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STEM Education and Cognitive Activity of Preschool-age Children

Edukacja STEM a aktywność poznawcza dziecka w wieku przedszkolnym

KEYWORDS

STEM education, cognitive curiosity, scientific potential of a child, preschool education, preschool education program

ABSTRACT

The research issue of the article focuses on presenting the specificity of STEM education as a space conducive to the development of cognitive activity of a child at the preschool age. The aim of the research is to recognize the dimensions of the child's reality, which are important scientific experiences for him/her. The subject of the analysis included the utterances of 54 older preschool children from a big city. The children's utterances took the form of questions. The research method was content analysis. The background for the research is the presentation of the essence of the transformations taking place in the space of education. The direction of change is determined by the STEM concept, which was created to increase the effectiveness of education and improve its quality. Its scope includes science, technology, engineering and mathematics. STEM education emphasises the ability to respond flexibly to change, and to cope with its unpredictability. It is desirable to develop an interest in STEM education from an early age. Education based on STEM themes becomes a space that triggers creativity and involvement of learners. It becomes a generator of ideas and an impulse for innovation. The last part of the article presents reports from the research on the cognitive curiosity of older preschool children expressed in the questions of the respondents. In order to illustrate the content of children's experiences related to science, the respondents' statements were referred to. The conducted analyses show the scientific potential of the child and constitute a recognition in the direction of personalization of the content in education.

SŁOWA KLUCZOWE

edukacja STEM, ciekawość poznawcza, potencjał naukowy dziecka, edukacja przedszkolna, program edukacji przedszkolnej

ABSTRAKT

Problematyka badawcza artykułu koncentruje się na ukazaniu specyfiki edukacji STEM jako przestrzeni sprzyjającej rozwojowi aktywności poznawczej dziecka w wieku przedszkolnym. Celem prowadzonych badań jest rozpoznanie wymiarów rzeczywistości dziecka, które stanowią dla niego ważne doświadczenia naukowe. Przedmiotem analiz uczyniono wypowiedzi 54 dzieci w starszym wieku przedszkolnym ze środowiska wielkomiejskiego. Wypowiedzi dzieci przybrały formę pytań. Metodą badania była analiza treści. Tło dla badań stanowi przedstawienie istoty dokonujących się przemian w przestrzeni edukacji. Kierunek zmian określa koncepcja STEM, która powstała dla podniesienia efektywności edukacji oraz poprawy jej jakości. W jej zakres wchodzą nauki ścisłe, technologia, inżynieria, matematyka. W edukacji STEM podkreśla się możliwość elastycznego reagowania na zmiany oraz radzenia sobie z ich nieprzewidywalnością. Pożądane jest rozwijanie zainteresowania edukacją STEM od najmłodszych lat. Edukacja oparta na tematach STEM staje się przestrzenią wyzwalającą kreatywność i zaangażowanie uczących się. Staje się generatorem pomysłów i impulsem dla innowacji. W ostatniej części artykułu przedstawiono doniesienia z badań na temat ciekawości poznawczej dzieci w starszym wieku przedszkolnym wyrażającej się w pytaniach badanych. W celu zobrazowania treści doświadczeń dzieci związanych z nauką przywoływano wypowiedzi badanych. Przeprowadzone analizy ukazują potencjał naukowy dziecka oraz stanowią rozpoznanie w kierunku personalizacji treści w edukacji.

Specificity of learning about the reality in the 21st century – implications for education

