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Impact of innovative STEAM education practices on teacher professional development and 3-6-year-old children's competence development

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Abstract

Over the last decade, STEAM has been treated as a model of interdisciplinary integral education that facilitates solving social, ecological and economic problems related to technological development in different countries. STEAM education is most efficient when it is organised in early childhood education, thus increasing children's motivation to study and to link STEAM disciplines with their career, as well as to develop as engaged citizens. The conducted empirical research revealed the following new data on STEAM at an early age: a) early childhood teachers apply practices of STEAM education that target the development of children's soft (problem-solving, creativity, ability to learn, communication) skills more frequently and employ practices for nurturance of their hard (mathematical, technological, engineering) skills less frequently ; this imbalance is favourable for the development of a proactive and critically thinking child, who is able to make decisions in a responsible way, but it does not ensure the sustainable development of STEAM abilities; b) the application of innovative STEAM education practices has effects on teacher professional development; c) STEAM practices have a bigger integral impact on the development of 3-6 year-old children's competences through the teacher professional development rather than directly.

Key words: *early childhood education, STEAM, practices, teacher professional development, children's competences*.

Introduction

In 1990, STEM (Science, Technology, Engineering and Math) was underscored as fundamental areas of learning in the 21st century (English, 2016; Ata Aktürk & Demircan, 2017; John et al., 2018). Later, this set of fields was supplemented by arts as a basis for creativity development, and STEM was modified into STEAM (Kim & Park, 2012; Land, 2013; Sochacka et al., 2016; DeJarnette, 2018). In this article, the concept of STEAM will be used. STEAM is defined as holistic education, integrating the fields of science, technology, engineering, arts and mathematics,

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as a model of interdisciplinary creative education (Bati et al., 2018; Wang et al., 2018; Ata Akturk et al., 2017).

The goals of STEAM implementation in different countries respond to both global and local challenges. The ambition to support a growth of technological innovations through training more employees with necessary competences is also a global phenomenon. Attention to STEAM education starting with the level of early childhood education contributes to the assurance of sustainable positive attitude of children towards STEAM disciplines, as well as sustainable, consistent development of their abilities (DeJarnette, 2018). Different countries face different challenges. For example, researchers state that the USA has fallen behind other developed countries in mathematics and science (DeJarnette, 2018) and that South Korea should increase school learners’ motivation for choosing to study mathematics and science (Park et al., 2016). They also refer to China’s challenge to cope with the lack of high-level talents (Wang et al., 2018) and to the timely preparation of Australia for the future, when about 75 percent of future jobs will require mathematical, analytical thinking and problem-solving abilities (Simoncini & Lasen, 2018).

It was very soon acknowledged that in order to seek better learning outcomes in STEAM education, actions are needed at the earliest levels of education, i.e. early childhood education, which provides the highest rates of return on the development of the individual’s motivation and abilities and ensures their further sustainable improvement (Bers et al., 2013; DeJarnette, 2018). The researchers raise the idea and substantiate the importance of early STEAM identity development by research (Dou et al. 2019; Hachey, 2020). The identity is explained as the child’s interest in investigations in STEAM areas and strongly predicted career choices in STEAM areas (Dou et al., 2019).

According to the researchers, early childhood and pre-primary education should be enriched with innovative practices (Akman et al., 2017; Monkeviciene et al., 2020) and aids in these areas to promote children’s interest and their intentions to link their future with activities in STEAM areas (Sharapan, 2012; Torres-Crespo et al., 2014; Kermani & Aldemir, 2015; Kazakoff et al., 2013; Ata Aktürk & Demircan, 2017; Park et al., 2017; Campbell et al., 2018). STEAM education practices are understood as an environment and aids suitable for STEAM education, activities and innovative pedagogical methods that stimulate investigations and creative thinking (Campbell et al., 2018).

