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Dorota Zdybel
ORCID: 0000-0003-3322-7570
Jesuit University Ignatianum in Krakow, Poland

Irena Pulak
ORCID: 0000-0002-7735-4590
Jesuit University Ignatianum in Krakow, Poland

Yvonne Crotty
ORCID: 0000-0001-9381-019X
Dublin City University, Ireland

María Teresa Fuertes
ORCID: 0000-0002-2652-406X
Universitat Internacional de Catalunya, Spain

Maria Cinque
ORCID: 0000-0001-7526-7728
Libera Università Maria SS. Assunta di Roma, Italia

Developing STEM Skills in Kindergarten: Opportunities and Challenges from the Perspective of Future Teachers[1]

Rozwijanie umiejętności STEM w przedszkolu. Możliwości i wyzwania z perspektywy przyszłych nauczycieli

KEYWORDS

STEM education, core STEM competencies, scientific thinking in children, preschool teachers, 21st century competencies

ABSTRACT

The article has been written as a part of Erasmus+ Project KLab4Kids. Its main aim is to present the idea of STEM education to readers, to explain the interdisciplinary nature of STEM education as a "meta-discipline," and to show the possibilities of implementing this type of curriculum/material in a preschool environment. The article consists of three parts. The theoretical part which aims to turn the readers' attention to the interdisciplinary characteristics of STEM skills.

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It also analyses different theoretical frameworks and classifications of such skills, and offers a list of core STEM skills which can and should be developed at an early age. The second part is empirical and compares the theoretical assumptions with survey results – the opinions of students of early childhood education – future preschool teachers. In this part we present our initial teacher educators concerns about the essence and objectives of STEM education. In summary, the authors look at some challenges which have to be addressed in order to prepare teachers for a more modern well rounded education which is capable of shaping young children XXI century skills.

SŁOWA KLUCZOWE

edukacja STEM, kluczowe kompetencje STEM, myślenie naukowe dzieci, nauczyciele wychowania przedszkolnego, kompetencje XXI wieku

ABSTRAKT

Prezentowany artykuł został opracowany w ramach projektu „Erasmus+ KLab4Kids". Jego głównym celem jest przybliżenie czytelnikom idei edukacji STEM, wyjaśnienie jej interdyscyplinarnego charakteru jak tzw. „metadyscypliny", a także ukazanie możliwości jej odniesienia do wieku przedszkolnego. Tekst składa się z trzech części. W części teoretycznej zwrócono uwagę na ponadprzedmiotowy/interdyscyplinarny charakter umiejętności STEM, dokonano przeglądu dostępnych w literaturze klasyfikacji tych umiejętności i zaproponowano listę tych umiejętności STEM-owych, które mogą i powinny być skutecznie rozwijane już w wieku przedszkolnym. W drugiej, empirycznej części tekstu, założenia teoretyczne zostały zestawione z wynikami badań sondażowych przeprowadzonych wśród przyszłych nauczycieli – studentów pedagogiki przedszkolnej i wczesnoszkolnej. Omówiono tu wiedzę i poglądy przyszłych nauczycieli na temat istoty i celów edukacji STEM, możliwości jej prowadzenia na zajęciach przedszkolnych, dostrzegane przez badanych bariery, wyzwania i potrzeby w tym zakresie. W podsumowaniu artykułu zwrócono uwagę na wyzwania, jakie stoją przed nauczycielami, aby mogli oni sprostać wymaganiom współczesnego procesu edukacji uwzględniającego kompetencje niezbędne w XXI wieku.

Introduction

In the modern, digitalized and unpredictable world, where knowledge changes more quickly than educational systems, STEM skills are perceived as the key to solving the problems of the contemporary life in an innovative manner, overcoming social and economic exclusion, as well as building sustainable, green economy (Jang 2016). Thus, it is worth analysing what STEM competences, specified as the skills of the 21st century, are and why they should be developed at an early preschool stage of education. According to McClure et al., "young children have the capacity for conceptual learning and the ability to use the skills of reasoning and inquiry as they investigate how the world works" (McClure et al. 2017: 15). They are naturally curious scientists and creative risk-takers, they tend to ask many scientific or philosophical questions (the "why" questions) and demand explanation from care-takers (Clements, Sarama 2016). Preschool can easily nurture these natural instincts by providing a supportive environment and offering playful STEM challenges where children can safely design experiments and learn by exploring the real world around.

The main objective of this text is to present the idea of STEM education to the readers, and to explain it's values and meaning at the preschool level. In the first part, apart from explaining the acronym "STEM," the interdisciplinary skills will be presented that, according to pedagogical research, are the main objective of this type of education. The aim of this presentation is to specify the STEM skills available for children aged 3-6, which is why it shall be accompanied by a synthetic review of psycho-pedagogical analyses related to the effectiveness of STEM education at the preschool level. Then, we shall present a part of the survey carried out within the Erasmus+ project: "Kitchen as STEM Laboratory for Kids" (Klab4Kids), which shall be the starting point for designing a digital database of didactic materials for teachers interested in extending their competences in this area. In the summary, the most popular examples of simplification and imprecision in the teachers' perception of STEM early education will be discussed.

In search of 21st century skills – what are STEM competences?

The acronym STEM refers to 4 pillars of modern education: science, technology, engineering and mathematics, understood as follows (White 2014: 3):

- Science: various areas of natural sciences, including systemic studies of nature and functioning of materials and the physical world (the universe), based on positivist and quantitative methods such as: observation, experiment or measurement, aimed at formulating the regularities that describe the analysed facts in a general manner. The term refers to biology, physics, chemistry, geology, and other sciences related to studying Earth;
- Technology: the field of science which refers to inventing and using technological tools, as well as studying their relations with life, society and the environment. This area of science is based on industrial art, engineering and applied sciences. Although most frequently mistaken for modern technologies, IT or robotics, T in the STEM acronym refers to each use of tools in order to improve the human environment or solve everyday problems (not only the use of modern technologies, but also tools such as a screwdriver, drill, hammer, mixer, knife, waffle iron, etc.);

- Engineering: an art of practical, useful application of knowledge driven from biology, physics and chemistry in order to design and construct various devices, such as: engines, machines, bridges, buildings, vehicles, vessels, etc. This area is the most poorly recognised in pedagogy, often treated as something inaccessible or even unnecessary to a young child;
- Mathematics: a group of interconnected areas of knowledge including algebra, geometry and arithmetic, focused on investigating the notion of a number, quantity, shape, space, dimensions and their mutual relations described through specialist terms/mathematical concepts.