The reality is changing at an unimaginable pace, the way we learn about it is changing, and so is education itself. A change in thinking about education is needed and necessary. Education cannot focus only on preparing for life in the existing situation (education for the job market). It has to be more "flexible" and related to the environment. The need for cross-curricular education that combines and integrates knowledge from different fields of science and technology remains open to the dimensions of art, creativity and innovation. Both in literature and in educational practice, it is possible to indicate solutions referring to the goals of education of the 21st century defined on a global scale in the document "Transforming our World: The 2030 Agenda for Sustainable Development" (UN 2015). The current efforts are aimed to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all"[1] (UN 2015: 16). The model of "flexible civic education" is also promoted by Agnieszka Rothert in her book *Władza wyobraźni. Edukacja, innowacje i demokracja* [The Power of Imagination. Education, Innovation and Democracy] (2015: 8). In her opinion, education has a huge impact on shaping the "visions of the future" and future worlds (Rothert 2015: 12), including, of course, visions for building the society of the 21st century that is defined as a "flexible society" (Rothert 2015: 14). The author believes that nowadays it is necessary to "learn flexibility" (Rothert 2015: 175). This is a kind of challenge that requires breaking down mental barriers and crossing the boundaries of thinking through the involvement of imagination. There is a great need for thinking and acting that will be relevant to both the needs of the modern man and the expectations of the society. It turns out that the modern society has enormous demands. It expects creative and innovative solutions that will not only provide functionality and usability, or dealing with the world, but that will also result from designing with the involvement of imagination. All creations must have a kind of "the creator's mark" and result from his creativity. The novelty that emerges in this context as a result of creative work cannot be a "mere" novelty, but something that will be able to impress and raise interest according to the growth understood as the driving force of technological development (cf. Rothert 2015: 160, 165). The author also invokes the term "resilience" meaning "elasticity, flexibility and suppleness" as the skills that are useful in overcoming life problems (Rothert 2015: 175). In the context of education, it is also important that these skills are acquired from an early age by growing up in an environment that is imbued with certain values, or by experiencing threats to these values. According to her: "*Resilience* is an 'on-the-run' reaction" (Rothert 2015: 175), it is something that will only be possible if one learns certain skills beforehand. Only then will they be able to react appropriately, but this does not mean that they can somehow become immune to any emerging threats (Rothert 2015: 175).

The "concept of flexibility" goes beyond linear thinking and refers to specific thinking in the meaning of the power of the mind, which, at the same time, influences and shapes the world around it. This concept takes into account relational aspects and evolves towards an emergent system (Rothert 2015: 177). Flexible thinking and acting means going beyond the established order of experiencing reality. Being flexible

[1] This is Goal 4 out of the 17 Sustainable Development Goals for the years 2016-2030 made by the UN, which are related to tasks implementation.

means, among other things, being open for change. The modern reality is characterized by a huge concentration of changes, their great dynamics and scope. It results in a great diversity of reality and its complexity in the real and created dimensions, which translates into unpredictability. Perceiving the reality in a linear and orderly way, from the perspective of rules, standards and procedures, greatly impoverishes its image in the mind (cf. Rothert 2015: 174). Therefore, there is a need for learning (including learning the necessary skills) to respond flexibly in a dynamically changing world and this is education's job. Similar views are voiced by many authors dealing with the issues of early childhood education. According to Józefa Bałachowicz and Anna Witkowska-Tomaszewska, the role of education, despite being admitted by the authors to be very difficult, is to help the child to understand the essence of the changes taking place, and to help him/her to interpret the changing life conditions and meet challenges (Bałachowicz, Witkowska-Tomaszewska 2015: 8). The aim of education is to create the conditions for the development of the learners' potential capabilities. This includes searching for and interpreting the meanings that children assign to the elements of reality. This is made possible by analysing the child's experiences. Knowledge integration in the mind of a child is not the same as content integration (Klus-Stańska, Nowicka 2014: 236-240). This is what Dorota Klus-Stańska and Marzenna Nowicka convince us of. According to the authors, what matters in the knowledge integration is the quality of the content (Klus-Stańska. Nowicka 2014: 240-247) which has to fulfil certain conditions of "novelty, science, complexity and explorability (…) It is only when they coexist that knowledge can be integrated" (Klus-Stańska, Nowicka 2014: 247). Without taking into account the child's perspective, experiences and personal knowledge, it would be difficult to discuss subjectivity in education. Thus, all educational activities must be accompanied by treating the child subjectively, respecting his or her rights, including "recognizing and respecting the child's right to his or her own way of thinking" (Chauvel, Michel 1999: 8).