Researchers, who study teachers' preparedness to implement STEAM in early childhood education, emphasize the differences in the level of preparation of pre-school and subject teachers. DeJarnette (2018) states that basic and secondary school teachers possess sufficient subject-specific and pedagogical knowledge necessary for STEAM activities because they are specifically trained. However, teachers at the early childhood education level do not possess sufficient knowledge and instruction, lacking resolution and self-confidence. They have unreasonable fears and avoid organising STEAM activities in their pre-school groups, even though they acknowledge the benefit of STEAM for learning outcomes of children (Bers et al., 2013; Park et al., 2016; Brenneman et al., 2019). The conducted research studies show a considerable advantage of professional development to abilities of early childhood teachers to implement STEAM education. It has been established that teachers lack knowledge of STEAM disciplines, understanding of technological and engineering processes and appropriate pedagogical strategies (Bers et al., 2013; John et al., 2018). A targeted 2-3-day professional development workshop (e.g. for using robotics) had a statistically significant influence on teachers' abilities in all the fields. Moreover, their professional self-efficacy strengthened and their attitude towards STEAM became more positive (Bers et al., 2013). The studies also evidence that workshops are more efficient when teachers participate in hands-on STEAM training and if a teacher gets support from an assistant or a mentor (DeJarnette, 2018; Aldemir & Kermani, 2016). Brenneman et al. (2019) designed the SciMath-DLL model for the development of a teacher's competence in the STEAM area, which aims to improve the teacher's preparation for natural science, mathematical and bilingual education. The researchers applied three forms of teacher competence improvement: workshops, reflective coaching cycles and professional learning communities. The model was efficient and contributed to improvement of STEAM educational practices. The teacher's competence in properly balancing educational content, STEAM aids and methods of education is also important for the implementation of STEAM (Bers et al., 2013; Mengmeng et al., 2019). The teacher's beliefs and attitudes towards STEAM implementation serve as the strongest prerequisite for his or her professional self-efficacy in this area (Park et al., 2017; Bagiatti & Evangelou, 2015).

On the other hand, all of the above-mentioned studies, which show a positive impact of teachers' professional development on the implementation of STEAM, were carried out by conducting training and organising other professional development activities and interventions for groups of teachers of limited scope. Meanwhile, today's educational issues motivate most teachers to apply

STEAM education practices spontaneously and in a planned manner without prior special training. It is likely that in the process of the implementation of STEAM practices, teacher professional development takes place naturally. Thus, after researching the impact of professional development on the implementation of STEAM, another equally relevant question arises as to whether the daily, natural application of STEAM practices may promote teacher professional development.

Some researchers claim that many teachers notice a positive influence of STEAM implementation on children's achievements in their school maturity (Toran et al., 2020), on acquisition of essential concepts, in knowledge and abilities of STEAM disciplines (Park et al., 2017), and in the enhancement of their interest in mathematics as well as on the development of their convergent thinking, creativity, and problem-solving skills (Bagiati & Evangelou, 2016; Park et al., 2016). The methodology of these studies included teacher professional development activities. Another study analyses the natural process of the implementation of STEAM without teachers' prior preparation for these activities. In their article, Brenneman et al. (2019) summarize research which shows that the implementation of STEAM in natural pre-school education is spontaneous and poor, and therefore has no major impact on the development of children's math, science, language and other skills. However, there is a lack of evidence on the impact of the application of innovative STEAM practices in the natural process of education without prior preparation in the development of 3-6 year-old children's general competences, not only on the development of abilities in the fields of STEAM.

Research Questions

This research study focused on finding the answers to the following research questions:

1) How often do pre-school teachers apply various STEAM education practices (environments, activities and methods of education)?
2) What impact does the application of innovative STEAM education practices have on teacher professional development?
3) What impact does the application of innovative STEAM education practices have on development of 3-6 year-old children's competences?

Literature Review

STEAM education is defined as interdisciplinary approach integrating the development of knowledge and skills in science, technology, engineering, arts and mathematics (English, 2016; Ata Aktürk & Demircan, 2017; Campbell et al., 2018). When referring to primary and secondary education, Bati et al. (2018, p. 3) emphasize the use of an engineering design model in STEAM education: ‘the concept of integrated design in engineering may be an important turning point for STEAM education.’ English (2016) distinguishes the following steps of the engineering design process: identifying and defining the problem, searching for and evaluating possible solutions, optimizing solutions through experimentation, testing and improvement, which are a way to integrate all STEAM subjects.

Meanwhile, a review of research carried out at the early education level allows us to define the process of STEAM education as a game and a natural interest in the world (Ata Aktürk & Demircan, 2017; Aldemir & Kermani, 2017; Campbell et al., 2018). Discussing the models of STEAM education, Murphy et al. (2020) characterise STEAM in early education as a daily natural process applying child-led ‘playful pedagogies’. Researchers state that STEAM education is not too complex for early age children as it is grounded on children’s natural interest in how the world around them ‘works’ and on their inclination to design things and test how they work (Knaus & Roberts, 2017; Ata Aktürk & Demircan, 2017; Kazakoff et al., 2013). A child’s daily environment is both natural and human-made (objects that ‘see’, ‘hear’, ‘speak’, e.g., toys that repeat the child’s words). According to Bers et al. (2013, p. 357), ‘what is unique to our human-made world today is the fusion of electronics with mechanical structures’, and a child is capable to investigate it. By playing in a natural environment and with human-made objects, children naturally explore complex phenomena, acquiring knowledge and abilities in the field of STEAM (Campbell et al., 2018). Practical activities with children prove that they easily memorise and start using elementary concepts of STEAM (Moomaw & Davis, 2010). The child’s holistic and syncretic understanding of the surrounding world is a favourable prerequisite for implementation of an important principle of STEAM education, i.e. integration of science, mathematical, engineering and technological education (Ata Aktürk & Demircan, 2017).

