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Developing Scientific Thinking as an Important Educational Task that Supports the Harmonious Development of a Child at the Preschool Age

Rozwijanie myślenia naukowego jako istotne zadanie edukacyjne wspierające harmonijny rozwój dziecka w wieku przedszkolnym

KEYWORDS

key competences, STEAM education, scientific thinking, kindergarten, development of thinking in children

ABSTRACT

The aim of the study is to emphasize the need to support scientific thinking of children at the preschool age, and to look at the possibilities of supporting this process in the realities of the Polish educational system. The intention of the work is also to pay attention to the advantages of teaching based on the STEAM methodology.

This reflection concentrates around the question about the purpose and possibilities of supporting the development of scientific thinking in young children. The question also concerns the role of the teacher in this process. The analysis of literature suggests that the development of scientific thinking should be a priority of educational programs implemented at the early childhood stage.

The first part of the study presents the definition of scientific thinking – the foundation for the acquisition of selected key competences. The author then looks at how the process of supporting the development of scientific thinking is implemented in the educational practice of kindergartens. In the further part of the study, the author argues that actions aimed at developing scientific thinking of children at the preschool age should be a priority educational task of kindergartens. Next, the idea of STEAM education was presented, including the role of the teacher.

On the basis of the literature analysis, we can indicate the need to support the development of scientific thinking at the early stage of child development. The role of the teachers is to create an environment that supports the development of children's scientific thinking. Teachers, however, need system support (courses, training, support from universities).

SŁOWA KLUCZOWE

kompetencje kluczowe, edukacja STEAM, myślenie naukowe, przedszkole, rozwój myślenia dzieci

ABSTRAKT

Celem opracowania jest zaakcentowanie potrzeby wspierania rozwoju myślenia naukowego u najmłodszych uczestników procesu edukacyjnego poprzez przyjrzenie się możliwościom wspierania tego procesu w realiach polskiego systemu edukacyjnego. Zamysłem pracy jest także zwrócenie uwagi na walory nauczania opartego na metodyce STEM.

Problemami, wokół których koncentruje się niniejsza refleksja jest pytanie o cel, możliwości wspierania rozwoju myślenia naukowego u dzieci, ale także o to, jaka jest/powinna być rola nauczyciela w tymże procesie. Analiza literatury źródłowej pozwala wskazać, że rozwijanie myślenia naukowego powinno się stać priorytetem programów edukacyjnych już na etapie wczesnego dzieciństwa.

W pierwszej części opracowania przedstawiona została definicja myślenia naukowego postrzeganego jako fundament dla nabywania wybranych kompetencji kluczowych. Następnie autorka przygląda się, w jaki sposób proces wspierania rozwoju myślenia naukowego jest realizowany w praktyce edukacyjnej przedszkoli. W dalszej części opracowania przekonuje, że działania mające na celu rozwój myślenia naukowego dzieci w wieku przedszkolnym powinny się stać priorytetowym zadaniem edukacyjnym przedszkoli. Następnie zaprezentowana została idea edukacji STEAM z uwzględnieniem w niej roli nauczyciela.

Na podstawie analizy literatury źródłowej można jednoznacznie wskazać potrzebę wspierania rozwoju myślenia naukowego na wczesnych etapach rozwoju dziecka. Rolą nauczycieli jest stworzenie środowiska edukacyjnego, które mogłoby wspierać rozwój myślenia naukowego dzieci. Pedagogom potrzebne jest jednak systemowe wsparcie (kursy, szkolenia, wsparcie środowiska akademickiego).

The art of teaching is the art of arousing curiosity in young souls and satisfying that curiosity; and curiosity is only lively and healthy in happy minds.
Anatol France

Introduction

In the situation of the constantly changing reality, in the era of information society based on knowledge, there is a noticeable need to support the development of scientific thinking at all educational levels, including the stage of preschool education. This concept is present in the assumptions of STEAM education which integrates five theme-specific components: science, technology, engineering, art and mathematics. This is a new trend in the educational practice of Polish schools and kindergartens, and, so far, it is not very popular. However, it certainly is a model that is worth introducing and disseminating, because it is an example of a modern teaching method that provides multi- and inter-disciplinary education. The purpose of the article is, above all, to emphasize the need to support the development of scientific thinking in preschool education and discuss the assumptions of the innovative STEAM educational model as well as its possibilities in relation to work with the youngest children.

