans have met each fundamental need across time. Children can also examine how people satisfied their needs in a chosen period and in different cultures living at one point in history (satisfying needs in a particular place).

The following exercises (based on Motz 2001; Duffy, Duffy 2002; Poussin, Roche, Hamidi 2019—materials copied for the internal use of members of the Polish Montessori Association) can be used as an introduction into the studies on history:

(1) Our needs

Materials: a set of empty circles with a diameter of at least 10 cm, a marker, two labels: spiritual needs, physical needs.

Presentation: *Look around you. There is a great variety of beautiful things at our disposal. We are satisfied, healthy and not hungry. Think what is the most important in a person's life. Without what could we not live and perform duties? What do we need every day? What are yours and your parents' needs?*

The children give their answers, the teacher writes them down on the prepared circles. He/she tries to stimulate them to identify needs and enumerate as many as possible, arranges the circles in such a way that children can see them. He/she summarizes: *Many of the above-mentioned needs concern our body: food, shelter, clothing. I have labelled them: physical needs. The other needs concern our spirit. These are spiritual needs*.

Students can draw and cut from newspaper illustrations of goods/things needed for life and put them on the circles. Children can also arrange their needs according to the fundamental human needs chart (Fig. 1). It might be interesting for children to analyze one need, such as a shelter, from the beginning of humanity to the present day. In this way the child carries out a vertical history study across the ages and years.

(2) Vertical history study

Materials: a set of cards, a set of labels with names; sets of e.g.: sea, air, land transport, lighting methods, seats, human shelters, history of clothing, history of weapons, history of the car.

Presentation: The teacher reviews the selected set with the child and discusses the content of the pictures. The conversation is based on the questions: Which is older, which is more modern, which is simpler, which is more primitive? He/she puts the picture of the oldest object, e.g. a house or a cave on the left side of the child and that picture of a contemporary house on his/her right side. This follows the principle of working with all timelines that past is on the left and present on the right. It is possible to arrange pictures from all sets. It may turn out that there are a few captions from the BC era and a majority of them on the right.

On the other hand, if the child is particularly interested in one historical period and draws up a graph of all needs for that era, he or she will carry out horizontal historical studies. Clarkson and Clarkson (2009: 77) suggest that the next stage of studies would be left until the Fourth Great Lesson when the children are introduced to the Timeline of Civilizations. They will be informed about satisfying the Fundamental Needs in a series of major stages in the children's culture (for example Ice Age, Early Egyptian, Ancient Greek, Roman Empire, Medieval, Modern).

(3) Horizontal history study

Materials: as above.

Presentation: The teacher chooses a period, preferably contemporary to the child, and discusses how people meet their needs. In turn, he/she moves to the periods more distant for the child. An additional advantage of the exercises, apart from recognizing how the ancestors' needs were satisfied, is the possibility of realizing that after crossing a certain stage of development, civilization began to develop very quickly.

The recognition of fundamental human needs structures students' research and is a starting point for further exploration. In this way, children can learn about the cultural and civilization achievements of mankind.

Conclusion

Cosmic Education proves to be something more than the subject of education. This is vital and educational philosophy, originating from Montessori's belief concerning the human close relationship with his/her surrounding and the nature scheme based on the rule of coexistence. It is developed by the Montessorian educators towards ecological education, sustainable development and peace education. Cosmic Education aims at inspiring students, arousing interest and causing delight at the complexity of the Universe vision so that the children would like to learn independently, explore various issues of interest for them thoroughly. If children take up an action for internal reasons, this is probably because this action is important for them. Even if they forget the facts, they will not forget the joy of learning, and the developed information processing strategies will remain a learning tool. Thus, the children are given keys to knowledge and the world. These are the only reasons for which Cosmic Education can be regarded as a unique area of pupils' studies. It is uncommon that the idea of Cosmic Education came into being based on cognitive, social and emotional interpretation of children's needs and the educational curriculum of each child is a result of his/her interests stimulated by teachers' presentations and stories. The uniqueness of the presented area consists also in the fact that it gives the children the opportunity and freedom to explore, study, and develop their knowledge of the universe not only in its globality but also in its complexity (Grazzini 2013: 112). It is worth mentioning that the Montessori cosmic curriculum is focused on the process and issues of science. It emerges from the study of life, the laws and structure of the universe, the coming and evolution of life, the significant discoveries and their consequences for the development of civilization. The methodical approach addresses the pupil's attention to the sense of wonder at the splendor of the Universe, the beauty of the physical laws, the phenomenon of life, and the respect for the efforts and inventions of forefathers. Searching for other arguments in favor of original character of Cosmic Education based on Grazzini's, one can recall its specific approach to culture. "With this approach, we pass from the whole to the detail; each detail is, or could be, referred to the whole; the whole is made up of ordered parts; and lastly, specialization of knowledge and interdisciplinary character developing simultaneously, integrate and complete one another" (Grazzini 2005: 112)

Thus, the primary goal of Cosmic Education is to encourage pupils to understand science as the process through which humanity has built up its legacy. The process based on asking questions, observing systematically, collecting and analyzing data and controlled experiments. This way Cosmic Education is a preparation for lifelong education.

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Presence or Absence of Cognitive Partnership in Early School Education: Research Report

(Nie)obecność partnerstwa poznawczego w edukacji wczesnoszkolnej. Komunikat z badań

KEYWORDS

early school education, cognitive partnership, teachers' convictions

ABSTRACT

The main aim of the article is to present the results of preliminary qualitative research on the ways in which teachers of grades 1–3 of primary school understand cognitive partnership and the meanings they assign to it in their own school practice. The method of individual open-ended interview was used in the research.

On the basis of the obtained research results, it can be concluded that, in the opinion of the respondents, cognitive partnership is possible and even necessary in early school education. The teachers' declarations show that cognitive partnership is present in their educational activities, but it is impossible to fully implement it due to the cognitive developmental features of children at the early school age. The vast majority of the respondents, when explaining the discussed concept, focused in their statements primarily on the intellectual aspect of cognitive partnership, but the importance of social relations between the teacher and the student/students in the process of gaining knowledge was emphasized less frequently. When explaining the concept of cognitive partnership, the surveyed teachers most often focused unilaterally either on the teacher's actions or on the child's activities that indicate cognitive partnership. The understanding of the discussed concept as a system of relations between the subjects of education, who co-decide about the course and effects of the education process, occurred much less frequently. The obtained results are a contribution to conducting further in-depth research, especially with regard to the place and manner of implementing the idea of cognitive partnership in the practice of early school education.

SŁOWA KLUCZE

edukacja wczesnoszkolna, partnerstwo poznawcze, przekonania nauczycieli

ABSTRAKT

Jednym z kluczowych czynników warunkujących przygotowanie dziecka do wyzwań, jakie stawia przed nim dynamicznie zmieniająca się rzeczywistość, jest partnerstwo poznawcze w edukacji. Głównym celem artykułu jest przedstawienie wyników wstępnych badań jakościowych nad sposobami rozumienia partnerstwa poznawczego przez nauczycieli klas I–III szkoły podstawowej oraz znaczenia, jakie mu przypisują we własnej praktyce szkolnej. W badaniu zastosowano metodę indywidualnego wywiadu otwartego.

Na podstawie uzyskanych wyników badań można stwierdzić, że w ocenie badanych partnerstwo poznawcze jest możliwe, a nawet konieczne w edukacji wczesnoszkolnej. Z deklaracji nauczycieli wynika, że partnerstwo poznawcze jest obecne w ich działaniach edukacyjnych, lecz niemożliwe w pełni do realizacji ze względu na cechy rozwoju poznawczego dzieci w młodszym wieku szkolnym. Zdecydowana większość respondentów dokonując wyjaśnienia omawianego pojęcia skoncentrowała się w swoich wypowiedziach przede wszystkim na aspekcie intelektualnym partnerstwa poznawczego, rzadziej natomiast podkreślano znaczenie relacji społecznych między nauczycielem i uczniem/uczniami w procesie dochodzenia do wiedzy. Wyjaśniając pojęcie partnerstwa poznawczego badani nauczyciele najczęściej koncentrowali się jednostronnie albo na działaniach nauczyciela, albo na czynnościach dziecka, które wskazują na partnerstwo poznawcze. Znacznie rzadziej ujawniało się rozumienie omawianego pojęcia jako układu relacji między podmiotami kształcenia, które współdecydują o przebiegu i efektach procesu kształcenia. Uzyskane wyniki stanowią przyczynek do prowadzenia dalszych pogłębionych badań, zwłaszcza w odniesieniu do miejsca i sposobu realizacji idei partnerstwa poznawczego w praktyce edukacji wczesnoszkolnej.

Introduction

One of the basic challenges of modern education is the search for a school model whose activity is aimed at “the development of the individual as well as the community, taking into account the social and intellectual capital represented by them as the primary factors of change and civilization continuity” (Bałachowicz 2017: 16). The main challenge faced by schools today is educating an individual who is constantly learning, ready to take on new challenges, flexible, and easily adapting to changing conditions and expectations (Nowak 2007). In the context of dynamic changes in the socio-cultural reality and technological development, it is particularly important to develop students' cognitive competencies at every stage of education, which allow people to "see what is happening around them, supplement the obtained image of the world with their own experience and predict what may happen" (Obuchowski 2004: 54). Cognitive competencies, understood as "competencies needed to process and create information about oneself and the world, i.e., competencies conditioning the effects of reading, writing, counting, using symbols and using the acquired knowledge in cognitive and social functioning" (Uszyńska-Jarmoc 2018), along with creative competencies, play a key role in education. They engage mental activities in the process of getting to know reality through more or less effective action in it. Thanks to this, the individual not only gets to know the world, gives it meaning, but gradually builds his understanding, which facilitates his effective adaptation. Direct interactions with the outside world are both the source and the means of learning about it (Michalak 2011). Developing cognitive competencies prepares people not only to use the achievements of modern civilization but also to creatively participate in the process of its development. In this context, Tadeusz Lewowicki (1994) has been for many years postulating a change in the model of contemporary school, manifesting itself in the transition from adaptive and reproductive education to critical and creative education, stimulating innovation, creativity and changes in the surrounding world. The perspective that completes the vision of the task of education defined in this way is the development of current trends, needs and potentials in people who create it in a school where partnership is the basic value.

The extremely complex and multifaceted category of partnership fits permanently into the area of theoretical considerations and research aimed at searching for a school model tailored to the education of tomorrow. This article attempts to present the beliefs of early school education teachers about the importance and place of cognitive partnership in relations with children in their educational practice. The research concept has been embedded in an approach referring to emancipatory rationality and constructivism creators who present the vision of the child as a fully-fledged participant in educational processes, organizing and interpreting the incoming information and reorganizing the existing knowledge with the participation of adults and peers, able to discuss, express their own views, present their own projects and striving for change (Klus-Stańska 2009a). Due to the nature of the study, the article presents a fragment of preliminary qualitative research[1] on the presence of cognitive partnership in early school education.

[1] The research was carried out as part of an individual research project titled "Child as a Student in the Common Beliefs of Teachers," carried out in the 2019/2020 academic year and currently continued at the Institute of Pedagogy of the University of Bielsko-Biala.