STEAM implementation practices (environment, aids, children's activities and ways of education), like the whole process of pre-school education, are integral. Pre-school education is not divided into separate subjects, such as science, mathematics, arts, etc. (Campbell et al., 2018). In a natural or specially created educational context, which includes the environment and aids, children engage in a variety of activities spontaneously or under the guidance of the teacher, exploring complex phenomena and creating models of these phenomena.

In order for teachers to be able to choose appropriate educational aids, create environments, anticipate activities accessible to children and choose effective ways of communicating with children, they need to be able to look at the phenomena naturally explored by children from different perspectives of STEAM subjects. As observed by Putriene (2017), who, in her dissertation analyses the problem of interdisciplinarity education and summarises the experiences of many researchers, each discipline is based on concepts, cognitive instruments and knowledge systems of a separate scientific field, which can be combined in the educational process. Those teachers who have a better understanding of the perspectives of integrated disciplines are more successful in constructing situations of a holistic understanding of phenomena in the educational process (Putriene, 2017) and are more successful in using explanations and concepts of phenomena accessible to children from the perspective of different fields of disciplines (Knaus & Roberts, 2017). Studies show that teachers lack subject knowledge (DeJarnette, 2018), which reduces the effectiveness of STEAM education, since teachers' communication with children in the context of their natural explorations does not help them to reflect their discoveries from the perspective of different subjects. When conducting research, it is important that teachers look at the application of STEAM education practices from the perspectives of the fields of science, mathematical, technological, engineering and art education and thus reveal the depth of their understanding (see Fig. 1). There are studies that have followed this approach. The research carried out by Campbell et al. (2018) on STEM practices in pre-school education recorded children's play situations and themes of children's explorations, in which teachers recognised the content of different STEM disciplines, such as science, mathematics and technology. The teachers who participated in the research conducted by Aldemir and Kermani (2016) modeled integrated STEAM education situations in which the central theme was related to the field of science and was integrated with technology, engineering and mathematics activities and concepts for children to explore the theme of nature.

Practices that focuses more on science education in the integrated context of STEAM education (see Fig. 1) include environments, aids and activities that encourage children to explore natural objects and phenomena (water, soil, weather, wind, heat, motion, plants, animals, the human body) and systems (the Ecosystem, the Earth, the Solar system); to explore and to create models of these objects, phenomena and systems (a garden of a young gardener, an insect 'hotel', a river in the sandbox, models of the planets); to raise questions about the surrounding world, to observe it, to interpret relations and to make observations and conclusions (Campbell et al., 2018; Aldemir & Kermani, 2016; Ata Aktürk et al., 2017). *Practices of technological education* in the context of STEAM education include environments, aids and activities which, through the use of Engage-Explore-Reflect (E-E-R) cycle, stimulate explorations of the structure and functions of tools (measuring tools, magnifying glasses, sand sifters, wooden sticks), simple mechanisms (levers, pulleys) and instruments (microscopes, wind vanes, scales) and the development and testing of models of the above-mentioned tools, mechanisms and instruments, as well as explorations of technological processes (cooking, robotics), chemical reactions (dissolution in water, vinegar and baking soda reaction) and the use of modern media and augmented reality objects (Hoisington & Winokur, 2015; Campbell et al., 2018; Ata Aktürk & Demircan, 2017; Aldemir & Kermani, 2016; Knaus & Roberts, 2017; Bers et al., 2013). *Practices of engineering education* in the context of STEAM education include environments, aids and activities which, when following the steps of the engineering design process, encourage explorations of the properties of diverse open-ended, structured and semi-structured materials (blocks, Lego, robotics kits, natural materials), design of buildings and equipment (bridges, roads, cities, robots, inclined plane), development of design solutions, building and construction as well as explorations of balance, stability, connections and distinctive features of structures (English, 2016; Bagiati & Evangelou, 2015; Campbell et al., 2018; John et al., 2018; Ata Aktürk et al., 2017; Knaus & Roberts, 2017; Moomaw & Davis, 2010). *Practices of mathematical education* in the context of STEAM education include activities in which children use Lego, Duplo, constructors, robotics kits, natural objects, calculators and measuring instruments, which help them discover number sense and sequences, recognize scales, regularities, patterns and structures as well as create and measure thereof and thus develop mathematical thinking. These practices also make use of coding and programming toys, which develops computational thinking skills (Campbell et al., 2018; Aldemir & Kermani, 2016; Knaus & Roberts, 2017; Tarman & Tarman, 2011). Art education includes children's interest in new, unknown and complex objects of artistic expression and design as well as in two- and three-dimensional visual modeling (representation of natural objects, photography, design of sculptures, tools and structures; creation of 3D models and printing) (Ata Aktürk & Demircan, 2017; Tylor, 2016; Kazakoff et al., 2013).