The first part of the study explains the concept of scientific thinking, which is perceived as the foundation for the acquisition of selected key competences. After that, the possibilities of supporting the development of scientific thinking in preschool education are discussed. Then, the idea of STEAM education, which is based on the need to develop scientific thinking, is presented. This part emphasizes the role of the teacher in the process of supporting the development of children's scientific thinking, and in consequence, in STEAM pedagogy.

Scientific thinking as the foundation of mathematical competences and basic competences in science and technology

Eight key competences were identified in the Recommendation of the European Parliament and Council of the European Union of 18 December 2006 on key competences for lifelong learning. They are to integrate knowledge, skills and attitudes that are considered necessary for self-fulfilment, personal development, being an active citizen, social integration and, as a consequence, taking up employment (L394/13).[1]

[1] This document lists eight types of key competences a person should have in order to properly function in the changing reality, especially in the economy based on knowledge 1. Communication in the mother tongue; 2. Communication in foreign languages; 3. Mathematical competence and basic competences

The key competences include basic competences in science and technology, as well as mathematical competences. The former refer, among others, to mastering, using and applying knowledge and methods explaining the world of nature (Recommendation of the European Parliament and Council of the European Union No. 2006/962/EC of December 18, 2006 on key competences for lifelong learning – OJ L 394, 30.12.2006).

The basic competences in science and technology can be acquired by enabling a child to learn and understand selected processes occurring in the surrounding world (e.g. natural phenomena). They are also shaped as a result of recognizing the principles of technology functioning and acquiring the skills of their proper and effective application. It is also important to understand the principles and relation of the technology being studied with other areas of human functioning (e.g. medicine, functioning in a peer group, culture, environment). Scientific and technical competences also include the ability to plan and implement even simple experiments and research processes (it is important to be able to indicate the purpose of the study, ask questions and hypotheses, make conclusions and refer to them critically, search for the reasons and assess their validity). They also include the ability to use the current resource of knowledge to attempt to explain the natural world in order to formulate questions and draw conclusions based on evidence (Annex to the application for the Council's Recommendation on key competences for lifelong learning, Brussels, 17.01.2018: 3).

Mathematical competences, of course, include the ability to perform basic mathematical operations (such as: addition, subtraction, multiplication, division, etc.; in preschool, e.g. sorting – independent determination of the segregation principle, classification, comparison, simple conversion, determining the location of selected objects) in order to find solutions to various types of problems in everyday situations. More importantly, however, it also includes the child's ability and willingness to use mathematical ways of thinking (among others: logical and spatial thinking, the ability to follow the reasoning of others, the ability to abstract, generalize and asses things in a critical manner – the ability to separate proven statements from assumptions), as well as presentation skills (presentations put in formulas, models, charts, tables) (Annex to the application for the Council's Recommendation on key competences for lifelong learning, Brussels, 17.01.2018: 3).

The basis for acquiring key competences, especially scientific – technical and mathematical ones, is scientific thinking generally understood as the ability to formulate conclusions based on empirical observations regarding nature and society (Kłos, *Myślenie naukowe…*). Deanna Kuhn identifies three signs of scientific thinking: the

in science and technology; 4. Digital competence; 5. Learning to learn; 6. Social and civic competences; 7. Sense of initiative and entrepreneurship; 8. Cultural awareness and expression.

ability to notice cause and effect relationships; knowledge and understanding of the scientific basis of selected phenomena and processes; the ability to make arguments referring to the theoretical basis and evidence obtained (Kuhn et al. 2008: 435-451).

The issue of scientific thinking is so important that, for almost a hundred years, psychologists who are interested in human cognitive development, have formulated numerous research concepts and implemented empirical research to discover and understand the trajectory of the development of scientific thinking and scientific concepts. They have studied various methods of enriching children's understanding of scientific procedures and concepts. The topics of the research often referred to the category of early childhood curiosity and its role in the child's cognitive development, the development of concepts related to understanding scientific phenomena, methods and techniques supporting the development of scientific thinking (among others DeClory 1914; Wygotski 1971: 159-488; Filipiak 2018, et al.).

While analysing the learning objectives of the Core Curriculum for General Education in the primary school, it can be seen that the main emphasis was put on shaping scientific thinking in students. As a result, many courses, trainings and methodological studies were created for teachers of individual school subjects, whose task is to support teachers in the realization of such an important educational task.