As Kennedy and Odell (2014) have noticed, STEM education is not a simple sum of the described constituents, and it cannot be perceived as a new name for the traditional methods of teaching biology and mathematics. Also, it cannot be an attempt to implement or add new layers of "engineering" and "technology" to the traditional education standards/curricula. "On the contrary – STEM education is such an approach to teaching that offers a broader perspective than the sum of its constituents; it is a (…) meta-discipline" (Kennedy, Odell 2014: 253), the objective of which is to remove the traditional barriers among particular subjects, and to focus teachers' energy and effort on the "practical application of knowledge in the process of designing solutions for multidimensional, complex problems, with the use of modern tools and technologies" (Ibidem 2014: 246). It requires a radical transformation of curricula so that they not only highlight the interdisciplinary connections between different areas of knowledge but also show the practical usefulness of such knowledge:

- "The engineering component emphasizes the process of designing and testing solutions, not the solutions themselves. Such approach makes it possible for the students to explore mathematics and natural sciences in a more personalized context, and, at the same time, it helps them develop critical thinking which they can use in all aspects of their work and academic life" (Kennedy, Odell 2014: 254). "What is great in engineering is the way the work of brain and hands are connected" (S.G. Pasterski, after: Czubkowska 2019), which not only gives the opportunity to a direct, practical application of knowledge, but also to check the effectiveness and precision of one's own action – the work of hands means using simple or more complex tools to build a prototype/model of a device. It often involves traditional tools – underestimated or even disregarded in modern education, nevertheless these tools, such as a hammer, drill, crochet or mixer help us solve dozens of everyday problems: assemble new furniture, hang a painting on the wall, etc. Without the ability to use such simple tools, we would be helpless in everyday life. Thus, the engineering component is a natural link between biological/mathematical knowledge and the skilfulness in using technological achievements of civilization – both the simplest and the most advanced ones.

- The technological component also has a more advanced dimension, related to the effective use of modern technologies, obtaining programming skills, understanding the structure and work of robots, etc. As emphasized by Kennedy and Odell (2014: 254), such technology makes it possible for the students to apply what they learnt while interacting with the computer equipped with specialist, professional software – using technology becomes a practical tool for learning, studying and organising one's knowledge, as well as sharing it with a community learning online. Also, it facilitates understanding interdisciplinary connections and the holistic nature of human knowledge.

Those two components – engineering and technology, are barely present in preschool education. Meanwhile, as Umaschi Bers, Seddighin and Sullivan (2013) have indicated, they provide the tools necessary for understanding the world created by humans, the way people transformed and used the world of nature for their own needs, the role which technical and technological inventions played in human civilization, as well as threats and limitations of an intensive technological development:

> This is the realm of technology and engineering, which focus on the development and application of tools, machines, materials, and processes to solve human problems. Just as it is important to begin science instruction in the early years by building on children's curiosity about the natural world, it is as important to begin engineering instruction and the development of technological literacy by building on children's natural inclination to design and build things, and to take things apart to see how they work (…). Early childhood education has not ignored that; it is common to see young children using recycled materials to build cities and bridges. However, what is unique to our human-made world today is the fusion of electronics with mechanical structures (the author's emphasis).We go to the bathroom to wash our hands, and the faucets "know" when to start dispensing water. The elevator "knows" when someone's little hands are in between and they should not close. Our cell phones "know" how to take pictures, send emails, and behave as alarm clocks. We live in a world in which bits and atoms are increasingly integrated, however we do not teach our children about that (Umaschi Bers, Seddighin, Sullivan 2013: 357).

Contrary to the traditional subject teaching, STEM education focus on the interdisciplinary connections, showing their backgrounds rooted in certain skills – independent of a given field of science – that constitute broadly defined "scientific thinking," i.e. precise and logical reasoning activated in the process of inquiring the reality, drawing conclusions based on the data collected and checked earlier (so-called inquiry-based learning). Pedagogical literature offers different classifications of STEM skills, majority of which however are dedicated to the needs of higher stages of education (table no. 1). The lacking element is the description of STEM skills applicable in a preschool education. That is why the overview presented in this article should be seen only as an initial recognition of the problem.

The comparative analysis presented in table 1 refers to different options of classifying the key STEM skills which allows to perceive some characteristic regularities. Different authors pay attention to the same categories of skills, although they give them different names and levels of importance.

Table 1. Comparative analysis of different categories the STEM skills

Framework/authors	**Categories of STEM skills**
STEM-ED Scotland (2007) – Building a new educational framework to address the STEM skills gap; a fundamental review from a 21st century perspective (Cooperation between Scottish Government, universities and industry)	1. Learning, study, self organization and task planning 2. Interpersonal communication and team working 3. Numeracy – assessing and manipulating data and quantity 4. Critical and logical thinking 5. Basic IT skills 6. Handling uncertainty and variability 7. Experimentation and prototype construction: design and execution 8. Scientific analysis 9. Entrepreneurial awareness
ISTE Standards (2007) (International Society for Technology in Education)	1. Creativity and innovation – creative thinking, constructing knowledge, and developing innovating products and processes using technology 2. Communication and collaboration – using digital media and environments to communicate and work collaboratively, including at the distance, to support individual learning and contribute to the learning of others 3. Research and Information fluency – applying digital tools to other, evaluate and use information 4. Critical thinking, problem solving, and decision making – using critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decision using appropriate digital tools and resources 5. Digital citizenship – understanding human, cultural and societal issues related to technology and practice legal and ethical behaviour 6. Technology operation and concepts – demonstrating a sound understanding of technology concepts, systems, and operations

Framework/authors	Categories of STEM skills
The Assessment & Teaching of 21st Century Skills (2012) (Collaboration between Cisco, Intel, Microsoft, the University of Melbourne and others)	1. Ways of Thinking: – creativity and innovation, – Critical thinking, problem solving, decision making – Learning to learn – "meta-cognition" 2. Ways of Working: – Communication – Collaboration – teamwork 3. Tools for Working: – Information literacy (includes research on sources, evidences, biases, etc.) – ICT literacy 4. Living in the World: – Citizenship – local and global – Life and carrier – Personal and social responsibility – including cultural awareness and competence
21st Century Skills (2008) (National Research Council – NRC)	1. Adaptability 2. Complex communication/Social skills 3. Non-routine Problems Solving Skills 4. Self-management/Self-development 5. Systems Thinking

Source: Author's own work.