"STEM" education – outline attempt

The concept of STEM[2] (Chyrk 2015: 162) is an outcome of the efforts to improve competitiveness and economic growth. It is an educational policy solution, the development of which can be treated as a kind of remedy for the illnesses of the educational system in the United States. This concept fits into the broadly understood space for innovative education to enhance its effectiveness and improve quality. It is a source of inspiration for the initiators of changes in education. STEM education, which is

[2] "STEM" is an English acronym for: Science, Technology, Engineering, Mathematics (Chyrk 2015: 162).

currently the most desirable in the world, comprises education in science, technology, engineering and mathematics (Gonzalez, Kuenzi 2012). The STEM agenda covers four categories relating to science, technology, engineering and mathematics. However, the definitions of STEM vary depending on the adopted educational policy perspective. A narrower definition rather refers to sciences and comprises mathematics, physics, chemistry, information technology and engineering, while a broader scope covers physical and natural sciences, engineering (including physics, chemistry, biology, mathematics) as well as psychology and social sciences (Granovskiy 2018: 2). The impact of STEM in education lies in the synergy effect that arises from the permeation and mutual interaction of the science and technology fields. The emerging educational strategies at the curricular level are based on common fields of study. Depending on the adopted perspective of educational policy and educational goals, they refer not only to natural sciences, but also to social sciences and art. STEM education is close to life and the modern reality (Chyrk 2015: 162-164). It enables the acquisition of the skills required today, which translates into individual success, increases competitiveness and contributes to economic growth. This is the desirable direction of educational thinking and acting. The fields constituting the STEM framework complement each other and provide a stimulus for development. The resulting scientific space becomes a platform for sharing experiences and knowledge, as well as for cooperation and innovation. Referring to different disciplines is more effective in solving real problems which are very complex. Complex efforts generate thinking "beyond objects".[3] In fact, STEM is a generator of changes in the educational space – an impulse for innovation.

STEM education goes beyond the framework of disciplines that constitute STEM definitions. The educational projects and curricula are interdisciplinary, multidisciplinary in nature, and they are based on the idea of transdisciplinarity as a solution that integrates sciences but also goes beyond the boundaries of scientific disciplines (cf. Rothert 2015: 167-168). In the above context, previously mentioned Rothert, who deals, among other things, with shaping the space for innovation, invokes the term "transformable" in relation to education, which, in her opinion, is the most appropriate for the forms of education that encourage the learners' creativity (Rothert 2015: 168-169). In the transdisciplinarity space there is room for a new type of knowledge generation, which is not limited only to the area of scientific institutions. In this process, the society and social institutions also play an important role. The idea of transdisciplinarity enables the spectrum of research interests to include areas that are

[3] "Beyond Objects" is the subject of one of the "Education Congresses" held periodically in Katowice. The Education Congress entitled "Beyond Objects" was held at the premises of the Silesian Museum on 10th April 2018.

outside the centre of a given scientific field. In this way, the interest areas emerging from the generation of knowledge, as well as its practical application, can be scientifically penetrated (cf. Włodarczyk 2011: 57-63).

STEM education aims to raise awareness (through education) of the importance of STEM and the meaning of studying. It covers different areas of activity related to the scientific activity. In these areas, emphasis is placed on the acquisition of practical skills that are important from the perspective of the modern world's requirements and the development of critical thinking. Children have the opportunity to learn and act in a practical way both in and out of the classroom (nursery room). STEM education also focuses on creating a safe and sustainable learning environment. The importance of the dialogue with parents and the family background is emphasised in order to support and encourage the kids to become interested in science, engineering, mathematics and information technology, and to study STEM courses in the future. Cooperation and partnership to improve the quality of STEM education is multisectoral and involves different subjects: teachers, scientists, entrepreneurs, business people, and administrative staff. STEM education emphasises gender equality above all (UNESCO 2017). It is essential to cognitively provoke, to evoke children's fascination with science, to suggest and encourage various activities, and to inspire them. It aims at triggering the children's creativity and creating the conditions for them to explore and investigate reality by themselves. Education based on STEM topics gives children the space to reveal their own ideas for acting, to share what is important, interesting and amazing to them. It provides an opportunity to investigate learning problems from the child's perspective.