Cognitive Partnership in the Teacher-Child Relationship

According to a dictionary (Doroszewski 2000), the essence of partnership is the equal treatment of each other by people whose relationship is based on the principle of voluntary character, and whose goal is to run an enterprise and share its profits or losses. Partnership means equal rights and obligations, mutual respect, which obliges to learn and understand the so-called other party (Kocór 2018). Partnership understood as a social responsibility tool is a process that guarantees: voluntary participation of partners from various sectors, joint active action, social goals, investing resources, taking risks and benefits, and long-term cooperation (Ordon, Gębora 2017: 58). In addition to the above-mentioned features of partnership relations, such as reciprocity, cooperation, awareness of rights and obligations or respect, the concept of partnership occurs in the context of such terms as: dialogue, cooperation, trust, help, commitment, but also autonomy, subjectivity and responsibility. In relation to education, the discussed concept is most often understood as an upbringing partnership, a type of specific relations between three subjects: a student, a teacher and parents, who are linked by a common goal accepted by three parties, a positive emotional attitude towards each other, mutual respect, cooperation and co-responsibility (Milerski, Śliwerski 2000). In this perspective, school partnership mainly means cooperation and self-management of teachers, students and parents, and includes co-management of the education process.

In the field of education, partnership is most often analyzed in the social aspect, and much less often in the cognitive aspect. According to Dorota Klus-Stańska, cognitive partnership is based "on the symmetry of the statuses of meanings given to reality. The student's knowledge is considered worth considering and deliberating, which results from the social nature of all knowledge. Giving a sense of reality, the content of education is perceived horizontally (revealing a multitude of meanings and arguments), and not vertically (as definitely correct and incorrect)" (Klus-Stańska 2019: 17). In this sense, the basic indicator of cognitive partnership in the teacher-student relationship is the acceptance and respect for the child's personal knowledge. In addition to the intellectual aspect, the essence of which is expressed in the dynamic relationship between personal and public knowledge, cognitive partnership also consists in building a space for communication (social aspect) and includes a personally dialogical perspective (ethical aspect) (Klus-Stańska 2019).

The basic condition for the implementation of the idea of cognitive partnership in the practice of early childhood education is to adopt the vision of the children and their learning potential in line with the assumptions of cognitive and social constructivism, in the light of which children have their own rich world of meanings and have the competencies to be active participants in the learning process, exchange of meanings, interpreting the world, oneself, others and the surrounding reality (Nowak-Łojewska 2017). Similarly, in the contemporary sociological approach to the category of childhood by William A. Corsaro (2015), the children are perceived as the active subjects simultaneously participating in the world of adults and peers with whom they negotiate, share and create culture. At the beginning of school, the child is ready for active, not passive learning. Child learning understood in this way also plays a key role in the theory of socio-cultural development by Katherine Nelson (2007). According to the American developmental psychologist, in the classroom, thanks to the externalization process, "students' minds" become elements of the outside world that can be shared by students and teachers. The child develops not only in the context of social interactions but also through these interactions.

Treating a child from the very beginning as a subject with a mind, encouraging independence, and describing the child's mental states are all important for the child's development, understanding other people and communication (Pikul-Białecka 2012). Establishing a partner relationship cognitively with a child is associated with taking into account their individual resources. Among them, the following are distinguished (Filipiak 2008: 23):

a) child's own activity,
b) susceptibility and resilience to react in a certain way to the teacher's instructions and guidance,
c) being amenable to learning (cognitive modifiability),
d) child's current developmental status, including "tacit knowledge" and the child's previous experiences and perceptions,
e) contents of the "toolbox" and the ability to use tools in action,
f) properties of the child's attention, the ability to pay attention, focus on the problem,
g) ability to follow the directions of Others.

The child's individual resources and the current developmental status imply the course of the relationship between the teacher and the student. Cognitive partnership is, first of all, a kind of relationship that enables the creation of opportunities for learning and the inclusion in the process of education of a child's cognitive space understood as "a zone where everything that is new and surprising inspires thinking and discovering. It cannot be limited by frameworks or ready-made solutions that inhibit the natural desire for independence" (Robinson, Aronica 2012: 74). The cognitive development of the student and his/her social competencies is primarily favored by situations in which the following conditions are met:

1. the condition of diversity: creating a richness of diverse social situations in the classroom, constituting the basis for various experiences of students,

2. the condition of conformity: conformity of the information contained in the transfer with the reality outside school,
3. the condition of dialogue: the teacher's opening to out-of-school experiences of students and their relations on this subject (Klus-Stańska 2009b: 17).

Learning based on cognitive partnership is deeply personalized, i.e., the learning environment is highly sensitive to individual and group differences related to the background and experiences of students, to previously acquired knowledge, to their motivation and abilities, and provides them with personalized feedback (Dumont, Istance, Benavides 2013). For the process of acquiring and developing cognitive competencies, it is important for the teacher to organize educational situations stimulating the student to undertake various forms of activity that bring richness of experiences.

Research Procedure

One of the main factors determining the teachers' approach to the issue of cognitive partnership in education is the way it is understood and teachers' convictions about its implementation in early school practice. Convictions are commonly referred to as all "mental" premises about the world that the subject feels as real (Lemańska-Lewandowska 2013: 15). In dictionary terms, conviction is defined as "a judgment, an opinion based on the belief that something is true or false, an established view of something; belief, view-point" (Szymczak 1979: 979). According to Magdalena Grochowalska (2012), building convictions is a process in which an individual aims to recreate hypotheses and theories that already function socially, and their formulation in practice determines the subjective interpretation of educational reality. Conviction research allows to describe the content that teachers attribute to reality in the education layer, in this case, cognitive partnership in early school education.

In order to determine the understanding and meaning which teachers assign to cognitive partnership in early school education, qualitative research was carried out using the individual open-ended interview method. Due to the adoption of the interpretative paradigm of qualitative research the research was aimed at showing different ways of thinking of early school education teachers about the essence and features of cognitive partnership and the methods they declare to implement in their work with children in grades 1–3 of primary school. For Neuman, "the most important thing in an interpretative approach is the systematic analysis of social meanings created by people in their natural conditions of functioning, with a view to understanding and interpreting how people create and understand their world in which they function" (Neuman 1994: 62). In an interpretative approach, words are data from the research on which the researcher's attention is focused. It is thanks to the respondents' statements, their narratives or written texts that it is possible to gain insight into the meanings given by informants to the events in which they participate (Zwiernik 2015).

In the course of the research, answers were sought to research problems formulated in the form of questions:

1. In the opinion of teachers, what is the meaning of cognitive partnership in early childhood education?
2. What importance do teachers assign to cognitive partnership in their work in grades 1–3 of primary school?

According to the position expressed by Earl Babbie, the method of the used individual open-ended interview "is an interaction between the interviewer and the respondent. The facilitator has a general plan of action in it, but it is not a specific set of questions that should be asked in specific words and in order" (Babbie 2008: 342). The questions addressed to the respondents were open-ended. Some of them were basic questions, directly oriented towards undertaken description and conceptualization of experiencing phenomenon of cognitive partnership by the interviewee. Among them, there are questions such as: What is a cognitive partnership in education for you? How do you understand the cognitive partnership in relations with a child? Under what conditions and situations is cognitive partnership manifested in early childhood education? The remaining questions were formulated in the course of the interview and were aimed at making it easier for the respondents to thematize their experiences.

The research covered 23 teachers of early school education working in schools in the Silesia and Małopolska Provinces. They were conducted directly by the researcher between November 2019 and February 2020. Only women were among the respondents. As far as the work experience of the respondents is concerned, 8 teachers (34.78%) have worked at school for no more than 10 years, the work experience of 10 people (43.48%) was between 11 and 20 years, and the remaining 5 teachers (21.74%) worked in the school for over 20 years.

As a result, the interview allowed to capture what the respondents think about reality, and not what the researcher thinks about it, only looking for confirmation of her own thesis. According to the adopted research approach, the ways of understanding the studied phenomenon expressed in the analyzed material implied categories of description determined by the researcher. They are "generalized and structured descriptions of understanding the phenomena present in the respondents' experience" (Męczkowska 2002: 18). The categories of description are selected through the condensation of topics that appear while reading the answers of the respondents. Established description categories, on the other hand, constitute the result space and then may or may not be subject to hierarchy, resulting in a structure of the description category. It should be emphasized that the discussed categories of description are always individual and collective at the same time, which means that the same statement may reflect various expressions of the same concept or different concepts (Jurgiel 2009).

Research Results

According to the adopted qualitative research procedure, the presentation of the results, for the purposes of this study, has been limited to the presentation of the categories of responses identified as a result of the analysis of the content of the respondents' statements in the interview, with the dominant tendencies in their selection marked. Due to the adoption of the interpretative paradigm of qualitative research, the research did not aim at considering the studied phenomenon in terms of quantity and multiplicity, which is characteristic of the quantitative approach, but at extracting the meanings and dimensions of cognitive partnership in early childhood education. The analysis of empirical material obtained as a result of research conducted on small groups of people is qualitative in nature and does not involve statistical tools. Nevertheless, the possibilities of using quantitative terms in qualitative and explanatory projects are indicated. David Silverman justifies it as follows: "Simple computational techniques can become a way of probing an entire set of data that is usually lost in intensive qualitative research" (Silverman 2008: 62).

The analysis of the content of the statements showed that all respondents emphasized the importance of cognitive partnership in early school education. In the opinion of the respondents, cognitive partnership is possible and even necessary at the discussed stage of education. The justifications for the opinions formulated by the surveyed teachers referred to the following categories of responses:

a) the need to treat the child as the subject,
b) changing the school to the one open to the needs and capabilities of children,
c) the need to trigger activity and meet the needs of the child,
d) introducing children from an early age to independence and responsibility for the learning process.

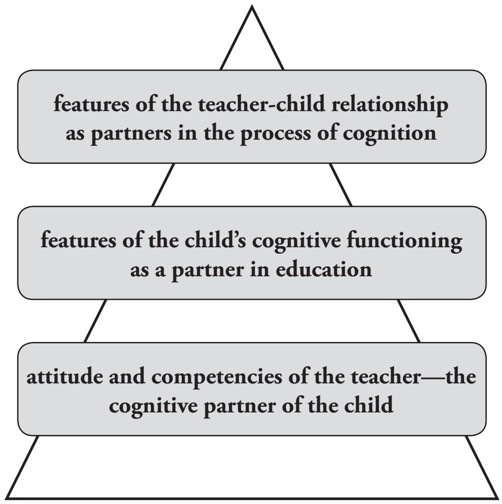
All the above-mentioned categories, based on the analysis of the answers, may prove that teachers are familiar with contemporary trends in early school education focused on the humanistic paradigm in the education of a young child, and in the case of less than half of the respondents, additionally with the importance of preparing a child for lifelong education.

All respondents declared that their functioning in the area of early school education is marked by cognitive partnership, although many statements (16 respondents) raised reservations that due to the features of development and the level of cognitive maturity, full cognitive partnership of children is impossible to implement in practice.

An example of an expression: *What the child thinks and knows about the topic is important, but we should also remember that we work with children. Their knowledge concerns those things and phenomena that they are able to know because of their cognitive abilities*. In this context, the analysis of the content of the interviews leads to the conclusion that the consciousness of most of the respondents is dominated by the traditional psychological approach to the child development, expressed, inter alia, in assigning capabilities to learn and understand the world "limited by the developmental phase" and linear increase in knowledge to a child at the early school age.