The majority of researchers point to the fact that the basis of STEM thinking is the process of problem-solving which includes identifying and verbalizing the problem, formulating hypotheses, planning and conducting research/experiment for testing this hypotheses, noting the data and drawing data-based conclusions (What can we conclude from the experiment? Why do I think so? What are the proofs to confirm my thesis?). It is important for the problem situation not only to be complex and multidimensional (including elements of various fields of knowledge), but also to be useful and meaningful for the child, because only such a problem can evoke emotional engagement, which supports thinking and memorising experiences gained this way (meaningful learning). Thinking activated while solving such a situation is the core of STEM education – scientific thinking, i.e. precise, logical reasoning based on reliable, verified proofs, which requires independence in formulating generalizations and conclusions. The research shows that the children who participate in STEM education programmes reveal higher level of problem solving skills, being able to design experiment, provide more informative explanations of observed phenomena, and being perceptive to a particular variable in question (Dejonckheere et al. 2016:

161-162). In the authors' own words, "results suggest that children learned through exploration: (1) where there is information to be gained, (2) how to differentiate the causal role of different factors, and (3) how to manipulate particular features in order to test these factors" (Ibidem: 161). These are crucial elements of scientific reasoning and critical thinking fundamental for future self-regulated learning and school success (Kuhn, Dean 2004).

This area of thinking is very well described in pedagogical literature, as it is the basis of the so-called "inquiry-based learning" or "problem-based learning," which is commonly applied in preschool education. As McClure et al. noticed, when young children enter school, "they already have substantial knowledge of the natural world, can think both concretely and abstractly, use a range of reasoning processes that represent the underpinning of scientific reasoning, and are eager, curious, ready to learn" (McClure et al. 2017: 15-16). Strengthening these abilities appears to be aided by early educators' use of scientific and engineering practices, including inquiry-based teaching. This approach is extremely effective because knowledge constructed this way is personal and operational, as it comes from direct, sensorial experience, which facilitates rooting information in long-term memory.

Another important area of STEM skills is creative thinking perceived as the ability to deal with non-routine problems (NRC 2008) – problems that are not typical and require "thinking outside the box." Facing an open problem, to which there are no ready and standard solutions, and which requires the rejection of practiced paradigms of thinking, is a great opportunity to build the flexibility of thinking and adaptability defined not only as the ability to adapt to materials, tools or ways of thinking available here and now, but also as an attitude of openness, readiness for a change, coping with the feeling of uncertainty, incompleteness of data, and contradictory information or opinions coming from the world.

Such divergent thinking involves critical reflection which includes the ability to consciously select materials and information, evaluate the quality of the sources of knowledge – i.e. distinguishing reliable sources from unreliable one, true from false, facts from opinions or other people's interpretations. It involves answering the following questions: How do I know that? Am I sure of my own knowledge? Do I know or guess? In such reasoning, critical thinking becomes the path to the flexibility and adaptability – something we knew for sure yesterday, can be questioned today by the newest scientific discoveries. ISTE Standards specify such reasoning as "information proficiency," indicating that the ability to find information, evaluate its value and usefulness is the basis for adapting to challenges of the modern, changing, uncertain and digitalized world. The authors of The Assessment & Teaching of 21st Century Skills (2012) perceive critical thinking as the basis for meta-cognition, i.e. conscious reflection on the course and efficiency of one's own thinking – What do

I know for sure? What do I fail to understand? What would I like to know and how can I obtain such information? The next step is epistemological reflection, i.e. thinking about the essence of knowledge and criteria of it's validity (Is knowledge certain/permanent or rather susceptive to change? Is knowledge objective, independent of a person, or subjective, personal? Is my knowledge complete and well-ordered?). In case of a young child, such information proficiency or monitoring of one's learning process are beyond the developmental range, however some related skills are available to children although they can be described in literature under a different name, e.g. as "the child's wisdom" (Płóciennik 2018: 121).

An interesting type of STEM education rooted in problem solving, barely present in preschool education, is design (or constructive) thinking (Umaschi, Seddighin, Sullivan 2013), applied by fashion designers, engineers and architects. Its starting point is recognizing the needs in a given situation (i.e. formulating the problem: What do we want to improve and why?). The next step includes brainstorming, searching for possible solutions during teamwork, drawing an initial design of a solution and building a prototype of a machine or device, as well as testing it, i.e. checking whether it works (What works and what does not and why? What should be changed or corrected?). Thus, the phase of testing the prototype ends with drawing conclusions and improving the solution. This kind of thinking is hardly ever activated in preschool, although children eagerly take up activities like that. An important advantage of design/construct challenges is creating educational opportunities for practicing the children's ability to use simple technology, deal with available materials and tools, get to know their properties, and look for innovative and effective solutions. There is an obvious relation between design thinking and Guilford's sensitivity to problems, device tests and other training tasks of divergent thinking.

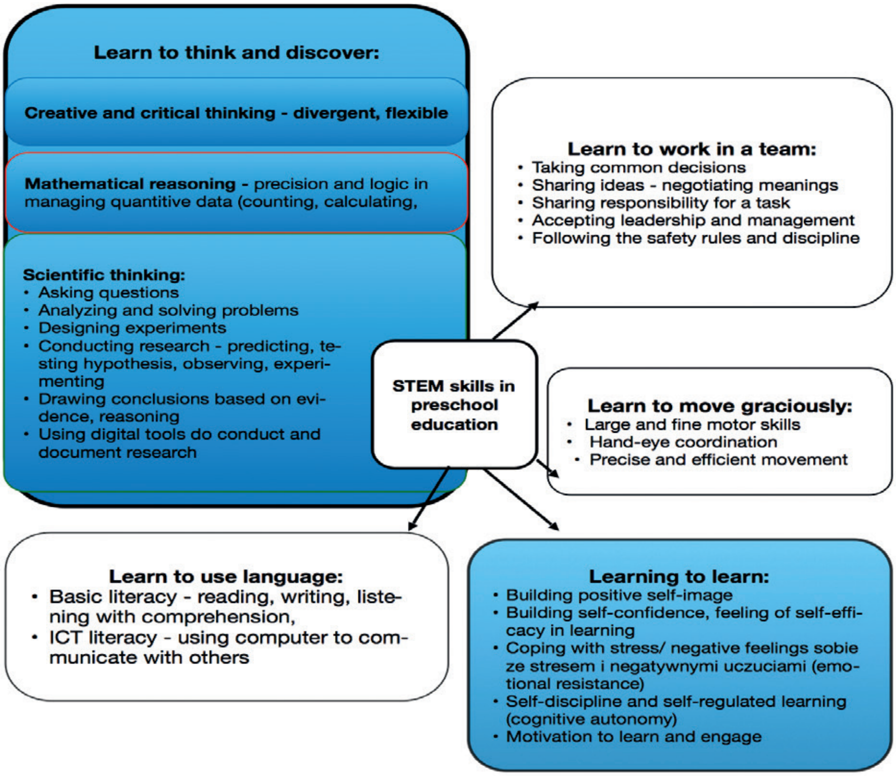
All the above-mentioned core STEM skills clearly belong to the cognitive sphere of development. However, the idea of STEM education also emphasizes the role of emotions in learning – not only in terms of arousing the internal motivation to learn. As the authors of *STEM-ED Scotland* say (2008: 3), learning is best driven by "thirst" of knowledge, implying interest and engagement. That is why, an important place in the classifications of core STEM skills is occupied by self-regulation of learning – the ability to plan tasks on one's own, organise and summarise information, make clear notes, evaluate the effectiveness of one's own learning, realise the scope of one's knowledge/lack of knowledge, etc. The National Research Council specifies such attitude as "self-management/self-development" (2008), pointing out that cognitive autonomy and the student's sense of subjectivity built in early childhood shall become the basis for conscious management of one's own career and lifelong learning. The research proves that early experiences in learning science are critical for the school readiness as a foundation for future learning (Dejonckheere et al. 2016: 149). They also stimulate the development of a concept of oneself as a science learner, empowering the child and supporting him in the process of building self-efficacy and the individual learning potential (Claxton et al. 2016).