Child's curiosity as an impulse for educational activities – research approach

In order to meet the challenges of modern education, it was decided to conduct research aimed at recognizing the dimensions of the child's reality, which – from his or her perspective, in the subjective approach, constitute important scientific experiences.[4] Recognising both the content of the child's experiences and their contexts will be very valuable in terms of educational practice. It will provide an opportunity to refer to what is known by and close to the child, and, therefore, refer to his or her ideas and fascinations. A specific action in this respect is manifested by the child showing his or

[4] For the purposes of the article, the research material obtained through free interviews with children and having a reduced content due to the research objective was used. The research group comprised older preschool children from a big city. The children's statements form part of a larger research project. For the purpose of the study, the statements of 54 children aged 5 and 6 (28 girls and 26 boys) were analysed.

her cognitive curiosity by asking questions. Expressing his or her curiosity by asking a question, the child fills it with content and, at the same time, communicates with the world what is currently the subject of his or her scientific curiosity. It is a situation that allows to recognize what content is currently important, interesting and cognitively useful for the child, that is, what serves the child to build his or her knowledge. The research method was content analysis (Silverman 2009: 145-150). According to Rothert, "curiosity is a desire to learn, see or experience something which leads to or stimulates the acquisition of new information" (Rothert 2015: 30). The above mentioned author believes that while searching for the answers to basic questions, we touch the essence of explaining the world (Rothert 2015: 33).

When asked about what they are curious about ("What are you curious about in this world?"), older preschool children formulate several types of questions starting with: *How? Why? What for? For what reason? What from? Do/Does/Is/Are/...?* [Yes/No questions] *Where? When? What? How many?* Their questions vary depending on their gender. The variations concern the types, forms and content of the questions asked, as well as their quantity. It appears that children usually ask "How?" questions. This group is dominated by boys, who do it almost twice as often as girls. Curiosity hidden in the boys' questions particularly concerns the technology and design areas. They need information on technology and engineering. These are questions like: *How to make everything new and pretty? How to make bottles? How to get the key to Atlantis, which is sunk in Iceland?* They are interested in design and construction, where knowledge means solving a specific problem of, e.g., functionality or usability of objects. They ask for solutions that, in the world of technology and engineering, are based on scientific and technical knowledge, but also on experience, the choice of an appropriate method of action, or the use of imagination: *What are houses like? What does a rabbit without legs, ears and tail look like?* They ask questions concerning existence itself: *What is it like all over the world?* They want to know: *What are other countries and what is it like in other countries? What is it like in Greece and in England*? The girls' curiosity in this respect is manifested primarily by questions about the world: *How was the world created? How big is the globe?* They want to learn about natural sciences: *How do trees grow? How does the sun shine? How do spiders make their webs?* Children's curiosity concerns not only the outside world, but also themselves, who they are, and even what the meaning of life is (cf. Rothert 2015: 33). Jolanta Kruk relates the designer's actions to the area of practical actions, but preceded by a series of decisions that affect the final result (Kruk 2008: 185). By building structures, children develop planning skills (Dolya 2007: 120), but they also learn about the properties of objects, their structure and materials they are made of. Also the size, shape, colour and number of elements is important. This is all reflected in the child's language in the action context, i.e. in a particular situation when the child makes an effort to create a particular structure (Dolya 2007: 119-120).