According to the researchers, the aim of all this is socially responsible STEAM education, based on the ideas of STEAM philosophy in the Anthropocene epoch (Guyotte, 2020) and sustainable development (Tylor, 2016; Knaus & Roberts, 2017). Socially responsible STEAM education, according to Tylor (2016, p. 91), can help to cope with dangerous influence of our technological superpowers on the natural systems of the planet, including the climate, oceans and soils, which results in fundamental changes to biological and geological systems. Following Tylor's insights (2016, p. 89), it can be stated that there are two groups of outcomes (disciplinary knowledge, skills and liquid abilities) that are relevant to STEAM education. Liquid abilities include creativity, communication, problem solving skills, and the ability to learn. Some other researchers (Laureta, 2018) refer to those 2 groups of abilities in early childhood education as ‘hard’ (pre-academic, cognitive, disciplinary) and ‘soft’ (personality-related, social) abilities. Nurturance of children’s liquid/soft abilities contribute to children’s development of active citizenship qualities and to their commitment to creation of more productive, sustainable and just society. Children prepare to solve ethical problems related to the global influence of science and technologies on environment and society. In Australia, these priorities are considered as early as the level of early childhood education. (Tylor, 2016; Knaus & Roberts, 2017). Innovative STEAM practices that target at development of skills from these two groups in pre-school education institutions have not been extensively analysed so far. Therefore, they have been chosen as one of the focuses in the present research.

The methods used by teachers to create and moderate STEAM education situations may be viewed as another component of STEAM practices (see Fig 1). The researchers distinguish between two effective groups of ways of STEAM education in pre-school age: the first group includes methods of supporting and extending children's interests and initiatives, whereas the second group includes ways of proactive moderation of STEAM education. Methods of supporting and extending children's interests and initiatives involve the establishment of a stimulating and challenging environment; use of open-ended (divergent) and exploratory materials (Kermani & Aldemir, 2015; Hoisington & Winokur, 2015); targeted STEAM-in content-based discussions, debates and considerations built on everyday moments in the ‘here and now’ (Sharapan, 2012); proactive moving of a teacher towards play when seeing an opportunity for inquiry questions; extension of children-initiated activities; and activity planning considering children’s own interests (Campbell et al., 2018). The group of methods of proactive moderation of STEAM education includes methods of joint activities, joint participation and thinking together; the use of activities that promote, facilitate and lead children to explore and discover (Knaus & Roberts, 2017; Kermani & Aldemir, 2015); stimulation of inquiry-based learning (McDonald, 2016); guidance by questions (Moomaw & Davis, 2010); promotion of deep learning; provision of appropriate scaffolding to foster understanding and reasoning (Park et al., 2017); the use of stories that engage children into explorations; exploratory conversations; analysis of a significant case (Torres-Crespo et al., 2014), promotion of computational thinking; and promotion of reflection and self-reflection (Knaus & Roberts, 2017).

A number of studies have been conducted that prove the impact of STEAM education on children's achievements. Toran et al. (2020) conducted an experiment targeted at identifying if STEAM education has an influence on children’s school maturity. The results revealed significantly higher values of school maturity indicators among the children in the experimental group. Carrying out their quasi-experiment, Kermani and Aldemir (2015) focused on the effect STEAM activities and projects have on achievements of pre-primary children in mathematics, science and technologies. Higher children’s achievements (better expanded concepts and developed abilities) were identified compared to the control group. The results of the research conducted by Aldemir and Kermani (2016) show that children start to better understand STEAM phenomena and concepts if support to them well-planned and developmentally appropriate activities are employed. It has been established that use of robotics, when children design and learn to program robots, improve their understanding of concepts of consistency, sequence and mathematics (such as number, size, form), and weaken gender-related stereotypes regarding their future career in STEAM (Kazakoff et al., 2013; Park et al., 2017; Torres-Crespo et al., 2014). According to Campbell et al. (2018), the research results also show that time dedicated to STEAM and the quality of its implementation influence children’s outcomes. The majority of research studies on evaluation of impact of STEAM on the children’s outcomes were carried out while implementing projects, experiments, i.e. making interventions to a limited number of teachers. Moreover, the influence on school readiness and on abilities related to STEAM disciplines was also evaluated. The present research targets at examining how naturally occurring processes of STEAM education influence all the competences of 3-6-year-old children: cognitive, communication, social, artistic and health protection competences (see Fig 1).