The core curriculum of preschool education, aiming at supporting the child's overall development, also obliges teachers to facilitate the development of scientific thinking. The records of the document suggest creating conditions enabling children to safely and independently explore elements of technology in the environment, constructing, DIY, planning and undertaking intentional actions, presenting the products of their work; conditions enabling safe, independent exploration of the nature surrounding the child, stimulating the development of sensitivity, and enabling a child to learn about the values and norms related to the natural environment (The preschool education core curriculum for kindergartens, preschool departments in primary schools and other forms of preschool education 2018/2019).

Children's natural competences vs. the process of supporting the development of scientific thinking in preschool education in Polish realities

In the context of the constantly changing reality, the phenomenon of globalism and multiculturalism, the education system is facing new challenges. One of them is to prepare young people to cope with the new reality, to use technological inventions efficiently, to constantly strive to discover the truth, as well as to make assessments and choices (Surma 2012b: 23). Children have unlimited access to information almost from their birth. Such a situation makes their functioning easier (the access to information is simple and immediate), but, on the other hand, it creates many difficulties (the experience of being overloaded with information as a consequence of disinformation, puzzlement associated with the need to assess and select information that is reliable).

> The requirement of the modern reality is, therefore, not only to care for the transfer of knowledge about the world around us, but also to educate about how to understand the mechanisms of the functioning of this world, develop decision-making skills, critical thinking, and analysis of the obtained information. For that reason, scientific thinking should be seen as an important competence in the rapidly changing reality and economy based on knowledge – in the world created by the third technological revolution (Bartnik 2016: 32; Czachorowski 2016: 30; *Konferencja Pokazać – Przekazać* 2016).

Supporting the development of preschool children's scientific thinking by involving them in the learning process should become one of the main goals of the didactic and educational process, and it should be implemented already in the kindergarten (however, the family environment is also of great importance in this aspect, see Reynolds, Walberg 1991). Educators must become aware of the fact that scientific thinking is not exactly the same as the ability to remember scientific facts. Scientific thinking leads children to their own discoveries that are deeply rooted in their consciousness – unlike the process based on teaching about other people's discoveries. The manifestation of scientific thinking includes constant questions asked by children, searching for answers, gathering information and conducting their own investigations. On this foundation, the ability to effectively formulate conclusions based on empirical observations regarding the world of nature and society is created.

Barbara Surma claims that "the main goal of upbringing is to support the individual development of the child" (Surma 2012: 7) who "develops through their own activity when put in the right environment" (Surma 2012a: 23). Therefore, the main task of the kindergarten should include the creation of an environment in which it will be possible to support the development of the desired attitudes and skills of children (especially the ability to formulate conclusions based on previously made observations, and the critical analysis of these observations), which may contribute not only to their educational success, but also to successful life. This can be achieved by making children interested in the world that surrounds them, and shaping the attitude of the researcher.

Abandoning the efforts to shape children's competences related to scientific thinking can have far-reaching consequences. Scientific research in developmental and cognitive psychology indicates that the environmental impacts are extremely important, especially in the first years of individual development. The lack of the necessary stimuli may prevent the child's development from reaching its full potential (Hadzigeorgiou 2002: 373).[2] Thus, early childhood scientific education is of great importance for many aspects of the child's development, and researchers suggest that the basics of this education should begin as early as in the kindergarten (Ramey-Gassert 1997; Watters, Diezmann, Grieshaber, Davis 2000; Eshach, Fried 2005).

Haim Eshach lists six reasons supporting the idea that the youngest children should be given the conditions to recognize the basics of scientific mechanisms. The author indicates that:

1. it's in the nature of children to like watching and thinking about nature,
2. creating interesting conditions for learning about science develops a positive attitude towards it,
3. early exposure to scientific phenomena leads to a better understanding of scientific concepts later studied in a formal way,
4. the use of scientific language at a young age affects the final understanding of scientific concepts,
5. children are able to construct scientific concepts and understand them,
6. teaching science is an effective way to develop scientific thinking (Eshach, Fried 2005).

Therefore, properly organized children's involvement in the process of learning is of key importance for supporting them in the process of exploring and understanding the world, collecting and selecting information. These basic skills and scientific knowledge make it possible for children to understand key scientific concepts and create more abstract scientific ideas in the future (Reynolds, Walberg 1991: 371-382).

It is worth emphasizing that preschool children (and younger, too) actively watch the environment they live in. They learn with passion and enthusiasm and they try to understand the essence of the phenomena that they observe and experience. During this time, they also acquire and improve skills such as observing, classifying and sorting (Platz 2004; Eshach, Fried 2005). Thus, the basic skills for scientific thinking begin to develop already in early childhood, and they improve in the course of development (Piaget, Inhelder 2000; Meyer 2010).