Why? or *What for?* questions about causality are the boys' domain. They are particularly interested in: *Why did dinosaurs become extinct?*, but also: *Why does the sun shine?*, or: *Why does someone know everything?* Girls, on the other hand, ask about causality in the world of living creatures, e.g.: *What are the animals in the world for?* or: *Why is the man in the world?*; they also ask questions concerning the essence of existence itself, such as: *Why is there the world in the world?* The fields of mathematics and natural sciences are conducive to building explanatory knowledge in the mind of a child, which is based on cause and effect thinking (Klus-Stańska, Nowicka 2014: 243). An emerging problematic situation is reflected in the child's question. A large group is made up of questions concerning the resolution of a particular issue. These are usually *Yes/No* questions to which the children expect a definite answer at a definite time. Girls inflict them twice as often. The problems which, according to the girls, need to be solved immediately, concern both very complicated issues: *Is the devil good or bad? Would I go to heaven?*, as well as less difficult things, such as: e.g.: *Do sirens exist? Are there any strange creatures on Earth?* There are also questions requiring the knowledge of both inanimate and animate nature: *Is Jupiter or Mercury closer to the Sun? Are there green flowers?* Girls also want unambiguous and immediate answers to questions concerning mathematics, natural sciences, engineering, e.g.: *Can you build large houses from sand? Is a hedgehog square, is the sun square, are teeth round? – because I don't know that*. Difficult questions about that are also asked by boys. Those which, in their opinion, require an immediate answer or an unequivocal solution are, among others: *Could it be now as it used to be?*, or: *Do aliens exist? Can I meet a dinosaur?* Both boys and girls demand answers that will, at the same time, provide solutions to important life problems, such as: *Will my friend get better soon?*, or: *Are my parents in good health?* Questions that reveal the children's cognitive curiosity concern other issues as well: *What is blood, bones and brain made of?*, or: *What is snow made of?* A special group of questions, due to their content, are questions about space (*Where?*). In order to satisfy their curiosity in this respect, girls formulate questions relating primarily to space in the geographical and biological sense. They are interested in issues related to the spatial management of a given area as a habitat for people or animals, e.g.: *Where do other people live? Where are houses? Where are meadows?*, or: *Where is the jungle?* Boys are more interested in geographical location and the identification of a place in space, such as *Where is Italy? Where is Malbork*? *Where is Germany?* They also want to obtain information on the places of residence of unusual characters, such as: *Batman, where is he?* Preschoolers show great ingenuity in taking into account the aspects of reality which, in their opinion, can be expressed in the mathematical language, e.g.: *How many stars are there in the sky? How many leaves are there in the tree?* An intellectually challenging question is also: *How long will I be able to live?* An example of a question that reflects the child's cognitive curiosity in terms of time can be, e.g.: *What year was the globe created?* When asking questions, children want to obtain different types of information or assistance in resolving the problem they are currently facing. They ask about the way of action, behaviour, and about advice and guidelines for their lives, e.g.: *What shall I do to be polite? What do I need to become Spider-Man?* Questions asked for information (covering the value of novelty, science, complexity and explorability at the same time) are, e.g.: *What is happening up there?*

The presented children's questions indicate that, by experiencing reality, they experience a number of difficulties in recognizing and understanding it. The ability to use tools such as mathematical language, concepts of mathematics, properties of objects, relationships and relations between objects as elements of reality, will help the child[5] to learn (Dolya 2007: 71-72). The answer to the question of how to use these tools in the child's learning process to bring him or her precious cognitive value will be easier if we set the child's learning in the context of STEM education.

Conclusion

Following all the considerations, a question arises in the final reflection: How to develop the scientific potential of a preschooler? What can be done to arouse children's interest in learning to encourage them to take an active part in discovering processes and to explore the mysteries of the world in which they live? While attempting to answer them, it must be admitted that the most important task in this regard will be to make the child's learning important for him or her, so that it remains in relation to what surrounds him or her, to his or her experiences, problems, joys and sorrows. The stimulus for educational activities may be "content personalisation" (cf. Guzik 2015a: 14-16; Guzik 2015b: 34-36; https://www.stem.org.uk/news-and-views/opinions/science-capital-making-science-relevant [access: 29.08.2019]). Referring to the considerations mentioned in the text about the role of content quality in building knowledge, it must be admitted that this quality is of the utmost importance in the process of learning and knowledge integration (Klus-Stańska, Nowicka 2014: 240-247). It is important for triggering the cognitive curiosity of a particular child whether the content will be new for him or her, whether it will allow for independent experimentation and conducting research (the science condition), whether it will be able to cause a cognitive conflict in the child's mind (the complexity condition), and, finally,

[5] According to Galina Dolya, these are important mathematical skills.

whether it will be interesting enough to trigger an unflagging desire to explore reality (Klus-Stańska, Nowicka 2014: 240-247).

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