The experience of Maria Montessori kindergartens proves that the development of a cognitive autonomy is strongly connected with shaping the sense of responsibility for one's own learning and understanding the consequences of not doing something we are obliged to do. Naturally, young children are unable to write down their plans, but they can draw them on a weekly card, planning what they would like to learn and achieve on particular days of the week. Children are also able to report the results of their work in front of the group, describe their obligations, admit that they failed and look for the reason of such failure (Stoll Lillard 2007). Such experiences help to build the child's identity as a learner, the awareness of one's own potential in the area and a feeling of self-efficacy allowing to take up further actions without internal fear and hesitance, undertaking the control over their own learning process (I know/I can).

The social-emotional dimension of the learning process includes the ability to work in a team, which consistently appears in all the classifications of STEM competences. The awareness of the group work mechanisms, taking the role of a leader and subordinate, sharing tasks and responsibility, negotiating the meanings, explaining one's process of thinking to others – these are important constituents of teamwork skills. The effect of group work is always synergic; it goes beyond the cognitive possibilities of both an individual and the sum of participants' individual knowledge. Group members encourage and motivate one another, which facilitates the creation of innovative solutions. The complexity of modern knowledge results in the fact that no researcher, constructor or scientist working alone is able to achieve such results as he/she would be able to achieve in a well-organized and differentiated group. The internal diversity of skills and experiences defines the team richness and determines its strength.

To summarize, the above-mentioned STEM skills are very difficult to classify due to their interconnected and interdependent character. Ranking them is even more difficult considering that fact that the set of skills needed in a particular task may be different in another. The figure below presents the STEM skills that should be shaped in preschool education – the matrix was created as the result of focus group and individual interviews with kindergarten teachers, carried out in 4 partner countries participating in the project KLab4Kids (the exact description of the methodology of the research is presented in the next part of the text).

Graph 1. Matrix of Core STEM skills for preschool education designed within the Erasmus+ KLab4Kids project.



The reference of STEM education to the kitchen and the cooking process, suggested in our project, makes it possible to introduce the metaphor of a kitchen as a specific scientific laboratory equipped with tools and ingredients necessary for carrying out scientific experiments, causing chemical reactions, and observing their course and results. The project is based on the idea of cooking as a scientific process that integrates the elements of scientific, chemical and physical knowledge with the values of healthy, sustainable cuisine.

In this context, it is worth checking which of the values and aims of STEM education are recognised and appreciated by the students of preschool and early school education – future teachers of young children.

Methodology of research

The research was carried out from June to September 2019 on a project website where an anonymous survey was included. Its main objective was recognizing the knowledge and opinion of preschool teachers about the possibilities to carry out STEM education with the use of a preschool kitchen perceived as a kind of laboratory equipped with various materials and tools that can be used to conduct interdisciplinary scientific experiments. The research was designed and carried out within the project Erasmus+ KLab4Kids. Five universities from 4 EU countries are participating in the project: Fondazione Politecnico di Milano (FTM – Italy), Universitat Internacional de Catalunya (UIC – Spain), Dublin City University (DCU – Ireland), and Libera Università Maria SS. Assunta di Roma (LUMSA – Italy). The method employed has a qualitative-quantitative character and included two stages of work:

1. At the first stage, each of the partner countries carried out focus group interviews with the students of preschool and early childhood education (2 groups of 8-10 people in each country), and semi-structured interviews with in-service teachers (10 teachers in each country). The aim of that stage was collecting the empirical data for preparing the main research tool – project survey, i.e. the initial recognition of the teachers' opinions and language they use to explain the essence and objectives of STEM education at the preschool level. The most important result of this stage was designing the above presented matrix of core STEM skills available to the children at the preschool age;
2. At the next stage, the collected empirical material was ordered, selected and used to prepare an e-questionnaire consisted of 19 questions. The survey included two main parts: the first one was dedicated to the teachers' knowledge of STEM education, and the second one – to the opinions on the possibility to use the kitchen/cooking environment for organizing the STEM workshops in preschool. This tool was later translated into national languages (Polish, Italian and Catalan) and uploaded on the project website (the full version of the questionnaire is available at http://kitchenlab4kids.eu/?page_id=688).

Due to the extend of the collected material, only partial results shall be presented here, i.e. the opinions of the Polish group of respondents (pre-service teachers only), referring to only a few selected questions of the questionnaire (8 questions were selected for the analysis). The research problems of the presented part of the survey were as follows:

- How do pre-service preschool teachers understand the essence of STEM education?
- How do they define the objectives of this education in reference to the cognitive, social and emotional areas of child's development?
- What opportunities and barriers/challenges of such education do they notice in the preschool environment?