Young children are inquisitive by nature and passionate about science (Raffini 1993). From birth, they want to learn and naturally look for problems to solve (Lind 1999: 79). Preschool children are open to what is new to them, they are interested in the world around them and getting to know it gives them extraordinary joy. They are usually willing to act and happily adopt the attitude of experimenting researchers

[2] Yannis Hadzigeorgiou presents theoretical frames of teaching and learning physics in early childhood. In his text he presents the results of his own research according to which preschool children (aged 4.5–6) can (on their own) create the concept of mechanical balance through structured practical activities that include building a tower on a slanting surface.

(Żylińska 2013: 58). With enthusiasm and incredible perseverance, they constantly ask questions starting with the word "Why." Therefore, it is an excellent period in the child's development, in which it is worth to shape and support the development of scientific thinking and a passion for learning. Scientific thinking of preschool children is precisely taking the attitude of a researcher, based on the curiosity about the world and the desire to experience reality, check it and shape it (Sendecka 2017: 5).

Unfortunately, on the basis of observation and review of literature, it can be stated that at the stage of preschool education, the value of methodological support for the development of children's scientific thinking is underestimated. There are three reasons for this situation. First of all, one can notice the problem of preschool teachers who do not recognize the need and importance of supporting the development of children's scientific thinking. Such support could be achieved by creating the opportunities for conducting scientific experiments, performing directed research explorations, and solving scientific problems adequate to children's development possibilities and needs.

Second, there are not enough sources of inspiration for early education teachers (blogs, methodological guides, sets of materials supporting children's scientific education) so that they can work with the youngest children in such a difficult educational task. Another reason for this situation is often the lack of basic scientific knowledge among the teachers (deficits in the education of preschool teachers are pointed out). Third, preschool education teachers do not understand the value of education and its role in the development of young children, or they understand it only as the necessity to teach children about scientific facts (Watters, Diezmann, Grieshaber, Davis 2001). In this context, it is worth emphasizing that both the National Science Education Standards established by the National Research Council in 1996, and the Science Literacy (American Association for the Advancement of Science, 1993) call on teachers to do their utmost to work with young children towards an investigative approach to learning.

As I have already mentioned, many people, especially teachers, when they think about teaching, they associate this process with the need to provide, and then verify, the knowledge about facts related to the world around us, as well as with frequent testing and measurement of knowledge. As a consequence, they do not see the benefits of active, practical learning. Unfortunately, only few teachers associate the teaching process with generating ideas for solving selected problems and predicting the effects of certain phenomena (the teaching process is associated here with an active exploration of the surrounding world, and shaping the students' research attitude) (see Duckworth 1987). Teachers working with the youngest children rarely use teaching methods that enable a deep understanding of the content discussed, and they do not really teach scientific basics and principles (Mayer 2004). It seems that introducing older students to the world of science and expecting them to learn facts that had been discovered by others is partly justified. However, the youngest children should be taught to learn through active engagement, i.e. first-hand research experience, and teachers should take advantage of the children's natural curiosity about the world. Such involvement should be both physical and intellectual. For this reason, the children should be involved in many aspects in researching and manipulating the selected elements functioning in their environment. That is why, the process of teaching young children should be based on asking questions (especially the child's own), finding answers, conducting investigations, and collecting data. Science cannot be only perceived as remembering facts; it must become a way of thinking and understanding the world (Kilmer and Hofman 1995; Mayesky 1998; Lind 1999; Zeece 1999). "In shaping scientific thinking, it is important to bring one closer to true discovery and continuously deliver real problems, even the ones taken from everyday life" (Czachorowski 2016: 30, *Konferencja Pokazać – Przekazać 2016*).

Conditions of the educational environment facilitating the development of scientific thinking in the context of the assumptions of STEAM pedagogy

The nature itself has taken care of the willingness and positive attitude of preschool children to learning about the surrounding world. It is because children are equipped with cognitive curiosity, internal motivation and the need to act (Żylińska 2013: 54). Education based on the assumptions of STEAM methodology makes full use of these natural assets and individual talents of children. STEAM pedagogy (science, technology, engineering, art, maths), a relatively new trend in the educational reality, is an approach to teaching that involves education in science, technology, engineering, mathematics, and art, using the latest technologies. Such approach is supported by the increasing number of teachers enabling the creative development of scientific thinking among children.