As discussed in the introduction, the conducted research studies have revealed teacher professional development to be of great benefit to STEAM implementation in pre-school education: it increases teachers' motivation to apply STEAM educational practices, enhances subject competence and facilitates the understanding of technological and engineering processes as well as methods of STEAM education (Bers et al., 2013; John et al., 2018). However, the relationship between the application of innovative STEAM education practices and teacher professional development has not been investigated in greater detail. The large-scale research on preparedness of early childhood teachers to implement STEAM education conducted by Park et al. (2017) revealed that teachers tended to better evaluate their preparedness for STEAM education, when they had more practice in early childhood STEAM education and perceived the importance of this education. The research carried out by John et al. (2018) confirmed that teachers' attitudes towards STEAM positively correlate with their STEAM practices in the group. As the previous research has already identified the relationship between STEAM education practices applied by teachers and their attitudes and preparedness to implement STEAM, our research sought to reveal another aspect, i.e. to determine the impact of the frequency of the application of STEAM education practices on teacher professional development.

Methods

The goal of the research is to reveal the influence of innovative STEAM education practices applied by early childhood teachers on teacher professional development and 3-6-year-old children's competence development.

Research Design

The quantitative research approach was most favourable for implementation of research goal. The research design was constructed on the basis of the theoretical analysis (Fig. 1). In Stage 1, the research study sought to determine the frequency of the application of environments and children's activities of science, technological, engineering and mathematical education and of the development of creativity and arts design, problem solving, ability to learn and communication skills as well as the frequency of the application of ways of STEAM education by calculating mean values of the teachers' estimates. The aim of the research was also to calculate the mean values of the teachers' estimates, which reveal the teachers' opinion about the impact of STEAM practices on their professional development and on the development of children's competences. In Stage 2, the research study sought to determine the impact of STEAM practices on teacher professional development and on the development of children's competences. For this purpose, the Exploratory Factor Analysis (EFA) was carried out, since the research construct presented in Fig. 1 is only an implicit but not empirically validated model (Fabrigar & Wegener, 2011), and the Structural Equation Modeling (SEM) was conducted in order to identify correlations among the distinguished latent factors (Fodikes, 2017; Henseler, 2017).

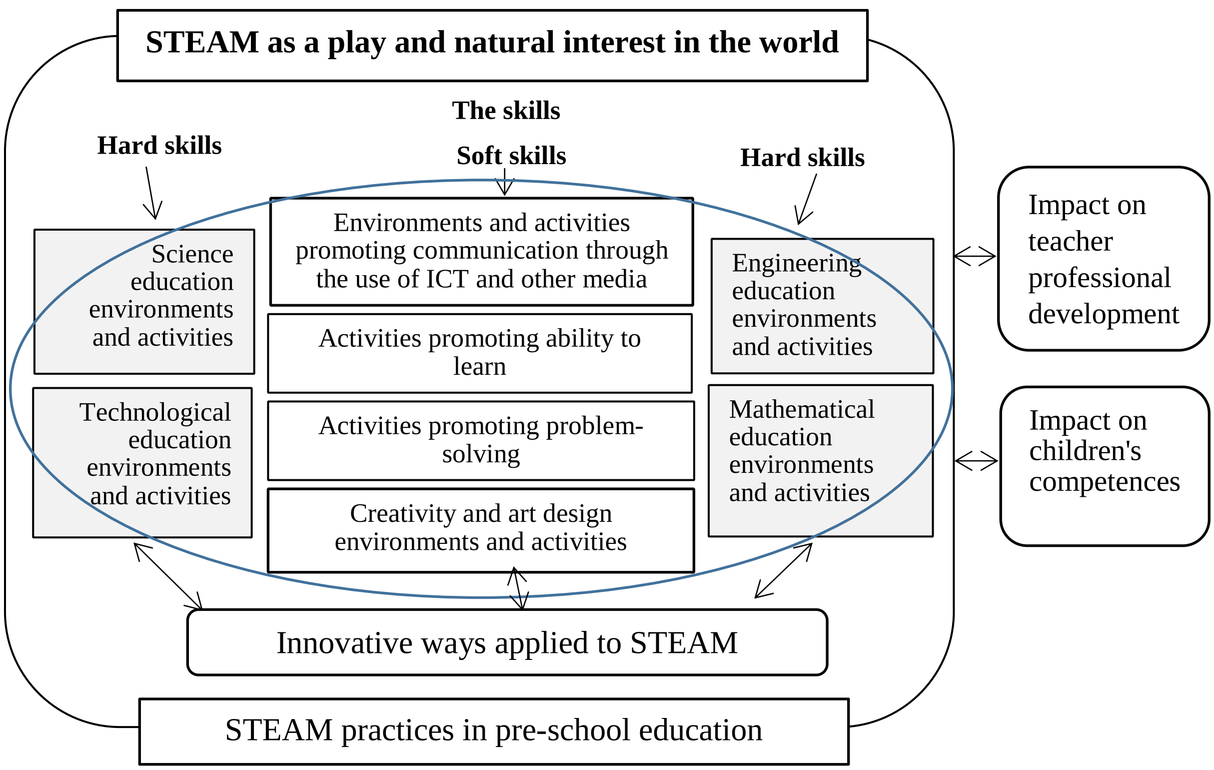

Figure 1. Construct of components of STEAM practices and their impact on the development of children's competences and teacher professional development