Pre-service teachers on the possibility to develop STEM skills in preschool – research results

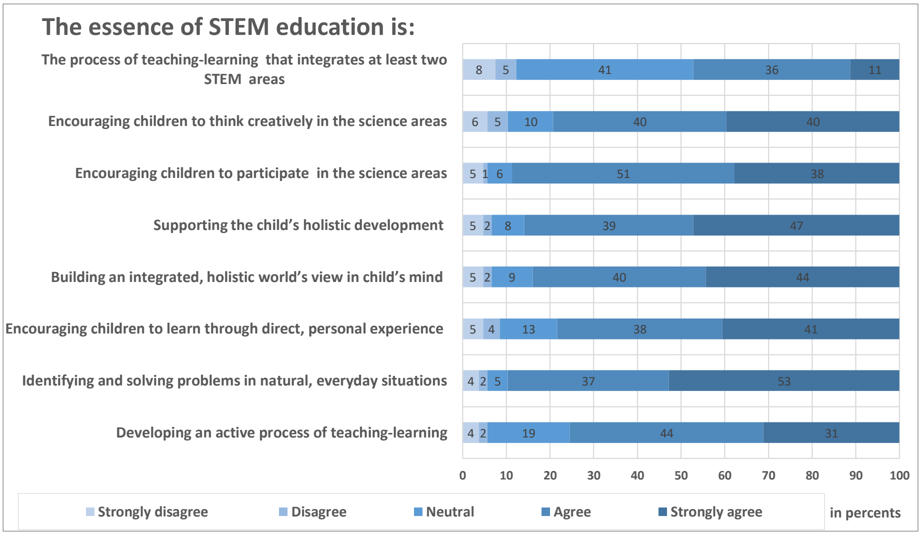
The research sample consisted of 106 students of preschool and early school pedagogy attending the 3rd year bachelor's studies and 2nd year master's degree. Among them 59% have already worked with children, including 34% in private institutions and 12% in public kindergartens.

Majority of the respondents (91%) declared that they know what STEM education is. However, their awareness of the essence and aims of this area of education seems to be rather superficial – they associate STEM with broadly understood holistic education based on the problem-solving strategy and the children's active participation in the learning process (chart 1. When asked about the essence of STEM education, the students replied that it is:

- identifying and solving problems in natural, everyday situations with which preschool children are familiar (so-called meaningful learning) – 90% of the answers;
- encouraging children to take active participation in the process learning science – 89%;
- building the holistic image of the world in the child's mind – another 84%;
- encouraging children to creative thinking in the science area – 80% of the replies.

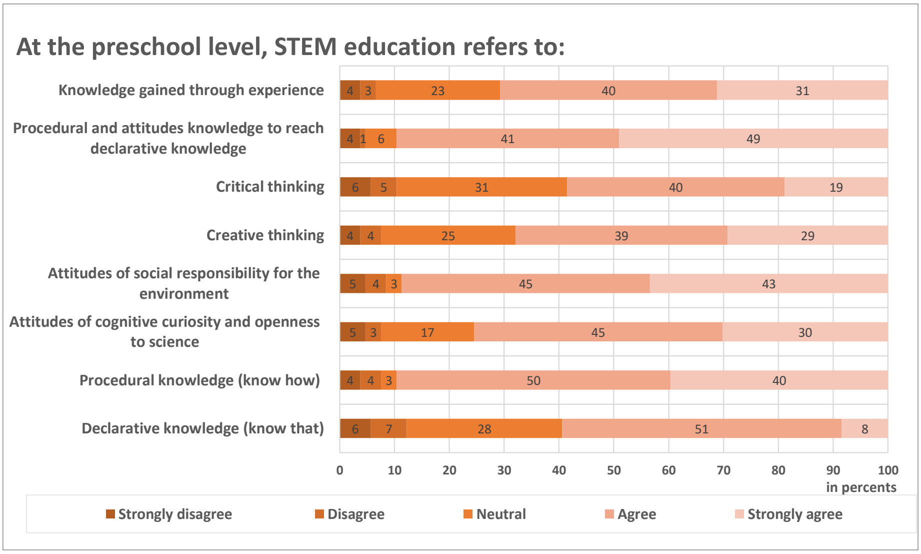
Interestingly, the smallest number of people agreed with the statement that the essence of STEM education is integrating the contents of least two different STEM disciplines in one situation/task/problem (which according to pedagogical literature constitutes a defining feature of STEM education). Over 13% of the respondents disagreed with such statement and another 41% were unable to take any stance on this issue (chart 1).

Chart 1. The respondents' replies to the question: what is the essence of STEM education? Source: Authors' own research.



An interesting aspect was respondents' perception of the main objectives of STEM education at the preschool level. In students' opinions, the preschool STEM workshops refer mainly to gaining procedural knowledge and attitudes as the starting point for reaching declarative knowledge (90% of replies) and shaping the attitudes of social responsibility for the environment (87%). Quite a large group of people also indicated the role of STEM education in strengthening the attitudes of cognitive curiosity and openness to scientific knowledge (75% of replies), another 71% emphasized the meaning of practical knowledge obtained through direct, sensorial experience.

Chart 2. The respondents' replies to the question concerning STEM education aims at the preschool level. Source: Authors' own research.



The most poorly identified objectives of STEM education at the preschool level were:

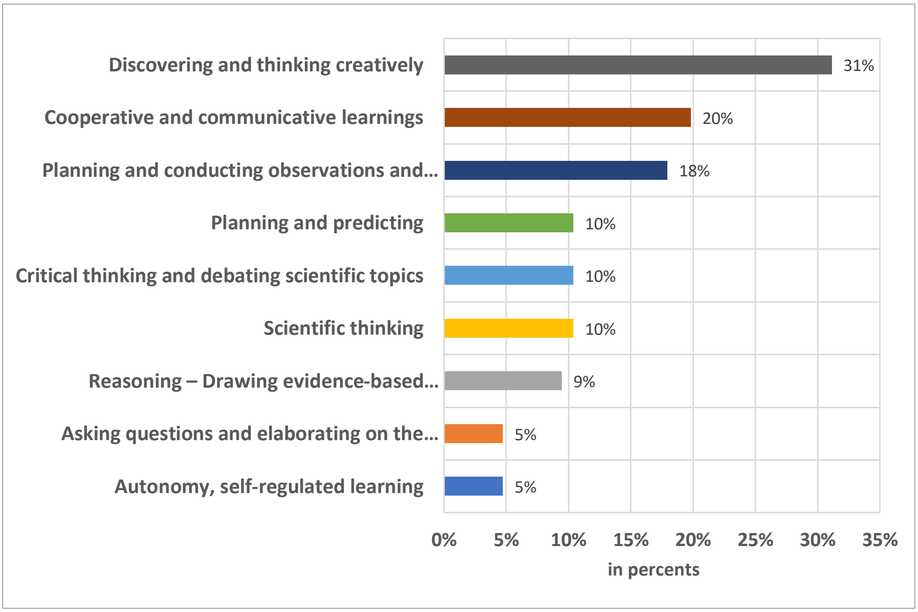
- shaping critical thinking (49% of the respondents agreed that it is an important area; further 31% were unable to give their opinion on it, and 11% disagreed), and
- developing creative thinking (only 68% of the respondents recognised its meaning; 25% were unable to take any stance, and 8% questioned the role of creative thinking in the preschool STEM education).