The vast majority of respondents (19 interviewees), while explaining the discussed concept, focused in their statements primarily on the intellectual aspect of cognitive partnership, and less often (10 respondents) additionally on social relations between the teacher and the student in the learning process. Three basic groups of factors determining the cognitive partnership in work with a child at early school age, appearing in the respondents' statements, were distinguished. The division made is not separable and elements of statements belonging to particular groups of factors often coexisted in the interviews. The teachers' statements contained content elements related to several areas (Diagram 1).

Diagram 1. Groups of factors determining cognitive partnership in early school education as assessed by teachers



Source: Author's own elaboration.

In their statements, all respondents pointed to the teacher's attitude and competencies, which determine the creation of space for children treated as partners in the educational process.

Table 1. Response categories defining the concept of cognitive partnership in relation to the teacher's attitude and competencies during the classes

	Response categories	**Number of indications**
Attitude and tasks of the teacher—the child's cognitive partner	providing support to the child according to his/her cognitive needs in the learning process	22
	creating situations conducive to triggering various forms of child's activity	21
	the ability to match control to the child's level of development and the action taken	20
	creating a friendly, safe learning atmosphere	19
	the teacher's readiness to develop the child's cognitive interests	18
	the teacher's faith in the child's abilities and motivating him/her to learn	16
	accepting knowledge gaps and understanding the child's difficulties in understanding things	11
	taking into account the topics and problems reported by children in the classroom	11
	respect and trust in the child's personal knowledge	8
	posing open-ended questions during classes	7

Source: Author's own elaboration based on the results of the research.

The respondents' statements show that the presence and quality of cognitive partnership during classes in grades 1–3 of primary school is primarily influenced by the teacher's competencies and attitude towards the child. The most numerous group of responses in their statements referred to the personalization of the educational process in terms of diagnosing the needs of children's cognitive abilities and interests, as well as adjusting the methods and level of control individually to the child's needs by the teacher. An example of an expression: *If you approach the children individually and understand their needs, then they open up and speak willingly. You can then find out what they know about the topic, what they think about it and what they feel.* In the opinion of less than half of the respondents, cognitive partnership is expressed as the teacher's understanding of the problems in a child's learning and shaping a positive attitude towards learning. They attach an important role to building a child's positive self-esteem in the learning process. They recognize that a child's school success results not only from actual competencies, but also from a sense of their own competencies. In this context, it is worth emphasizing that the conducted research shows that the children's faith in themselves, their abilities, capabilities and skills have a positive effect on the results of intellectual or social functioning (Uszyńska-Jarmoc 2007). Most of the respondents emphasized the importance of the ability to create an appropriate atmosphere in the learning process and to create didactic situations comprehensively involving children, containing elements of novelty and interest.

In their statements, the surveyed teachers also indicated the features of the child's cognitive functioning, which, in their opinion, prove cognitive partnership in early childhood education.

Table 2. Response categories defining the concept of cognitive partnership in relation to the child's functioning during classes

	Response categories	**Number of indications**
Features of a child's cognitive functioning	child's independence in action during classes	23
	cognitive openness, motivation to acquire new knowledge	20
	child's questioning activity	16
	submitting new ideas by a child	15
	independence in work planning	12

Source: Author's own elaboration based on the results of the research.

According to all respondents, the essence of cognitive partnership is expressed in the child's activity and independence during classes. The respondents emphasized in their statements that the child is not a passive observer of reality and the recipient of the teacher's messages, but is a dynamically developing person in social contacts. The functioning of a child as a partner in the educational process is characterized primarily by a readiness to acquire knowledge and a cognitive attitude, which manifests itself in asking numerous questions regarding the issues discussed in the classroom. An example of an expression: *A child who is a partner in the cognition process is active, independent, and asks a lot of questions.* The children—treated as cognitive partner in the education process—have the opportunity to express their own understanding of the world and reveal the rich interior of experiences and thoughts. According to the respondents, cognitive partnership manifests itself in the child's independence in planning and carrying out tasks as well as creating and reporting solutions to problems. Then the child has a sense of agency and independent learning.

The least frequent statements of the respondents (14 interviewees) at the same time contained descriptions of mutual relations between the teacher and the child based on cognitive partnership.

Table 3. Response categories defining the concept of cognitive partnership as teacher-child relationship

	Response categories	**Number of indications**
Features of the teacher-child relationship	dialogue with children	15
	friendly mutual relations based on respect for autonomy, freedom of action and a sense of security	15
	joint problem solving with the child	12
	child's participation in the selection of methods and forms of learning and the assessment of learning outcomes	10
	discovering and constructing knowledge together	7

Source: Author's own elaboration based on the results of the research.

In a manner similar to the way the concept is defined in theoretical studies, the discussed group of respondents explained the concept of cognitive partnership using terms such as: relationship, relation or arrangement of relations between the teacher and children based on the sense of understanding and support from the interaction partner. According to the respondents, partnership in education is to ensure respect for one's own autonomy and freedom of action, as well as a sense of acceptance and security. The concept of cognitive partnership outlined in the statements by the teachers corresponds to the vision of the teacher-student relationship in line with the sociocultural concept, in the light of which the teacher becomes a partner in the child's development, "supports, structures, organizes, expands knowledge, enriches the child's efforts, knowledge and experiences in the field of specific competencies" (Filipiak 2008: 22) and adjusts the level of support to the current level of the child's activity. As Anna Brzezińska writes, "for this to be possible in the relationship between the teacher and the students, four elements must be in balance: the teacher's competencies, students' competencies, the requirements of the nature of challenges appropriate to both, and appropriate to the challenges as well as varied forms of support and assistance. Only then the system of mutual—unilateral, bilateral or multilateral—relations between the teacher and students and between the students themselves creates a truly stimulating social environment for both parties to develop" (Brzezińska 2008: 48). In the statements of the respondents (9 interviewees), it was difficult to find references to the teachers' creation of conditions for the development of a learning mechanism based on processes of mutual interaction, consisting in the exchange of meanings between interaction partners, i.e., the teacher and the student, and especially between the students themselves.

Conclusion

Cognitive partnership understood as "the equality of intellectual strategies, valuations and interpretations" (Klus-Stańska 2008: 69) of educational entities is one of the key factors determining the preparation of a child to the challenges posed by dynamically changing reality. Based on the conducted research, it can be concluded that when explaining the concept of cognitive partnership, the surveyed teachers most often focused unilaterally either on the teacher's activities or on the child's activities that indicate cognitive partnership. In the teacher's understanding of cognitive partnership in education, one can clearly see a tendency to emphasize the role and competencies of the teacher, whose task is primarily to personalize the education process and create conditions for building an educational space marked by a child's sense of security and enabling the child's activity and independence. In turn, in the case of children, the main manifestation of cognitive partnership is their behavior characterized by a high level of activity in classes, independent thinking and a high level of cognitive attitude. Much less frequently, the respondents' statements revealed the understanding of the concept in question as a relationship between two equal subjects of education, who co-decide about the course and effects of the education process. Few of the respondents indicated the key role of dialogue in the teacher-student relationship. A partner adult—in the opinion of only a few respondents—participates in the process of constructing knowledge by a child, does not impose meanings. Worryingly, only a few respondents emphasized the importance of creating conditions for peer social interactions that can form the basis of negotiating meanings.

There is no doubt that the key role in understanding the essence of cognitive partnership by early childhood education teachers is played by the way they think about the mind and cognitive abilities of children. What is important in this process is the departure from the way of perceiving the student's mind as learning by imitation or as learning as a result of exposure to didactic activities and acquiring declarative knowledge in favor of perceiving a child who, like an adult, has more or less coherent "theories" not only about the world, but also about their own mind and how it works (Bruner 2006: 82–89).

The fragmentary results of the presented research on the understanding of cognitive partnership and the declared place of it in early school education may be an inspiration to conduct further in-depth research on its meaning and forms of implementation in school practice.

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Creativity and Parental Involvement in Early Childhood Education in the Reggio Emilia Approach and Philosophy

Kreatywność i zaangażowanie rodziców we wczesną edukację dzieci w podejściu i filozofii Reggio Emilia

KEYWORDS

children, creativity, parents' involvement in education, preschool education, Reggio Emilia educational philosophy

ABSTRACT

In the article the authors discuss the importance of parental creativity and involvement in early institutional education of a child on the example of Reggio Emilia educational method. Among the main aspects of this involvement are the quality of education, child support, cooperation between teachers and parents as well as a positive feedback. The authors of this paper also deal with one of the main aspects of early education—creativity and its importance for a child's psychosocial development. The preschool curriculum has been designed for children of the preschool educational institutions to provide them with a rich learning experience and to help them to develop properly. Creative education starts at an early age, therefore kindergartens and families play a very important role in supporting and developing creativity in child's everyday routine. It is stressed that being creative is primarily about taking initiatives and innovative behavior. These are the qualities required in contemporary society, especially by employers in private and public sectors. However, the process of involving parents in their child's education starts at the preschool stage and plays the most important role in child's socialization. It is also emphasized that if children feel the support of both educational subjects (teacher and parents) in the process of preschool education, they feel safer, more comfortable, and much more confident.

SŁOWA KLUCZE

dzieci, kreatywność, zaangażowanie rodziców w edukację, wczesna edukacja, filozofia edukacyjna Reggio Emilia

ABSTRAKT

W niniejszym artykule autorzy omawiają znaczenie kreatywności oraz zaangażowania rodziców we wczesną edukację instytucjonalną dziecka na przykładzie metody Reggio Emilia. Głównymi aspektami takiego zaangażowania są zapewnienie jakości edukacji, wsparcie dziecka, współpraca nauczycieli z rodzicami oraz pozytywna informacja zwrotna. Autorzy tego artykułu zajmują się również jednym z głównych aspektów wczesnej edukacji dziecka – kreatywnością i jej znaczeniem dla rozwoju psychospołecznego dziecka. Program nauczania przedszkolnego został opracowany dla dzieci w placówkach edukacji przedszkolnej, aby zapewnić im bogate doświadczenie edukacyjne i pomóc we właściwym rozwoju. Edukacja kreatywna rozpoczyna się od najmłodszych lat, dlatego przedszkola i rodziny odgrywają bardzo istotną rolę we wspieraniu i rozwijaniu kreatywności w codziennych sytuacjach rozwojowych dzieci. Podkreśla się, że bycie kreatywnym polega przede wszystkim na podejmowaniu inicjatyw i innowacyjnych zachowań. Są to cechy wymagane we współczesnym społeczeństwie, zwłaszcza przez pracodawców w sektorze prywatnym i publicznym. Jednak proces angażowania rodziców w edukację dziecka zaczyna się już na etapie przedszkolnym i odgrywa najważniejszą rolę także w socjalizacji dziecka. Podkreśla się również, że jeśli dzieci czują wsparcie obu podmiotów wychowania (nauczyciela i rodziców) w procesie wychowania przedszkolnego, czują się bezpieczniej, bardziej komfortowo i dużo pewniej.