Sample

Seeking to reveal the situation of STEAM education in the country under natural conditions, a random probability sample was applied. The research was conducted in all the municipalities of Lithuania. The sample of the large-scale research included 1232 early childhood teachers, who work with 3-6 year old children in state and private early childhood education institutions. Table 1 provides data on the age, length of service and education of the teachers who participated in the research. The majority of the respondents were females—only 3 males participated in the research. The sample characteristics correspond to the characteristics of the population of teachers working in pre-school institutions.

Table 1

Distribution of the respondents by age, length of service and education

Age of teachers	cases	%	Length of service	cases	%	Education	cases	%
up to 30 years	97	7.87	up to 5 years	186	15.10	secondary	19	1.54
20–40 years	231	18.75	5–10 years	141	11.45	vocational	261	21.19
41–50 years	428	34.74	11–20 years	223	18.1	voc. bachelor's degree	671	54.46
51–60 years	393	31.90	21–30 years	574	46.59	bachelor's degree	146	11.85
over 61 years	83	6.74	over 31 years	108	8.76	master's degree	135	10.96

Instrument

The research study used a questionnaire developed by the authors of the article on the basis of the theoretical construct. The questionnaire consisted of 12 subscales (each subscale included a question and statements which had to be evaluated by the teachers). The Likert's scale was employed to rank the responses (teachers were requested to mark from 1 to 5 in the scale how frequently they apply the indicated STEAM practices and how strong their impact is). 4 questions were intended to evaluate what innovative pedagogical practices teachers implement in their educational institutions in the fields of science, mathematical, technological and engineering education (for development of hard, i.e. disciplinary, pre-academic, skills), e.g. 'How often do you practice the children's exploratory and creative engineering activity (STEAM) in the group and in the institution?' Each question was followed by 7-8 statements, e.g. 'Together with children, we create projects of real and imaginary buildings, bridges, vehicles, etc., models of natural objects', 'Together with children, we explore the stability, symmetry and asymmetry, proportions and features of constructions, etc.', 'Together with children, we explore materials used for building structures and mechanisms: constructors, blocks, natural materials, secondary raw materials, etc.' The teachers ranked each statement in a 5-point scale from 1 to 5, depending on how often they apply the indicated activities, environments and aids in practice. 4 questions were intended to evaluate what innovative pedagogical practices teachers implement for strengthening of children's creativity, problem-solving, learning to learn and communication skills (for development of soft, i.e. personal, social, skills). The above-mentioned areas of education ensure socially responsible STEAM education for. One analogously constructed subscale was designed to evaluate how often teachers use innovative ways of STEAM education in practice. The ways were listed below the question (13 statements) and each was rated on a 5-point scale. The questionnaire also included two questions which targeted at evaluating the impact of innovative practices of STEAM education on teacher professional development (9 statements) and on 3-6-year-old children's (cognitive, communication, social, artistic and health protection) competences (5 statements). The questionnaire also included a subscale on questions related to demographic information. 168 respondents were interviewed in the pilot stage of the research study. The measurement of internal compatibility of the questionnaire showed either good (Cronbach alpha from 0.788 to 0.890, 8 subscales) or very good (Cronbach alpha from 0.939 to 0.965, 3 subscales) internal compatibility of subscales. Data collection tools that are utilized for the study should be stated in this section. Each tool should be introduced by describing its features and explaining the reasons for choosing it while providing information regarding reliability and validity issues.

Data Collection Techniques

In order to collect data, the questionnaire was placed online. We contacted the principal of each of the 721 pre-school institutions in the country by e-mail, providing electronic access to the questionnaire. In the e-mail, we explained the aim of the research, provided a definition of STEAM practices and comments on how to evaluate the frequency of the application of practices. We asked the principal to forward the e-mail to teachers who work with 3–6-year-old children. In addition, we made a phone call and tried to motivate them to participate in the research. During the telephone conversation, 14% of the institutions requested paper questionnaire forms, so the researcher handed the questionnaires directly to the teachers and then collected them. The questionnaire was completed online and in writing by 1 or more teachers from 584 (81%) institutions.