The next three questions also referred to the objectives of STEM education at the preschool level, but instead of the Likert scale, the multiple choice questions were used in this part. The freedom of choice was designed as a form of verification of the answers to the previous two questions. The surveyed students were asked to select three most important (a) cognitive, (b) social and (c) emotional skills, the development of which is particularly stimulated by STEM education. The selections made by the respondents are presented in the following charts.

A particularly interesting part was students' perception of the possibilities to support young children's cognitive skills. Almost 1/3 of the respondents indicated creative thinking as the most important task in this area. Almost 1/5 of them underlined the capabilities of planning, experimenting, observing and learning to cooperate with others. The skills which – according to the literature – are the core of STEM thinking, have not been appreciated by the respondents:

- only 10% of the respondents noticed the importance of young children's scientific thinking, as well as their ability to formulate action plans and predict their efficiency, critical thinking, the ability to evaluate and assess validity of scientific statements, to find "pros" and "cons" arguments;
- only few people paid attention to the possibility of developing the skill of asking questions, formulating hypotheses and building the child's autonomy in the learning process;
- interestingly enough such ability as searching for information and comparing data presented in different resources was not appreciated by any respondent.

Chart 3. The most important cognitive skills that can be developed by STEM education in preschool – in the opinion of the respondents. Source: Authors' own research.



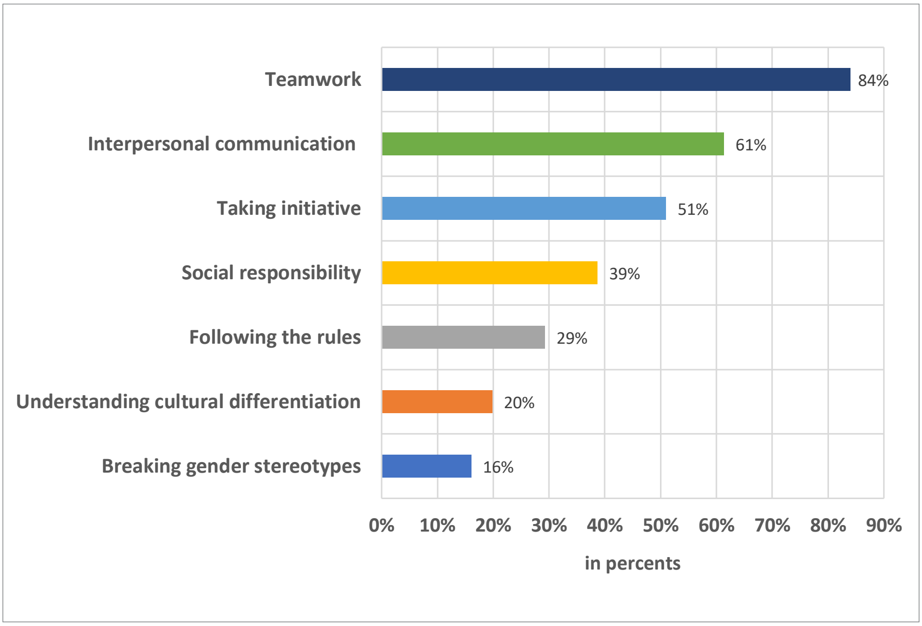
While analysing STEM education as the area of social development of young children (chart 4), the respondents decided that it mainly facilitates the teamwork abilities, taking up different roles in a team (more than 84% of replies), and develops the ability to communicate with others while performing tasks (61% of replies). Other social skills were not so widely appreciated:

- only 51% of the respondents believe that STEM education allows to strengthen young children's ability to take initiative reflected in such skills as asking spontaneous questions, experimenting, suggesting other ways of fulfilling a task, etc.;
- only 39% believe it is the opportunity to develop social/group responsibility (as opposed to individual, personal responsibility) for fulfilling the task;

- only 29% of the students agreed that the important aim of STEM education is also following the rules and obeying the teacher's instructions which ensure order and safety in the class.

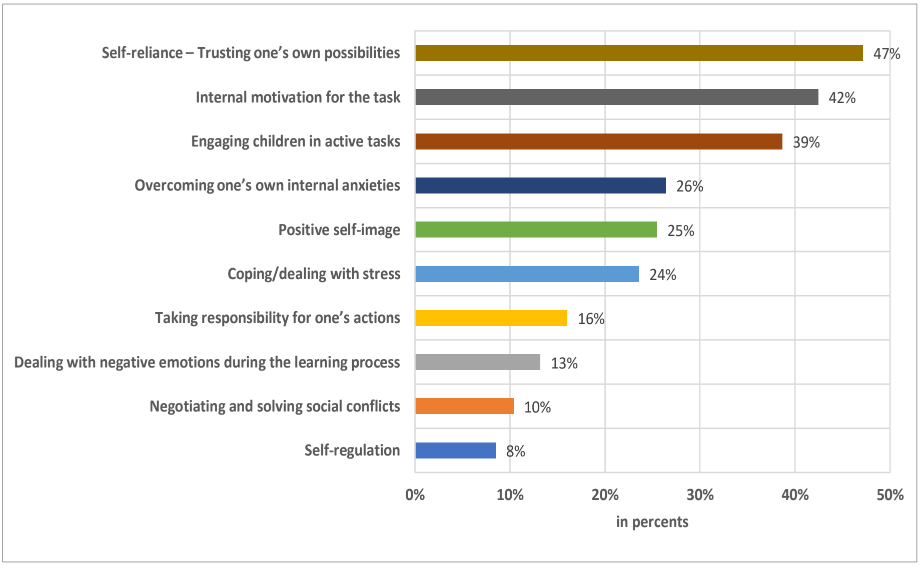
The smallest number of respondents appreciated such aims as respecting cultural diversity (20% of the replies), which may be justified by the homogeneous nature of the Polish society, along with overcoming gender stereotypes which, apparently are not perceived by students as important among preschool children (16% of the replies).