In addition, according to the assumptions of STEAM education, the teacher can equip students with the key competences that are necessary in the modern reality (including creative thinking, the ability to generate many possible solutions and make logical conclusions, and the cooperation in a group to solve a problem). STEAM pedagogy perceives children as active creators of their individual knowledge (Fosnot 1996: 8-34; Gunstone 2000: 260). It promotes active learning by implementing practical exercises in small groups (working in small groups teaches cooperation and creates opportunities to develop the skills to understand the peer's perspective of thinking), experiments, experiences, and discussions using appropriate tools and educational aids. The basic assumption of the education based on STEAM methodology is the belief that students are more likely to acquire and understand the scientific content in a learning environment that is based on the opportunity of independent inquiry. The teacher-led approach seems to be the most effective way in which young children can learn scientific theories and associate what they already know with what they are currently learning.

Therefore, in the education based on STEAM methodology, the student is an active participant of educational activities, which undoubtedly strengthens their sense of responsibility for work and increases their motivation to continue their effort and to deal with difficult emotions that may occur in the course of learning. The child has the opportunity to rediscover what has already been discovered in a creative way using new technologies.

Those teachers who implement the STEAM assumptions in their teaching process are aware that overloading students with facts is not effective, especially when teaching young children. The cognitive overload impairs the ability to process new information and makes it difficult to learn (Mayer 2004; Kirschner, Sweller, Clark 2006). STEAM supporters know that facilitating the development of scientific thinking is the priority. That is why, they work with children to improve their inquiry skills, stimulate asking their own questions and encourage them to seek answers on their own, as well as design their own research adequately to their developmental possibilities.

The teacher, being the organizers of the teaching process, acts as a mentor and advisor who is ready to help at any time in the individual student's search. STEAM education is based on the belief that students (even the youngest ones) can manage their own learning. Teachers are only there to facilitate this process and support the students with appropriate resources.

Therefore, the child is in the center of the educational process, and the role of the teacher in this approach is to act as an observer and facilitator cultivating the children's curiosity and stimulating their continuous intellectual development – not as an instructor or supervisor (Martens 1999; Chaille, Britain 2003). In teaching young children, we should avoid situations in which the teacher is in the center of the educational process and plays the role of the all-knowing authority giving information about facts (Johnson 1999: 14-25).

Thus, in the contemporary reality, the main challenge for the teachers is to find the answer to the question of how they can help children develop knowledge, skills and attitudes necessary for them to become people with scientific skills (Watters, Diezmann, Grieshaber, Davis 2001). This is particularly important in the context of the fact that traditional teaching mainly based on lecturing methods (working with a text is often used in those methods) is ineffective in teaching science.

The pre-primary education teachers should, therefore, learn how to create an optimum work environment. Such environment must support the youngest participants of the educational processes in researching, testing and self-correcting their ideas. According to Mary Lee Martens, the key components of an environment facilitating students' scientific thinking are:

a) using many interesting materials, didactic aids, including technologically advanced ones, facilitating the development of children's scientific thinking by encouraging discovery and independent inquiry,
b) leaving unstructured time for children to develop and test their own ideas (it is important to give the children freedom to engage in individual searches and experiments),
c) caring for the social climate in which children know that asking questions and conducting experiments are as valuable as knowing the right answers,
d) developing the curiosity and openness to new ideas (Martens 1999).

Creating such an educational environment that could facilitate the development of scientific thinking of the youngest participants of the educational process is a considerable intellectual and organizational effort for teachers. It often takes a lot of money (the STEAM products are not the cheapest educational aids). Teachers cannot do it alone. What they need is the support of the system (courses, trainings, the support of the academic environment).

Conclusions

Preschool students are naturally interested in the world around them. They want to know as much as possible about it. However, instead of listening to others answering their questions and instructing them how they can gain knowledge, they prefer to ask, experiment and discover things on their own. They do not want science to be just something that is given to them through lectures. They want to learn science through action. They want to ask their own questions, collect information themselves and create new, great ideas. It is these childhood desires that should be the basis for the early childhood curriculum.

In the education based on STEAM methodology, young children are perceived as active participants in the educational process, responsible for the course of this process, and teachers are to plan many interesting and difficult situations that become an invitation for children to observe, explore and experiment. The possibilities offered by STEAM education allow children to construct meaning and develop understanding of specific phenomena and processes. This is extremely important and valuable for their continuous intellectual development and is the foundation for the scientific thinking and, consequently, the acquisition of key competences (especially mathematical, scientific and technical ones).

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