Data Analysis Techniques

Statistical data processing methods were applied for analysis of quantitative research results. The obtained research data were processed using SPSS 22 and MS Excel programs adapted to Windows. The EFA was used for identifying latent factors (Fabrigar & Wegener, 2011). The

Maximum Likelihood (ML) method of the Common Factor Model (CFM) was also applied. The Oblique Rotation (Promax) is used, when factors are interrelated and demonstrate correlation (Brown, 2009; Costello and Osborne, 2005; Finch, 2006; Schreiber et al., 2006). The SEM analysis for developing a model of impact paths was employed (Fodikes, 2017; Henseler, 2017). Version 24.0 of the statistical program SPSS AMOS was used in the analysis.

Findings

Frequency of the Application of Innovative STEAM Education Practices

Innovative STEAM education practices applied by early childhood teachers. Attempts were made to identify how often teachers apply innovative educational practices (activities, aids, environments) in different fields. The teachers indicated their frequency of STEAM education practices using a 5-point system: 1- never, 2 – rarely, 3 – neither frequently nor rarely, 4 – frequently, 5 – always. Fig. 2 presents mean values of all the 1232 teachers in the survey.

The research results (Fig. 2) show that teachers apply innovative practices of STEAM education for development of *soft* (problem-solving, creativity, learning to learn, communication) abilities and *hard* (science) skills more frequently than for development of *hard* (mathematical, technological, engineering) abilities. Thus, more attention in early childhood education is allocated to development of civically active, socially responsible children, who feel a relation with nature, than to development of pre-academic, mathematical, engineering, technological skills and knowledge.

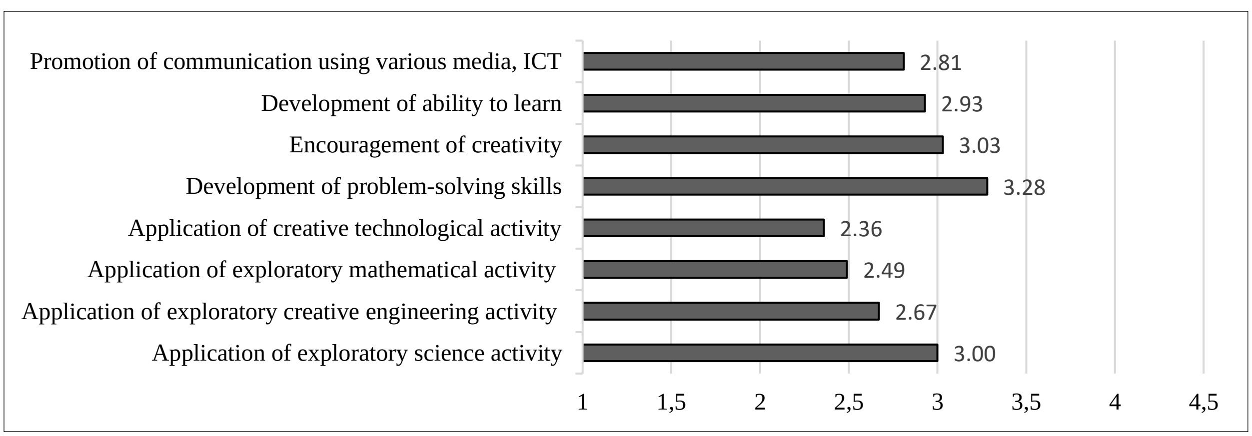

Figure 2. Mean values of frequency of applying innovative STEAM education practices in a 5-point scale (teachers' opinion)

Innovative practices of mathematics, engineering and technologies, such as establishment of robotic laboratories, investigation of mechanical laws (levers, pulleys, slides, etc.), designing of mechanical models, clarification of stability of constructions, symmetry-asymmetry, use of 3D printers, interactive tables and floors, discovering of mathematics through arts and other practices are rarely used. Activities of natural sciences such as explorations of water, soil, plants, animals and natural phenomena using a magnifying glass, a microscope, mirrors, bug traps, building "earthworms' houses", insect "hotels", setting up terrariums for growing butterflies and water collectors are implemented more often. Some teachers frequently employ such activities.

Methods applied by early childhood teachers for STEAM education. Methods of education are also attributed to STEAM education practices, although they formed a separate group in this research. The authors of the article aimed to identify how frequently teachers apply the ways included into the questionnaire that support and extend children's initiatives and interests and proactive moderation of educational process. The research results are presented in Fig. 3. The research data reveal that teachers frequently apply child's experiential learning; learning through questions, argumentation; ways of listening to child's voice; search for information or ideas on the internet websites, children's encyclopedias, etc.; ways of proactive involvement in child's play. This shows that the child-directed trend prevails in STEAM education: ways of supporting and extending children's initiatives and interests.