Chart 4. The most important social skills that can be developed through STEM education in preschool – in the respondents' opinion. Source: Authors' own research.



Another interesting and highly differentiated area of pre-service teachers' opinions was the perception of the role of emotions in STEM education (chart 5). The most essential task in this area of education was perceived as improving young children's independence and emotional resistance, as well as building their trust to their own strengths and possibilities (47% of the replies). Also developing the children's internal motivation to act was perceived as important (42%). At the same time, only ¼ of the respondents believe that STEM workshop can create the possibility for learning to overcome children's internal fears and anxieties (26%), build a positive image of oneself as a person/individual/friend/learner (25%), and deal with fear, stress and shyness that may accompany preschool classes (24% of the replies). Surprising low position in students' choices was obtained by self-regulation, as if they failed to understand or appreciate it, although it is a necessary prerequisite for building preschool children's autonomy in acting, thinking and studying. It seems that the concept of self-regulation is unknown to the majority of the respondents (only 8% of the replies).

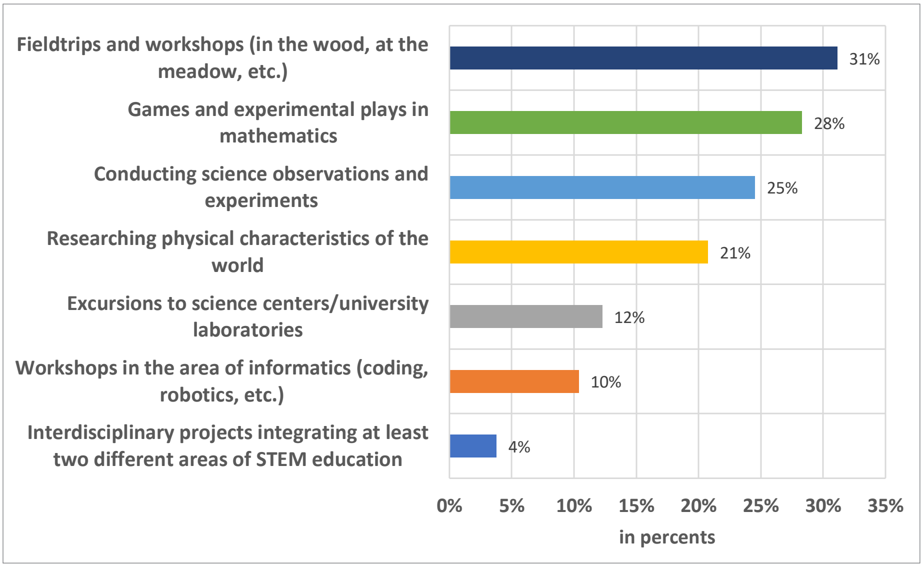
Chart 5. The most important emotional skills that can be developed through STEM education in preschool – in the respondents' opinion. Source: Authors' own research.



Another question was related to the students' experience in carrying out STEM education in preschool environment (chart 6). Most of the respondents, despite having various experiences in working with children (a lot of them work in kindergartens or babysit), have not conducted any STEM workshops – neither in their own work nor while pedagogical practicum. Only 1/3 of the respondents took part in field classes (in the meadows, forests or gardens); another 28% organized mathematical games and experiments, and 25% of them conducted scientific experiments which are well-described, popularized in pedagogical literature, perceived as interesting and engaging for children.

Only 4% of the respondents have come across an interdisciplinary experience or project, i.e. project internally connected with at least two different STEM disciplines. Not only does it confirm low quality of pedagogical practices, but it also means that in the kindergartens in which the respondents learnt during the studies interdisciplinary projects hardly ever occur. The most surprising factor is however the low percentage of the respondents who had the opportunity to organize IT or robotics workshops – only 10%, although this area has been present and well grounded in the curricula of pedagogical studies since many years. The educational offer of such workshops for children and training sessions for teachers seems very rich and both children and their parents are really interested in them. Nevertheless, modern technologies seem to be barely present in the preschool practice.

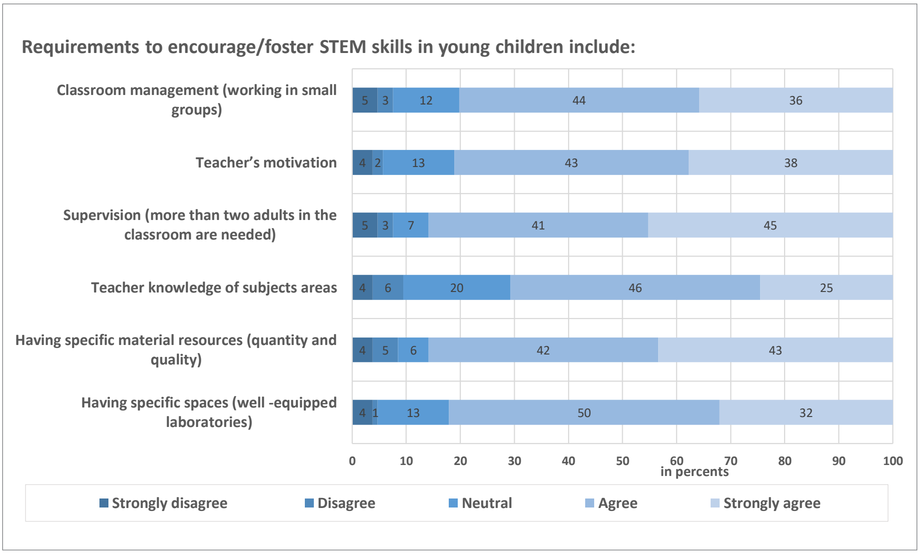
Chart 6. The respondents' own experience in organising STEM classes in preschool. Source: Authors' own research.



The respondents were also asked what are the main requirements to organize STEM workshops with preschool children. The replies focused mainly on external factors. Detailed answers were presented in chart 7. The most frequently indicated needs included:

- providing proper (in terms of quantity and quality) didactic materials necessary to carry out the scientific experiments (85% of the replies),
- well-prepared spaces (laboratories) where children can safely carry out experiments (also more complicated ones) and observations. These rooms should meet the proper safety requirements.