Introduction

Many scholars and practitioners would stress the fact that up to 65 percent of children currently in grade school will one day work in a job that does not yet exist. By this we mean that in order to prepare kids for these jobs, children need to be creative, adaptable problem-solvers, ready for anything in the near future to come (Davidson 2011). According to Loris Malaguzzi (1998), famous Italian educationalist and pedagogue, who originated and developed Reggio Emilia method, every child has a hundred ways (i.e. languages and hands) to express him/herself and these ways may appear very different and unique. Thus, one of the main principles of this learning philosophy says that children get to know the world and close surroundings through their senses: touching, seeing, smelling, hearing, tasting and acting as an independent explorer. Therefore, the child stays in the very center of education and all the other supportive factors (i.e. community, environment as the third pedagogue, teachers, family, arts & craft, project activities, children experiences, philosophy, light-color-action, children's work documentation, etc.) serve as the assisting measures in order to assure the quality of learning and two-way communication as well as collaboration between family and teaching staff (Malaguzzi 1998; Markevičienė 2010, 2012; Cadwell 1997; Gandini, Etheredge, Hill 2008; Lindsay 2015).

Creativity as such is mainly identified through the following elements: creative person (we usually accept it as the aftermath of other external and internal factors that lead to being creative), creative result (it has to be: smart, simple, well crafted, familiar, shareable, resonant, original, flexible, challenging), and creative process (this part remains most significant one as it consists of many different variables, such as: action, creative thinking skills, knowledge, motivation, personality, lateral thinking, divergent thinking, environment, etc.). Moreover, excellent ways of developing children's creativity with the participation of parents can be found, among others, in the publication by Teresa Amabile (1989). Putting all this into other words, we do not learn from experience, but we do learn by reflecting on our experience.

Having in mind parents' engagement in child's early education and collaboration activities between family and educational institution, a few very significant features should be revealed. First, parents are children's first and most enduring educators (according to the UNICEF,[1] being engaged in child's education is even both fundamental right and obligation of adults). Then it is worth to have in mind that parents and what they do have a powerful effect on children's learning (their attitudes, values, actions at home are equal to what the child will get and become in the near future). Also, when families and educational institutions work along, they undoubtedly benefit the child as both sides become equally responsible for the education and child's psychosocial development. Another rather important aspect of involving parents into children's early education is enhancing quality in early childhood education and care (hereinafter ECEC). This mainly means that engaging families in children's education remains one of the main five policy levels (accordingly to OECD[2]). Finally, through being involved into ECEC, parents get a positive support/assistance from the kindergartens as well, as they are taught, advised, guided, and mentored by the professionals. All this leads towards

[1] See more at: http://www.unicef.org/.

[2] For more see: http://www.oecd.org/.

lifelong learning activities consequently developing a positive parenthood idea and its implementation in real life contexts.

Thus, the main goal of this paper is to describe and discuss the meaning of creativity and the collaboration between families and educational institutions in early child education processes.

The methods of this research encompass the interpretation and analysis of scientific, educational, and philosophical literature.

Creativity in Early Child's Education

As Sir Kenneth Robinson (2014) would point out, creativity is as important now in education as literacy and we should grant it the same status. By saying this, the fact of child's unmeasurable abilities is indicated. Thus, within Reggio Emilia philosophy (see more Santín, Torruella 2017: 50–56), every child is perceived as:

- having unlimited potential,
- wager to interact with and contribute to the world,
- driven by curiosity and imagination,
- delighted in taking responsibility for his or her own learning,
- able to listen and listened to,
- having an enormous need to love and to be loved,
- valued.

Another important variable for creativity education is e n v i r o n m e n t, which has a significant place in Reggio Emilia philosophy and educational practice, as the e nvironment is seen as the third most important teacher. For creative activities on the educational light table children use sand, paper, glass stones, leaves, transparencies, etc. Projectors and light tables encourage exploring light penetration. Mirrors allow children to see themselves and their creations from all sides.

Therefore, it is worth to point out that playing with all the above-mentioned instruments creates rather a magical experience for children and adults alike. Besides the light, soft boxes (puzzles) and other measures undoubtedly serve for developing:

- social skills,
- language competence,
- cognitive competences,
- self-expression.

Even Jean Piaget found out that 3–4 hours per day of learning and playing on the light table increases the IQ of children, their innovative memory, and creative potential (Shaffer, Squire Halverson, Gee 2005; Dere 2019; cf. also: Babakr, Mohamedamin, Kakamad 2019: 517–524). In such creative activities not only children or pedagogues are involved in education, experiments or inventions, but also parents get the possibility to know closer their children's achievements, communicate and share ideas of education and child's upbringing with others, also get the feedback from the creative results about things where the child is strong and something about what still needs to be developed or requires more attention (Malaguzzi 1998; Markevičienė 2012). Putting it in other words, through education and creative processes the kindergarten community together with families creates safe and open environment for children's positive socialization. An educational institution becomes a place of creativity, learning, development, and sharing for all.

Yet, on the other hand, Stanisław Popek (2016) points out in his works on modeling creativity and psychological interactions that social reality nowadays is characterized by rapid scientific and technical progress, the disappearance of simple activities in favor of mentally and practically complex activities, which entails the need for creative people. Under these conditions, it is necessary to change educational strategies at all levels of education (Popek 2016). Therefore, his works outline the theoretical model of human personality, in particular special and creative abilities and talents in a systemic, holistic and interactive approach. It is also a model that takes into account individual differences of the human *psyche*, which makes the structure of these abilities and talents varied, and at the same time it is far from the traditional scheme based on the theory of intelligence (Popek 2016). The outlined model of the *psyche* shows the necessity of rebuilding the didactic system, i.e. departing from the strategies of providing and reproducing knowledge (i.e., the traditional school system) in favor of polymethodic strategies (i.e., the modern school system based on the interaction of individual differences).

Summing up: in developing the competence of creativity involvement in the processes of artistic self-expression has a long-term impact on the abilities of a child to understand, observe, and listen. Creativity is a fundamental key element for the preschool curriculum and can be defined as a procedure of creating original things. Both preschool teachers and parents (caregivers) should provide children with materials to trigger their imagination, should provide opportunities to imagine and to explain their ideas, should appreciate children's individuality, and should encourage their different viewpoints (Dere 2019; Popek 2016). I m a g i n a t i o n plays a key role in the child's search for knowledge and understanding, which in early child's education processes is more important than the results (though results are more wanted by parents and regulators, in some cases by teachers).

Creativity and Parents' Involvement in Early Education

As stated previously in this paper, the engagement of parents into ECEC bears many fruitful outcomes. Therefore, we briefly describe and present the importance of such collaboration.

Parents are children's first and most enduring educators. This statement gives an idea and reminds all of us that family is the first child's socialization institution and that children from the very beginning learn more, create more, care more, and experience more than we could ever have imagined (Przybysz-Zaremba, Kołodziejski 2018: 17–30; Kołodziejski 2010: 193–207). To put it in other words, children with the active support of their parents become constructive explorers rather than being just copying individuals. This fact also has some implications for the future, as if we raise creative and free personalities from their early childhood days then we are supposed to have more smarter, richer, happier, and—finally—fewer neurotic adults (quoted from: *Quality Education for All* 2004; Lindsay 2015; Popek 2016). It is worth to state that in recent decades this fact has been "frequently accompanied with recommendations firstly, about the need to support parents in their parenting activities, including their role in supporting their children's learning and development. A second focus in policy recommendations concerns strengthening the relationship between the home and the ECEC setting and schooling order to enhance children's learning and development. In fact, throughout the international field of ECEC, good communication and co-ordinated partnership between parents and staff is seen as essential to high-quality care and education of young children" (Kernan 2012: 12–13).

Another axiomatic approach towards parents' and institution's collaboration is that parents and what they do have a powerful effect on children's learning. Based on social learning theory, children mainly learn and get to know their closest environment by watching and observing what parents (or other close people) do. Thus, it is quite important for adults to bear in mind that the way they act, speak, behave—all of that—has an undoubted effect on children's further attitudes towards themselves and the others. The way kids identify themselves and find a place in particular sociocultural contexts depends on the style they were taught and what they have observed at previous stages of life.

The next meaningful consequence of being engaged in ECEC processes would be the statement that when families and educational institutions work along, they undoubtedly benefit the child. In this situation children gain an understanding that the things they do in life are both important for the family members and educational institutions where they spend almost a half of their time while learning and playing. The child gets an understanding that family and educational institutions/kindergartens are closely related and cannot not be seen as separate phenomena. While, on the other hand, "the notion of equal or coordinated partnership is emphasized, with each party recognizing and valuing the contribution of the other to children's wellbeing. Within such a vision, parents and practitioners are both viewed as experts: parents as experts on their own children and practitioners as experts in caring and educating children in the context of institution or group setting. Respectful sharing of information between parents and practitioners about children's learning and development at home and at school is viewed as being in children's best interests" (Kernan 2012: 12).

We should also not forget quite a significant fact that through such collaboration we are all heading towards enhancing quality in early childhood education and care. One of the essential goals remains shaping the concept of quality education which is "backed by social partners (especially parents), easy for the society to comprehend, and effective" (*Quality Education for All* 2004: 26–27). Many scholars state that both quality of education and parents' sensitivity to all those things that happen with their children have a significant impact on child's positive development and further socialization processes as well as assure the realization of quality measures within education, especially in ECEC (*Quality Education for All* 2004: 26–27).

Yet, last but not least outcome of collaboration is this that parents get a positive support/assistance from the kindergartens. This mainly means that being positively engaged in educational processes leads towards parents' support provided by professionals and practitioners. According to Margaret Kernan (2012), it is recognized internationally that ECEC has an important function in providing parents and caretakers with educational and social support in meeting their responsibilities in bringing up their children. ECEC can also contribute to engaging parents with related measures to improve employment, job-related training, parent education and leisure time activities.

Some other rather problematic aspects of parents' collaboration with kindergartens must be pointed out. Margaret Kernan (2012), Gai Lindsay (2015) and other scholars in the field (*Quality Education for All* 2004: 26–27) have stressed that:

- First, parents do not mean only mothers. However, children, mothers and fathers, and practitioners all have a role to play in early learning.
- Usually, parents' and practitioners' cooperation collapse because of several common misunderstandings:
  - lack of confidence,
  - different understandings and expectations,
  - different views,
  - teachers' preparation suffers the lack of attention to some specific subjects to be taught at colleges and universities.

Closing Thoughts

The Reggio Emilia educational philosophy is an innovative and inspiring approach to early childhood education, which values the child as strong, capable and resilient; rich with wonder and knowledge. This philosophy emphasizes the innate curiosity of children and aims to assist them with understanding their world and who they are in it. The Reggio Emilia approach starts from the premise that children use many different ways to express their creativity, understanding and thoughts (i.e., the 100 languages). This perspective has been endorsed by many artists, who state that these different ways of thinking, exploring and learning are expressed through drawing, sculpting, music, dance and movement, painting and drama (*The Scots Journey* 2017[3]). Thus, creativity remains one of the main features within Reggio Emilia philosophical approach and practical actions.

In children, creativity develops from their experiences with the process, rather than concern for the finished product. Thus, creativity should stand on the one line with literacy. Children get to know the world and close surroundings through their senses: touching, seeing, smelling, hearing, tasting, and acting as an independent explorer.

Creativity is identified through the following elements: creative person, creative result, and creative process. Based on Reggio Emilia philosophy, every child is perceived as: having unlimited potential, eager to interact with and contribute to the world, driven by curiosity and imagination, delighted in taking responsibility for his or her own learning, able to listen and listened to, having an enormous need to love and to be loved, and valued. A rather important variable for creativity education is environment, which has a significant place in Reggio Emilia ideology and educational practice, as the environment is seen as the third most important teacher. Instruments and tools (light tables, projectors, mirrors, soft boxes/puzzles), used in educational activities, allow children to free their imagination and creativity, and thus play quite an important role in developing the creative personality.

Working not only with children in kindergartens but also supporting parents and cooperating with them matters most. Children's education is understood as a supportive measure for the positive parenting and thus even must be taken into legislation practice locally, regionally, and nationally. Cooperation with parents strengthens the development of main competence of children and prevents them from developing anti-social and violent behavior.

[3] The brochure *The Scots Journey* can be downloaded from: https://www.tsc.nsw.edu.au/what-is-the-reggio-emilia-philosophy/.

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Students of Teacher Training Programs and Their Views on STEM: A Focus Interview

Studenci kierunków nauczycielskich i ich opinie na temat STEM – wywiad fokusowy

KEYWORDS

STEM, education, preschool, pedagogy students, kitchen as a laboratory, KLab4Kids

ABSTRACT

This paper presents the outcomes of a pilot study conducted with a group of students pursuing teacher training programs as part of the international research project called "Kitchen Lab for Kids" delivered under the "Erasmus+; Key Action 2" scheme. The aim of the research was to find out about students' opinions on STEM education, including the determination of the level of their knowledge about this trend. In this context, particular attention was paid to issues related to the goals of STEM education, problems and challenges that they may generate, as well as the needs (organizational conditions) necessary to implement this type of activity. The respondents also had the opportunity to present their own experiences in organizing and conducting STEM classes. The research was carried out with the use of the qualitative methods, where the basic research method

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was focus interview. The research group consisted of 8 students of teaching faculties, mainly pre-school and early school education. The selection of research units was purposeful. The conducted qualitative analysis of the material collected during the focus interview showed that STEM education is still a novelty among students of teaching faculties. Future teachers have little experience in the implementation of activities taking into account the STEM model, but it should be expected that the coming years will result in a number of changes and activities in this area.

SŁOWA KLUCZE

STEM, edukacja, przedszkole, studenci pedagogiki, kuchnia jako laboratorium, KLab4Kids

ABSTRAKT

Niniejszy artykuł prezentuje wyniki badań pilotażowych przeprowadzonych ze studentami kierunków nauczycielskich w ramach międzynarodowego projektu badawczego „Kitchen Lab for Kids", realizowanego w ramach programu „Erasmus+; Key Action 2". Celem prowadzonych badań było poznanie opinii studentów na temat edukacji STEM, w tym także określenie poziomu ich wiedzy dotyczącej tego nurtu. W tym kontekście zwrócono szczególną uwagę na zagadnienia odnoszące się do celów edukacji STEM, problemów i wyzwań, jakie mogą generować, a także potrzeb (warunków organizacyjnych) niezbędnych do realizacji tego typu aktywności. Osoby badane miały również możliwość przedstawienia własnych doświadczeń w zakresie organizowania i prowadzenia STEM-owych zajęć. Badania prowadzone były w nurcie jakościowym, w którym podstawową metodą badawczą był wywiad fokusowy. Grupę badawczą stanowiło 8 studentów kierunków nauczycielskich, głównie pedagogiki przedszkolnej i edukacji wczesnoszkolnej. Dobór jednostek do badań był celowy. Przeprowadzona analiza jakościowa materiału zebranego podczas wywiadu fokusowego wskazała, że edukacja STEM to wciąż nowość wśród studentów kierunków nauczycielskich. Przyszli nauczyciele posiadają niewielkie doświadczenie w zakresie realizacji zajęć uwzględniających model STEM, ale należy się spodziewać, że najbliższe lata zaowocują szeregiem zmian i działań w tym zakresie.

The Importance of STEM Education

The concept of education based on STEM emerged relatively recently—at the end of the 20th- and the beginning of the 21st century. The idea encompassed both a domain area as well as teaching curricula in the following disciplines: science, technology, engineering, and mathematics. A report called: *Science, Technology, Engineering, and Mathematics (STEM) Education: A Primer* provides a broader perspective on STEM, whereby it is interpreted as "teaching and learning in the fields of science, technology, engineering, and mathematics. It typically includes educational activities across all grade levels—from pre-school to post-doctorate—in both formal (e.g., classrooms) and informal (e.g., afterschool programs) settings" (Gonzalez, Kuenzi 2012: 1). This definition clearly emphasizes understanding STEM as an element of life-long and multi-contextual educational process.

The emergence and the widespread adoption of the idea has been also connected with the inclusion into the educational offering of the requirements and standards typical of the 21st century as well as the need to address the requirements of the ever-changing labor market. This could be done as the concept of STEM proves successful in education at all levels and with all learners. As the practical experience shows, contemporary educational systems do not concentrate enough on teaching children how to address real problems and—far from interdisciplinary—they get confined within the unnatural framework of standards and principles, which is what STEM aims to be an alternative to. The transition from the current, traditional teaching approach to a holistic, interdisciplinary method makes sense especially in modern times, when opportunities are as common as challenges. Therefore, it is incumbent on future generation of teachers to fine-tune the educational offering in such a way as to equip children with the skills required for living in a reality which, as of today, remains unknown to us.

The concept of STEM-based education emphasizes the importance of preparing the young generation to define and solve problems while at the same time promoting critical thinking. By asking questions, exploring and experimenting, children themselves work out solutions to various problems. STEM can be treated as an educational strategy that is in keeping with the current trend promoting interdisciplinary and life-long learning. Notwithstanding the above, the concept is close to everyday life and its various situations and problems and it promotes the development of interests and passions already in very young children. The STEM Model boosts learners' motivation to study and promotes the feeling of agency and in doing so, helps to prepare young researchers for their future careers in exact sciences, engineering or mathematics (Plebańska, Trojańska 2018).

It should also be stressed that the disciplines covered by STEM and their integration into various projects may constitute a very interesting area of educational activity for children. When working on projects, they gradually and systematically build up and expand their knowledge and skills within the scope of a particular problem area, they acquire new experiences and at the same time explore their immediate environment.

In conclusion of this overview of STEM impact we note that it is only recently that the importance of STEM-based instruction has been duly acknowledged not only in later stages of education but also in pre-school and early-school periods. Greater emphasis is currently being put on familiarizing young and very young learners with science and technology and the proper development of open attitudes and natural curiosity leading to more successful exploration of the world.

Application of STEM Concept in Pre-school Education

Exploration of the environment and becoming familiar with the surrounding world are very obvious aspects of the pre-school period. Children are naturally curious; they are happy to engage and ask questions. The role of teachers, parents and caregivers is to create an environment, which will promote the development of STEM competencies in children.

At this stage of education, children are normally interested in researching the properties of items, they learn basic notions, describe how objects appear, how things work and react to various external stimuli or factors. They like to contrast and compare features, look into how simple machines work or try to build, test or experiment with them on their own. They sometimes make attempts at categorizing and measuring things, weigh them, order them according to some pre-defined criteria. Another fascinating object of investigation can be natural sciences, topics related to ecology as well as technology, including using and combining various materials for making their own constructions and set-ups. It all enables them to carry out a number of interesting projects. According to the authors of *STEM Sprouts. Science, Technology, Engineering & Maths* (2013) a well-designed educational environment, which provides children with a properly selected range of educational experiences, enables them to succeed academically and ensures that the learning process is friendly for the brain. The nursery school period is also an ideal moment for the development of positive attitudes and learning skills. Making a common effort on a project prepares children for team work and assuming responsibility for the assigned tasks as it allows them to acquire and develop communication skills (*STEM Sprouts. Science, Technology, Engineering & Maths* 2013).

STEM sees the role of adults as essential to its success. Parents and teachers should accompany the child in their development. This has been communicated through a set of guiding principles proposed by the authors of *Early STEM Matters: Providing High-Quality STEM Experiences for All Young Learners* (Early Childhood STEM Working Group 2017). According to these principles:

“1. Children need adults to develop their ‘natural’ STEM inclinations.

2. Representation and communication are central to STEM learning.

3. Adults' beliefs and attitudes about STEM affect children's beliefs and attitudes about STEM.

4. STEM education is not culturally neutral" (Early Childhood STEM Working Group 2017: 7).

It is the role of teachers to encourage children to undertake the exploration of the surrounding world. Support and sustaining motivation are crucial as at this age they are too young to exercise patience when seeking answers to the questions that are posed. If the first one or two attempts at solving the problem fail, children tend to give up further efforts altogether. It is therefore important that—when confronted with such challenges—the child is accompanied by another person, who—through the actions taken—can help sustain their cognitive activity by helping for example to define the problem, direct the child towards the right answer, encourage persistence as well as supply valuable teaching aids and materials.

Another relevant question to consider are the opinions and stereotypes, still prevalent in the society, concerning some disciplines—including mathematics, technology, engineering or exact sciences in general, which are seen as determined by inborn aptitudes or gender. Such views, sustained and voiced by adults—parents or teachers—may constitute a serious obstacle affecting the child's development. A change of attitude in this respect may result in enormous benefits—it will, first and foremost, save the child from reinforcing negative and limiting attitudes and convictions. One of the paths leading to the improvement in the quality of STEM education should be proper teacher training so as to ensure that teachers are equipped with the necessary knowledge and skills as well as support in their teaching activity.

Kitchen Lab for Kids: Project Description and Aims

The international project called "Kitchen Lab for Kids" (Klab4Kids) has been developed as an Erasmus+ initiative since 2018 (http://kitchenlab4kids.eu/). The project is a joint action of five academic centers from Poland, Italy, Ireland and Spain (Jesuit University Ignatianum in Krakow, Libera Università Maria SS. Assunta, Fondazione Politecnico di Milano, Universitat Internacional de Catalunya and Dublin City University). The project is coordinated by Jesuit University Ignatianum in Krakow. The primary goal of the project is to facilitate the exchange of experiences and good practices in the scope of promoting an active learning of exact sciences in European countries. The project outcomes should also stimulate and encourage teachers to explore modern interactive methods of teaching and learning that would support STEM education provided to children aged 3–6. KLab4Kids aims to engage teachers and parents in assisting young children in integrating knowledge from various areas related to STEM. Kitchen is perceived as a creative space where children can undertake their first research and conduct their own experiments. The kitchen space may become a home-lab, in which children may be introduced to the world of science and knowledge in an interesting and accessible manner. The project has been designed to combine activities performed in the kitchen, including preparation of meals, cooking and exploring various alimentary products with the acquisition of scientific knowledge. Alimentary products used for cooking as well as technological processes and physical phenomena taking place while performing various kitchen tasks are seen as objects of research and children's analyses. Also, one of the project aims has been defined as raising children's awareness of hazards which they can encounter in the kitchen environment.

The project is predominantly addressed to pre-school teachers and students of teacher training programs as well as parents of pre-school age children. The outcomes of the KLab4Kids project are expected to include diagnosis and description of teachers' needs in the scope of STEM education in participating countries as well as the development of a teaching set dedicated specifically to the needs of educational work with children both in the nursery class as well as at home. The project also aims to create a KLab4Kids community of practitioners that would address aspects of STEM methodology in pre-school education as well as evaluate the materials collected. Teachers will not only be able to take advantage of a ready-to-use set of tools and documents, or get inspired by the ideas for class scenarios and descriptions of good practice but also exchange their own experiences related to the implementation of STEM.