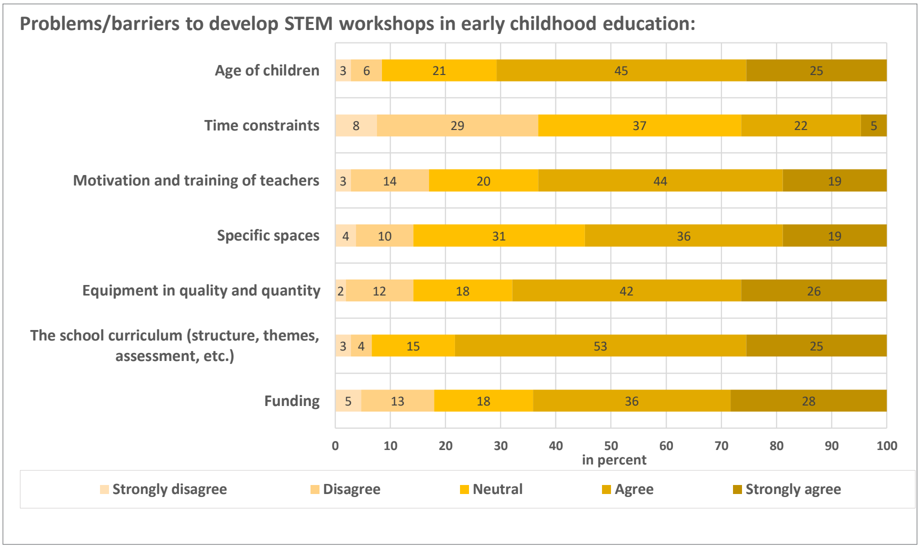
Chart 7. The respondents' replies concerning the needs related to the development of STEM skills among preschool children. Source: Authors' own research.



Additional didactic support was recognized as a very important factor, i.e. the supervision of more than two adults (86% of the replies), which allows to organize small teamwork and engage children into active work (another 80% of respondents). Additional support is very important in carrying out experiments that require particular attention, carefulness, following safety rules. Other elements highlighted as the aspects needed to carry out STEM education included the teacher's knowledge (71%) and motivation to conduct such classes. Interestingly, at the same time as much as 63% of the respondents considered the teachers' insufficient preparation and motivation as important obstacles in carrying out preschool STEM classes (chart 8).

However, the most problematic issue in introducing STEM classes into preschool results from the need to follow the curricula and other official educational documents which are perceived as stiff and hindering the implementation of STEM classes with their specific topic and structure (78% of the replies).

Chart 8. The respondents' replies concerning the problems they faced in the kindergarten with regard to STEM education. Source: Authors' own research.



Quite a numerous group of the surveyed students (70%) doubt whether it is possible to carry out the STEM workshops with young children – they believe that the children's age is a serious barrier. A similar number of the respondents (68%) indicates the insufficient equipment of the kindergarten with the proper tools and teaching aids as a problem. Another 64% points the lack of proper fundings necessary to buy products or ingredients for science experiments. Interestingly, only 27% of the students believe that time limitations are an obstacle in carrying out the STEM classes (37% has no opinion on this issue, and 37% do not perceive time as a problem). Due to the lack of experience, a lot of respondents did not express any opinion on the issues in question.

Conclusion

While summarizing the results of the research that has been carried out, it is worth mentioning that the pre-service teachers' knowledge of the essence and objectives of STEM education turned out to be rather superficial, poorly crystallized, and sometimes even internally contradictory, much closer to common convictions (lay concepts) than to scientific knowledge. It may be described as a "knowledge in the course of constructing" or "knowledge in development," not fully grounded in scientific ideas, and therefore difficult to be consciously justified or explained. Although majority of the respondents declared that they knew the term STEM, they associated it with broadly understood holistic education or thematic correlation rather than with the strategy of problem-solving or scientific thinking activated in a natural, meaningful context. It is difficult to indicate the reasons for such a superficial interpretation: it may result from insufficient professional preparation of pre-service teachers during their pedagogical studies, or from the awareness of preschool everyday limitations, or perhaps from the lack of faith in the young child's cognitive and social-emotional possibilities – underestimation of their potential as for the conscious learning and achievement of cognitive autonomy. The latter explanation is particularly confirmed by the fact that 90% of the surveyed students did not perceive STEM education support for young children scientific thinking development (with such important components as asking research questions, formulating hypotheses, evaluating and assessing scientific statements as true/false, or drawing one's own conclusions based on the conducted experiments). It seems that – for many students – also professional language and terminology used in the survey was a certain barrier (e.g. the term "self-regulated learning), which confirms the naive character of students' knowledge.

The research proves that such immersion of a teacher in the common knowledge is an extremely dangerous phenomenon leading to stiffening and trivialisation of pedagogical practice, as well as making the preschool activities shallow or intuitive. It is hard to avoid the impression that the surveyed students are not very well prepared for facing the challenges of the 21st century and it will be difficult for them to become the "architects of educational change" in the future (Goodwin 2019). As Lilian Katz emphasizes (after: Stewart 2012), to recognize the value of STEM education, teachers should grasp the difference between "academic learning" (based on intellectual abilities like memorizing, repeating, counting, reading and reciting) and "deep learning" which takes place through natural interaction with real things in the child's environment and engages cognitive operations like: reasoning, predicting, drawing conclusions, decision-making, etc. The research has demonstrated that "children benefit from contextualized, integrated lessons, and integration often deepens understanding of relevant concepts, promotes problem-solving abilities, and supports understanding how scientific concepts work/are applied in the real world" (McClure et al. 2017: 17). An important value of STEM education for young children is also the possibility of acquiring scientific language in a natural, meaningful context – which makes this language easier and handy, ready to be transferred into other contexts. Integrating language arts into STEM activities not only facilitates the process of acquiring scientific vocabulary, but also supports oral communication, creating the context for something that Lev S. Vygotsky calls "speaking for learning" (1989: 92). Being able to express one's own process of thinking in order to share the experiences and search for/negotiate common meanings with others is described by Jerome S. Bruner as "externalization" and should be seen as an important tool for creating "culture of thinking" in the classroom (2006). Providing preschool teachers with such tools for deep, personal learning is an important aim of the KLab4Kids project.

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ADDRESS FOR CORRESPONDENCE

Dorota Zdybel
Jesuit University Ignatianum in Krakow, Poland
e-mail: dorota.zdybel@ignatianum.edu.pl

Irena Pulak
Jesuit University Ignatianum in Krakow, Poland
e-mail: irena.pulak@ignatianum.edu.pl

Yvonne Crotty
Dublin City University, Ireland
e-mail: yvonne.crotty@dcu.ie

María Teresa Fuertes
Universitat Internacional de Catalunya, Spain
e-mail: tfuertes@uic.es

Maria Cinque
Libera Università Maria SS. Assunta di Roma, Italia
e-mail: maria.cinque@lumsa.it