Methodology

Research Goal and Questions

This paper provides an overview of a study which constituted one of the initial stages of the "Kitchen Lab for Kids" project and offered a preliminary diagnosis of the knowledge of STEM among students in teacher training programs.

The aim of the study was to recognize the students' opinions on STEM education. Specific problems have been formulated as follows:

- What is the level of knowledge about STEM learning among students of teacher training programs?
- What are students' attitudes towards classes incorporating elements of STEM learning?
- What are, in students' opinion, aims of classes delivered in line with STEM principles?

- What are students' personal experiences with regard to class arrangements promoting the development of STEM skills?
- What problems (and challenges) can be generated by this type of classes?
- What is needed for effective provision of classes developing STEM competencies?

Method

The main research method applied for the purpose of the study was focus group, whose aim was a group discission held in parallel with all involved persons taking part in the session (face-to-face focus). The moderator and students of teacher training programs were concentrated on the analysis of one specific problem, which in this case was STEM. The discussion was based on a protocol developed prior to the session, which covered: screening of two films, questions and answers, presentation of the definition of STEM and final questions.

Study subjects

The study involved students of teacher training programs, mainly in preschool teaching and early school education. The focus group interview was conducted in a small (8 persons) non-random group. Members of the group were selected based on purposive sampling according to a set of criteria predefined by the researcher and adjusted to the specific nature of the project. It was intended as an attempt at collecting empirical material to be used for developing a questionnaire necessary in the subsequent, core part of the study. While focus group interviews were held in all countries participating in the project, this paper focuses specifically on findings of the procedure conducted in Poland.

Procedure

The study was conducted in December 2018 and January 2019 at Jesuit University Ignatianum in Krakow, Poland, which was the primary place of employment for the moderators. A lecture room was adapted to the needs of the procedure. The participants had been informed of the study aims and participation consent was obtained from each member of the group. Their consent was verbal and was recorded by the persons conducting the research. The study subjects had previously met as they pursued the same university program.

Group membership was relatively homogenic (Hoffman 1959: 27–32; Hoffman, Maier 1961: 401–407; Krueger, Casey 2000) which removed barriers to effective communication between the participants, increased the feeling of comfort and eventually prompted the attendees to share their views with others. The focus session took

1.5 hours. The course of the session was recorded using a voice recorder. One moderator and her assistant were present at the session at all times. These were representatives of the Polish team taking part in the international project called “Kitchen Lab for Kids.” The moderator’s background was in psychology while the assistant moderator was a teacher. The presence of only one moderator in charge of a session increases the risk of deviating from the session’s intended purpose as the moderator concentrates efforts on ensuring the proper atmosphere in the group and the well-being of its participants. Furthermore, the presence of two session hosts, who can take turns when moderating those areas of discussion in which they have stronger competencies, may add to the varied nature of the session and reduce the risk of the participants providing responses they believe are anticipated by the moderator (Lisek-Michalska 2013: 42). Given that the moderator’s behavior may have an enormous impact on the final success of the focus group session, this must certainly not be a randomly-chosen person. Research practice has proven that a successful moderator should demonstrate specific competencies (traits), both in terms of personality as well as research and leadership. Among the personality traits the following have been identified as particularly relevant:

- genuine interest in what other people think and feel, inquisitive nature and desire to seek answers to quench his/her thirst for knowledge,
- emotional expressiveness demonstrated through the (controlled) ability to show personal reactions,
- spontaneity promoting high group dynamics,
- sparkling personality, essential for any stimulating activity,
- sense of humor without aggression or spite,
- empathy which encourages proper understanding of how the study participants perceive reality,
- introspection necessary to realize and understand one’s own views and emotions and—therefore—acknowledge limitations inherent in the procedure and acquire proper perspective,
- ability to quickly and clearly formulate one’s thoughts,
- flexibility: moderator must be able to respond quickly if any elements of the research tool are found to be ineffective,
- low level of stress in social situations,
- good improvisation skills,
- ability to maintain a high level of one’s task orientation.

As a leader, the moderator should be able to:

- state the problem in a way that will stimulate enthusiasm and willingness to seek constructive solutions by the participants,

- properly select information to be communicated to the participants so that it properly conveys the nature of the task without suggesting any expected responses,
- control and manage group dynamics,
- cope with interruptions and silence,
- restate the group's ideas to add precision and clarity to what was contributed by the group members themselves,
- ask questions to stimulate effective problem-solving,
- summarize the effects of work done by the entire group (Williams 2003: 67).

During the session the assistant handled general organization of the event (operating voice recording equipment, taking notes, offering assistance whenever complications occurred). Her presence reduced the moderator's workload, therefore creating advantageous conditions for the moderator to be exclusively focused on her core responsibility.

The focus group session had a clear structure consisting of 3 parts—each of them containing a specific type of questions. The questions asked in the early (preliminary) phase were intended as ice-breakers, increasing the feeling of comfort among the participants and setting the stage for the essential discussion. In the second part students were shown two short films (of approximately 3 minutes each), which were meant to, on the one hand, inspire the study participants to express their opinions and on the other—show the essence of STEM. The first film showed a fragment of a class with a group of preschool children experimenting with milk in what is a classic example of milk painting. The children carefully drop in some food coloring onto milk (poured into a bowl) and tap it with a toothpick or a small stick dipped in a detergent. Surprised and fascinated, they observe chemical reactions taking place in the milk, which they see as mixing of colors. The other film showed a preschool girl in the course of preparing a meal (salsa Bolognese) using Thermomix, with a little assistance from an adult person. After both films were screened, the participants were asked questions in accordance with a previously developed study protocol. Since the topics to be discussed during the session had not been disclosed to the participants (who had received only most general information on the subject matter of the session), the questions asked during the main part were specific, to the point, understandable and always referred to a single aspect only. During the last phase of the session the moderator asked questions mainly in order to establish whether everything had been said and fully and properly understood as well as to make sure that the participants did not wish to raise any additional points, make changes or supply further explanations. The three-part structure of the session was reflected in the design of the focus group protocol.

During the discussion, the invited participants enjoyed the convivial atmosphere to address the topics mentioned by the moderator, who oversaw the interview making sure it ran smoothly, with every participant effectively contributing to the discussion, aiming to obtain feedback on all questions contained in the interview guide. On the participants' leaving the room, the moderator together with the assistant checked the quality of the recording properly identifying the material collected and reviewed the most important ideas. Next, a transcript of the recording was made, according to the rules laid down for feedback processing.

Study Findings: An Overview

The films played to the participating audience at the beginning of the study show lively children involved in the activity. They joyfully begin the experiment, initially intrigued, then increasingly radiant and happy as they observe the outcomes of their own activity. Interestingly, the same emotional reaction was observed in the group of students watching the films. First positive comments were voiced already as the films were screened with students wondering “What will come next?” “Why did that happen?” “How is that possible?”

Student attitudes towards classes incorporating elements of STEM

The examples of STEM applications presented in the films were very enthusiastically received by the students. All members of the focus group agreed that they liked the films and found them interesting. Most of the participants commented along the lines of “I have never encountered anything like this before, I have seen it for the first time and I liked it a lot” or “If I find milk drawing interesting, then I wonder how crazy the kids are about it?” However, the students' comments referred solely to the situations observed in the films. This way of thinking proved immune to soft suggestions and questions coming from the moderator. The students participating in the discussion were not able to take a global look at the activities offered to children by nursery schools aiming to integrate various scientific disciplines (science, technology, engineering, mathematics). What is more, the students almost instantly alluded to several difficulties such classes posed. As one of the study participants remarked: “It appeals to me. Still, I believe that delivering this task in such a group can be challenging. I got the impression that the kids were very mature for their age. They could stay calm and quiet but not all children are like them.” This observation opened up the discussion for some more critical opinions as on the one hand, the activities were seen as appealing yet on the other, they obviously require thorough preparation, careful design and time. Thus, the students admitted that classes like this are necessary, but not very often, “certainly, not on a daily basis, the idea is unworkable, it can't be done. That would simply pose too big a challenge. You could do something new like this once a month perhaps."

Lesson objectives in STEM

Students pursuing teacher training programs become familiarized with the structure of a lesson plan already from the very early stages of their university education. The ability to formulate general, specific or operational objectives will enter the repertoire of basic skills, frequently used by academic teachers as coursework assignments. It is hence a puzzling observation that the question concerning the goals of STEM education was met with grim silence from the participants of the focus study. Soft stimulation from the moderator combined with some positive encouragement and a personal example provoked only occasional responses. These have been categorized and ordered in terms of frequency (from the most frequently cited to the least communicated ones). The goals of classes that draw on the STEM Model, according to the respondents, are as follows:

- language skills: "instruction-based performance," the subjects stressed the importance of children's oral production—their comments made during the class,
- motor skills: with emphasis on manual dexterity, as communicated through the following observations: "the kid in the film added ingredients," "the kid measured out something," "that means manual practice,"
- social skills: where the respondents stressed the children's responsibility and independence (feeling adult—in the case of cooking), as well as mechanical dexterity, like in "using such a device,"
- artistic and creative skills: "As I understand it, the kids focus their attention on something artistic, on performing such art-like things," "You could use it to calm kids down,"
- science skills: the participating students see them in actions that involve observation as well as experiential discovering of the world, as expressed in the following comments: "the child learnt something already, he could do that…," "they learn colors, experiment with color mixing."

The study participants expressed lesson objectives by reference to skills and it was how these objectives were, in fact, understood. Also, STEM classes are perceived by the teachers-to-be as effectively promoting language or motor skills rather than cognitive ones. The latter were mentioned only by two respondents, in brief statements.

Personal experiences of organizing STEM skills-oriented classes as reported by the participating students

As the study was carried out among students, the interviewers assumed that only a limited number of them would have any teaching experience. Even so, in the course of studies students tend to seek temporary or regular employment (e.g., babysitting), they are also offered some opportunities to organize classes during their teaching work experience and, in addition to this, classes provided by universities as part of their curriculum allow them to run activities to be later targeted at pre-school and early-school children. Notwithstanding the above, the assumptions made by the researchers proved accurate as only two subjects responded to the question relating to their personal teaching experience with STEM-based classes. One of them, employed by a Montessori nursery, observed that "some classes we do are very similar to those shown in the video. We also did classes based on color mix. There were four basic colors, which the child measured out into water with a pipette. The kid then mixed the basic colors and checked what would happen." The other person made a reference to the cooking video stating that she "had some experience with Thermomix but not in the classroom, it was more like at the kid's home. You could see the child was really fascinated by the opportunity to measure out things and then offer the final product for others to taste. It was a great fun and a good reason to feel proud." Students' responses demonstrated a clear tendency to perceive their own experiences (in the field of STEM education) in the context of the films shown to the group. The research authors hinted that the examples to be given by the students would not necessarily have to relate to the videos. Any participants who conducted classes combining at least two scientific disciplines could speak, yet the idea was not really taken up, which most likely demonstrates the subjects' very limited experience of STEM skills-oriented classes.

Problems and challenges that come with STEM-based classes

Organization of classes drawing on STEM education was considered by the subjects in terms of problems and difficulties rather than challenges leading to self-development or inspirational experience. Such attitudes were foreshadowed in the subjects' responses to the opening question that introduced the focus group interview.

Obstacles, which—according to the participants of the study—could significantly hinder more widespread introduction of STEM education in the classroom include:

- class arrangements: participants pointed to the need for small learner groups and higher number of teachers required to deliver such activities, which was expressed through responses like: "in-class performance depends on the group and the number of attending staff," "discipline is the key," "small number of children, there were 10 of them here, but if you have a class of 25 to look after, before you lay out the materials and props, approach every kid, explain things… that takes a lot of time," "you need to prepare the classroom in advance,"

- health and safety: classes which promote children's physical involvement can, according to the study subjects, increase the risk of hazardous situations, e.g., the use of knives by the youngest ones or occurrence of food allergies and intolerance in children. Also, subjects stressed the importance of maintaining order and cleanliness after the class. One of the participants expressed this necessity in the following words: "One needs to keep things clean. During my teaching placement we had these trays with cereals, then the whole floor was strewn with the stuff. You must bear in mind the fact that if there is active physical involvement, then cleaning it all afterwards may be a must,"
- parental impact: the respondents perceived parents as a factor that may hinder pupil activity. Also, parents are regarded as those who tend to frown upon such activities being introduced to the pupils by the nursery staff. Parents do not understand the need for active exploration of the world by children, which was best expressed through comments like: "you need to spell it out to parents in advance that kids could get dirty and stained and that they should not dress them in designer labels as oil gets spilled sometimes, etc." One of the participants working for a Montessori nursery reported a frustrating situation, when "a father or mother came and complained about a 50 Euro piece of clothing getting stained." Such reproaches are a very effective deterrent for proposing various forms of activity to the youngest learners.

Required arrangements for provision of classes developing STEM competencies (skills)

According to the study subjects, arranging classes focused on developing STEM skills is very demanding (students themselves pointed out that such classes cannot be held too often), so a number of varying needs were brought up in this regard. First and foremost, the participants pointed to the organization of the class, which they expressed with the following comments: "you must properly arrange the classroom for such activities," "you should find some space as when you make such cookies, you need to bake them later" and, last but not least, financial issues: "you need money for that," "you need to make a list of necessary things, figure out what we have to buy…, then collect money from the parents." Then, the discussion took a different perspective and focused more on the involvement of external actors, with four social groups being specifically named:

- Parents: the respondents observed the need for support and contribution from the children's parents and caregivers, e.g. with regard to teaching aids, financial issues as well as cleaning. Students maintained that parents must be advised in advance of this type of children activity so as to mitigate possible complaints about „there not being daily worksheets completed for that day." They claim that completing worksheets is commonly "enforced," only to show that "they do something at the nursery."

- Other nursery school staff: to be understood as the involvement and support contributed to the class by all members of the nursery staff—from the principal (whose consent is required to conduct this kind of class activity) to cleaners, cooks ("you do need somewhere to bake the cookies") to teachers of other groups.
- Nursery school teachers: respondents' comments in this respect fall into two distinct groups: junior teachers and their more senior colleagues. Young practitioners were perceived by students as more willing, creative and ready to work with children using innovative methods. One participant observed that "you must feel like doing it, those younger teachers are not part of the system yet and that is why they show more enthusiasm for their work. Seniority, on the other hand, means burn-out. The 'old-style' teachers think according to patterns they picked up in the past. They stick to the system… on the other hand, they might not have the chance to learn something new. They are used to doing things their way, they have their skillset, their methods and they keep relying on those."
- Children: the stimulus for organizing classes centered around developing STEM competencies can, according to the respondents, come from the children themselves or—to be more precise—from "child involvement," "sparking true interest in such classes," "if children were happy with that—then yes..."

Other issues raised by the study participants included: lack of support, insufficient access to published papers and books as well as few sources of inspiration for this type of classes. Teacher creativity is a positive feature yet there is little information on for example "advice and tips on what can be excessively difficult for children" that is: how to adjust certain solutions to learners' age. One person brought up the problem of the national curriculum for nursery education, which, as it was stated, "does not leave too much room for the teacher and does not put any real emphasis on STEM-based classes. There is a need for greater involvement of the central authorities so that there is some space in the curriculum for free classes like these. Nursery schools must follow the national curriculum."

Discussion

The knowledge of the students participating in the study about STEM education is negligible. The term "STEM education" is unknown to them. It was only when the definition was read, and the moderator drew attention to its essential elements, that triggered a few statements among the students, such as: "we do it, but we did not know what it was called." This situation may be caused by the lack of systemic solutions in educating students of teaching faculties in Poland. While Rodger W. Bybee (2010: 996) drew attention to the need to develop a learning strategy focusing on STEM, this idea is still underestimated in Poland. This does not mean, however, that nothing is happening in our country in terms of STEM education. The STEM trend has been noticed; representatives of the authorities point out the need to strengthen mathematical and natural science skills, training courses for teachers and conferences promoting this model of education are initiated. By cooperating with the local community, Polish scientists carry out various projects promoting STEM education, and the database of available materials, articles and other publications in this thematic field is expanding.

Conclusions

The study findings suggest that future teachers do not possess extensive knowledge of STEM methodology. The students participating in the study reacted enthusiastically to some examples of classroom activities incorporating STEM techniques. These were found interesting, yet the organization of such classes appears to arouse concerns rather than challenges that could lead for example to career advancement. The respondents saw all difficulties as originating in the demands of class arrangements, the need to ensure safe learning and working conditions for the children as well as in the lack of understanding on the part of parents. Also, it is a disturbing fact that future teachers perceive STEM-based classes mainly in the context of developing language or motor skills rather than cognition. They do not associate STEM with an approach that would serve to build creativity and develop skills in creatively solving problems in project work, nor do they see it as promoting critical thinking or learning based on insight. In addition, they fail to notice other advantages, which include sustaining natural motivation to learn exact sciences, improving the outcomes and quality of teaching or adjusting the skills developed to the needs of the contemporary labor market. As teachers-to-be, they ought to know that they must not limit their repertoire of teaching methods to the ones which instead of stimulating free thinking and freeing up the child's creative potential tend to encourage predominantly passive attitudes. Student experience of conducting classes geared to STEM skills development is limited. Obviously, lack of methodology handbooks or school curricula centered on STEM may impede provision of such classes in a nursery school. However, they must remember that the modern world is changing dramatically. It requires that teachers, including those involved in pre-school education, adjust their educational offering to the standards of the 21st century. STEM Education is the response to the neurobiological foundations of the educational process of a young person and thus becomes an effective means to develop a set of competencies for a fulfilling and rewarding life in the future.

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APPENDIX

Focus group protocol developed for a study into STEM Education involving students of teacher training programmes

I. Introductory phase

This part of the study is intended as an ice-breaker for creating more friendly and informal atmosphere. It aims to reduce the stress level that may result from the participants facing a new, unknown situation. The moderator seeks to create an atmosphere of trust and ensure that the participants feel comfortable and secure.

1. Participants are welcomed; facilitators thank them for accepting the invitation to take part in the study and turning up at the focus meeting.
2. Moderator and her assistant introduce themselves stating names and the place of employment and then briefly outline information on project participation.
3. Participants get to know each other. Self-presentation includes stating one's name and interests. The participants are then asked to prepare name cards.

Assistant moderator hands out small cards asking the participants to write their names on them (in block capitals). This way name cards are created to facilitate addressing each other during the discussion. Name cards should be pinned to clothes worn by the focus group members or placed in front of a person so that others can clearly see them.

4. Topic and purpose of the meeting are stated. The moderator briefly outlines the "Kitchen Lab 4 Kids" project encouraging active participation in the future learning community and introduces the topic and purpose of the meeting.
5. Rules of participation in the discussion are laid down. The moderator states the rules of discussion, emphasising politeness, respect for other members of the group, patience and the need to refrain from interrupting interlocutors while they present their opinions. The moderator assures students taking part in the study of its anonymity and the confidentiality of any collected data. It is explicitly guaranteed that responses elicited during the interview will be analysed and utilised exclusively for the purpose of the project. Towards the end of this part of the introduction the moderator specifies the expected length of the meeting

and makes sure that all the participants have been comprehensively informed about the session.

6. Participants are informed about the session being recorded. The moderator informs the participants about the discussion being recorded by means of a voice recorder and then ensures that all attendees give their verbal consent to their taking part in the interview and their opinions being recorded. Participants express their consent orally.

II. Main phase

This part of the study aims to collect information from group members, which is the main reason for the meeting. The moderator is an important figure here as she monitors rules of conduct during the discussion and makes sure that all participants are given equal chance to voice their opinions. The moderator is also responsible for feedback, understood as a clear and unambiguous explanation and justification of the expressed views.

1. Film screenings

The moderator informs the participants that they will be shown two short films. They are encouraged to watch attentively but also to voice their opinions while watching. Films screened prior to the discussion were short (approximately 3 minutes each) and were meant to inspire students to speak freely as well as to introduce the essence of STEM education.

The assistant moderator presents the first film showing part of a class during which a group of preschool children is experimenting with milk—a classic example of milk painting. The children carefully drop in some food colouring onto milk (poured into a bowl) and tap it with a toothpick or a small stick dipped in a detergent. Surprised and fascinated, they observe chemical reactions taking place in the milk, which they see as mixing of colors (Link: https://www.youtube.com/watch?v=T-Oa-uHP_t0).

The assistant moderator presents the other film showing a preschool girl in the course of preparing a meal (salsa Bolognese) using Thermomix®, with a little assistance from an adult person (Link: https://www.youtube.com/watch?v=me1DfTAqGWE).

2. Discussion

After the screenings, the moderator asks the following questions:

(a) What is your opinion about such classes/workshops?

(b) What are the aims of such classes/workshops?

(c) What skills/abilities are developed in children who attend such classes?
(d) What is your personal experience of organising such classes with preschool children?
(e) What challenges/problems can such workshops generate?
(f) What do you think should be considered necessary to deliver such classes to preschool children?

3. Definition of STEM is presented to the participants

The term "STEM" refers to the process of integrated teaching and learning in the scope of natural sciences, technology, engineering (technical sciences) and maths. It includes educational activity at all levels of education (from nursery school to adult education) and takes place in both formal and informal classroom settings. The general aim of STEM is to further develop STEM literacy in society. STEM literacy means:

- developing knowledge, attitudes and skills in identifying questions and problems related to every-day situations, explaining the natural and man-made world, formulating evidence-based conclusions,
- understanding the characteristic features of STEM disciplines as manifestations of human knowledge, research and projects,
- promoting commitment to STEM-related problems and ideas of science, technology, engineering and mathematics.

STEM remains a relatively unknown concept in Poland, hence persons who planned the focus group assumed that the participants would not be familiar with the very notion or the elements of the STEM model. In order to avoid awkwardness resulting from lack of knowledge of the notion among the participants it was decided that STEM would be explicitly defined during the session.

The moderator introduces the definition of STEM (each participant also receives it printed) which is followed by a brief analysis of the notion; any issues that remain unclear are thoroughly explained. The moderator responds to questions asked by the students, if they have any.

4. Discussion

After presenting and discussing the definition of STEM the moderator asks the following questions:

(a) Is it possible to develop science-oriented thinking in preschool children? How?
(b) What would you need to develop such skills/abilities in preschool children?

III. Closing phase

This part closes the discussion. It should essentially contain a summary of the discussion as well as acknowledgement of the participants' effort—their commitment as demonstrated during the session.

1. Discussion is briefly summarized

The moderator makes sure that the topic has been exhausted and all provided information has been properly understood. She then asks whether anyone would like to add, explain or further comment on any issues raised.

2. Facilitators thank the participants for their time and participation

The moderator and her assistant thank everyone for their participation in the discussion. The participants receive small gifts.

Once the study subjects have left the room, the moderator together with her assistant check the quality of the recording, summarise the most important ideas and clear the room. As soon as practicable, a transcript of the recording is made and analysed.

Table 1. Consolidated criteria for reporting qualitative studies (COREQ): 30-item checklist

No.	Item	Guide question/description
Domain 1: Research team and reflexivity		
Personal Characteristics		
1.	Interviewer/ facilitator	Which author/s conducted the interview or focus group? *The persons conducting the research were Irmina Rostek and Katarzyna Szewczuk*
2.	Credentials	What were the researcher's credentials? (e.g., PhD, MD) *Persons conducting the research have an academic title: doctor of psychological sciences, doctor of pedagogical sciences.*
3.	Occupation	What was their occupation at the time of the study? *The persons conducting the research are academic teachers employed at Jesuit University Ignatianum in Krakow, Poland.*
4.	Gender	Was the researcher male or female? *The people conducting the study were women.*
5.	Experience and training	What experience or training did the researcher have? *They have experience in conducting classes with students and participated in methodological workshops that dealt with the subject of qualitative research.*

Relationship with participants		
6.	Relationship established	Was a relationship established prior to study commencement? *The persons participating in the study knew the interviewers.*
7.	Participant knowledge of the interviewer	What did the participants know about the researcher? (e.g., personal goals, reasons for doing the research) *Some of the survey participants knew the moderators from previous activities during the studies. All students also knew that the moderators were taking part in the project "Kitchen Lab 4 Kids," and they knew the purpose of the meeting and its reasons.*
8.	Interviewer characteristics	What characteristics were reported about the interviewer/facilitator? (e.g., Bias, assumptions, reasons and interests in the research topic) *One moderator and her assistant were representatives of the Polish team taking part in the international project called "Kitchen Lab for Kids." A successful moderator should demonstrate specific competencies (traits), both in terms of personality as well as research and leadership.*
Domain 2: Study design		
Theoretical framework		
9.	Methodological orientation and theory	What methodological orientation was stated to underpin the study? (e.g., grounded theory, discourse analysis, ethnography, phenomenology, content analysis) *Conversational analysis*
Participant selection		
10.	Sampling	How were participants selected? (e.g., purposive, convenience, consecutive, snowball) *Members of the group were selected based on purposive sampling according to a set of criteria predefined by the researcher and adjusted to the specific nature of the project.*
11.	Method of approach	How were participants approached? (e.g., face-to-face, telephone, mail, e-mail) *The participants were recruited for the study by e-mail, as well as through conversations and information about the project—these were face-to-face conversations.*
12.	Sample size	How many participants were in the study? *The focus group interview was conducted in a small (8 persons), non-random group.*
13.	Non-participation	How many people refused to participate or dropped out? Reasons? *Two people withdrew from the study. The reasons are unknown.*
Setting		
14.	Setting of data collection	Where was the data collected? (e.g., home, clinic, workplace) *The focus interview was conducted at the Jesuit University Ignatianum in Krakow, Poland. One of the lecture halls was arranged for the research. This is the primary workplace for moderators.*

15.	Presence of non-participants	Was anyone else present besides the participants and researchers? *No. Only 8 students, moderator and assistant.*
16.	Description of sample	What are the important characteristics of the sample? (e.g., demographic data, date) *Group membership was relatively homogenic. The study involved students of teacher training programs, mainly in preschool teaching and early school education.*
Data collection		
17.	Interview guide	Were questions, prompts, guides provided by the authors? Was it pilot tested? *The focus meeting was conducted according to the scenario (the exact course can be found in the appendix). No pilot tests were undertaken, but due to the implementation of the research in 4 countries, it was discussed in detail and analyzed with partners. International team participating in the project (representatives).*
18.	Repeat interviews	Were repeat interviews carried out? If yes, how many? *No (but the same interviews were conducted in all countries).*
19.	Audio/visual recording	Did the research use audio or visual recording to collect the data? *Sound (audio) recordings were used in the study. Participants' statements were recorded using two dictaphones.*
20.	Field notes	Were field notes made during and/or after the interview or focus group? *Field notes were made by the assistant during the meeting.*
21.	Duration	What was the duration of the interviews or focus group? *The meeting lasted 1.5 hours.*
22.	Data saturation	Was data saturation discussed? *Yes.*
23.	Transcripts returned	Were transcripts returned to participants for comment and/or correction? *The transcript was not shown to the meeting participants.*
Domain 3: Analysis and finding		
Data analysis		
24.	Number of data coders	How many data coders coded the data? *The moderators coded the data. Several thematic categories were distinguished according to the adopted research questions.*
25.	Derivation of themes	Were themes identified in advance or derived from the data? *The topics were identified in advance because they were written in the script (as questions).*
26.	Participant checking	Did participants provide feedback on the findings? *The results of the study were made available to interested persons.*

Reporting		
27.	Quotations presented	Were participant quotations presented to illustrate the themes/ findings? Was each quotation identified? (e.g., participant number) *In order to illustrate the topics, selected quotes from the meeting participants were quoted.*
28.	Data and findings consistent	Was there consistency between the data presented and the findings? *Yes.*
29.	Clarity of major themes	Were major themes clearly presented in the findings? *Yes, the main topics were separated in the analysis of the materials from focus interviews.*
30.	Clarity of minor themes	Is there a description of diverse cases or discussion of minor themes? *Yes.*

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REVIEWS

RECENZJE

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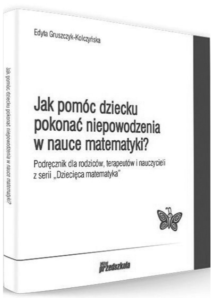

Success or Failure in the Mathematical Education of the Child

(Nie)powodzenia w matematycznej edukacji dziecka

Review: E. Gruszczyk-Kolczyńska (2021). *Jak pomóc dziecku pokonać niepowodzenia w nauce matematyki? Podręcznik dla rodziców, terapeutów i nauczycieli z serii „Dziecięca matematyka”* [*How to Help the Child Overcome Math Failures? A Textbook for Parents, Therapists and Teachers from the Series “Children’s Mathematics”*], Kraków: CEBP 24.12 Sp. z o.o., 270 pp.

> “Math is neither difficult nor boring.
> Especially if we become friends with her
> while we are still children.
> Math is the measure of everything.”
> (Aristotle)

Mathematics—the word that hides immense emotions. Probably each of us has some memories and associations related to mathematical education at school age. For some it was a pleasure, sometimes, when they delved into solving logical and difficult tasks, ending with pride and success. For others, learning mathematics was a nightmare they would prefer to forget, lost and sad time, marked by a streak of failures, often with a sense of inferiority. And it is the latter experience, which makes some people assume a priori that learning mathematics must be difficult, and perceive it as a cause of failure. The scale of the phenomenon is so large that in the literature we can find such terms as the scourge of mathematical illiteracy (Dąbrowski 2008), mainly blamed on teachers who failed to properly shape mathematical concepts in the minds of children (Karpińska, Remża 2019). This process is particularly important at lower levels of education: pre-school and early school education. Edyta Gruszczyk-Kolczyńska, the author of the publication I reviewed, is lending a helping hand in teaching mathematics at this developmental stage.

Edyta Gruszczyk-Kolczyńska is an unquestionable authority in the field of mathematical education for preschool children. She is known to the public mainly for the series "Matematyka dziecięca" ["Children's Mathematics"] but let us not forget that she has also authored publications on, inter alia, diagnosis, mathematical education in class I, and mathematically gifted children. This time the author returns to the topic of failure in learning mathematics. One may ask if the publication which to some extent duplicates the subject of the previous author's work is worth reading (Gruszczyk-Kolczyńska 2014). My answer to this question is an emphatic "Yes," because the contents of the book are presented in a broader perspective, holistic and complementary to the previous one.

The publication has been divided into two parts. In the first one, we will find some important information on the causes of children's failures in math. The author describes in detail the consequences of the so-called paper mathematics, i.e. of narrowing mathematical education to fulfilling tasks in exercise books (pp. 19–24), and also shows the correlation between emotions and reasoning (including mathematical thinking). In this section of the book, we will also find information on the importance of supporting and developing operational reasoning in a child (even before going to school) and we will read about the rules that should be followed when working with a child to eliminate failures in learning math. This short compendium of knowledge about failures in the initial learning of mathematics is transparent and understandable to the average reader. The added value of this fragment of the publication are numerous examples, descriptions of many situations that actually took place in classrooms during classes with children. It allows for an even better understanding of the analyzed content; shows the actual and potential consequences of an inadequate formation of mathematical concepts in the minds of children.

The second part of the publication focuses on supporting children in overcoming failures in learning mathematics in selected educational areas. The following aspects are described in detail: counting, calculating, word problems, spatial orientation, geometric intuitions, measurement of length, weight and fluids, time and financial calculations (money math). Each of the above-mentioned themes is treated briefly and at the same time exhaustively, maintaining more or less the same layout. This means that, first of all, we are given information on the psychological basis of the formation a given concept in the child's mind. Then we learn about the consequences and errors of the school system of teaching mathematics in selected areas of education. At the very end, we will find numerous suggestions how to assist the child in developing selected mathematical skills. Importantly, the information contained in this part of the publication includes both the diagnosis of and the corrective actions for a given skill. Thus, the reader can independently, by preparing a series of simple tasks, find out at what level the child is in terms of developing a specific skill, and then (if this level is insufficient) propose supporting tasks and games. It should be mentioned that the proposals of both diagnosis and the supporting tasks are described precisely, with attention to detail, and their implementation should not be difficult (they only require objects of everyday use).

Jak pomóc dziecku pokonać niepowodzenia w nauce matematyki? [*How to Help the Child Overcome Math Failures?*] is another of many publications by Edyta Gruszczyk-Kolczyńska. An attentive reader will surely notice numerous repetitions in the theoretical descriptions or examples of games provided by the author. On the other hand, he receives one book in which the content and ideas analyzed in many publications are collected. The issues related to the mathematical education of children are ordered and analyzed in terms of supporting their development. I think that the overriding goal of the book was to provide a tool that will help adults in the correct formation of mathematical concepts (based on psychological foundations) and help them notice and eliminate the mistakes that have been made so far. For those who are not convinced by the above arguments and are not influenced by the authority of the author herself, I would like to add another argument: *Repetitio est mater studiorum*.

The publication combines the simplicity of language with the professionalism of content. It is addressed to a wide audience, to all people who are not indifferent to the fate of children who fail to learn mathematics. In this context, it is worth mentioning that the prevalence of failures in mathematics does not decrease, and despite the use of various didactic and compensatory classes, it remains at a constant level (Czajkowska et al., 2015a, 2015b). For this reason, in the first place, I recommend the book to the teachers and students of pedagogy. The former will have the opportunity to verify and expand the methods of mathematical education of the child. The latter, on the other hand, will be prevented from making mistakes while forming mathematical concepts in the minds of future students. Undoubtedly, the publication should also be read by parents of children in preschool and early school age. Thanks to the content of the publication, they will be able to diagnose selected mathematical skills of a child and, if necessary, they will be able to introduce corrective measures. In this way, they will give their child a better start in learning math or will eliminate the obstacles that have caused the aversion to the Queen of the Sciences.

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