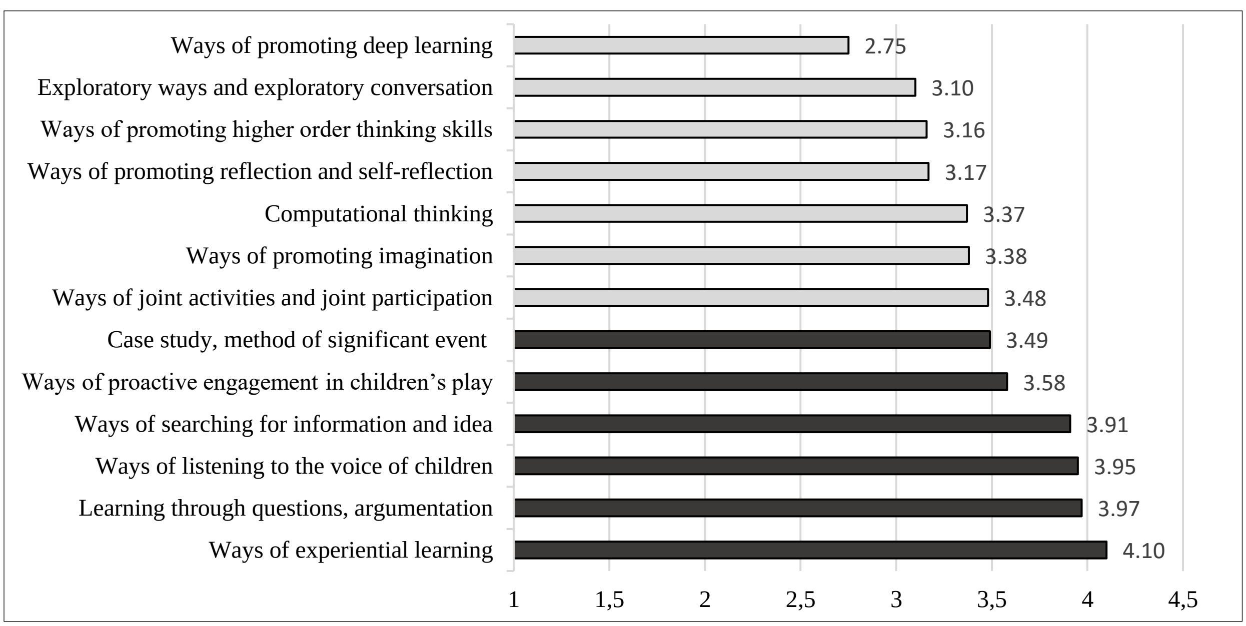

Figure 3. Mean values of frequency of applying ways for STEAM education by early childhood teachers in a 5-point scale (teachers' opinion)

Teachers use exploratory methods and exploratory conversation (moderate observation of plant growth and recording of changes or testing of a designed mechanical model, suggest using tools for exploration, etc.) moderately often. They apply methods of promoting higher order thinking skills (use “mapping“, model activities, where a child sees actions and results of his/her thinking, etc.), methods of promoting reflection and self-reflection (encourage autobiographic reflection of own past and future, reflection on activity consequences in the context of values, reflection of learning), computational thinking (dividing of complex problems into stages, narrower problems) with the same frequency. Teachers rarely use methods that promote deep learning (long collection of information on one object from various sources, its systemisation and reflection). This shows that teachers less frequently use ways of proactive moderation of STEAM education. This reveals lack of professionalism in this field.

Influence of Innovative Practices of STEAM Education on Teacher Professional Development

The results of the majority research evidence the influence of teacher professional development on STEAM education. The authors of the article set a goal to clarify another problem whether application of innovative STEAM education practices (without specially organised training courses) itself have influence on teacher professional development. The teachers ranked the influence of applying STEAM education practice in a 5-point-scale: 1 – no influence, 2 – minor influence, 3 – average influence, 4 – big influence, 5 –major influence. The results of the research are presented in Fig. 4. Following the research data, the teachers notice a considerable influence on their attitude towards STEAM education: they have become more open to innovations of STEAM education, feel more responsibility for children’s learning outcomes and have started perceiving STEAM education as quality education for sustainable development. Another important aspect of the influence refers to the increased ability of teachers to adapt education to diverse children ensuring equal learning opportunities because STEAM aids and technologies enhance possibilities of multimodal and experiential learning, make invisible actions of thinking as well as abstract ideas visible and targeted. The teachers also point to average and major influence on their abilities to organise education: to develop integral curriculum, to establish STEAM education environment, to work in teams, networks, to use new media and ICT in the process of education. Thus, implementation of innovative STEAM education practices has average or considerable influence on various professional areas of teachers.

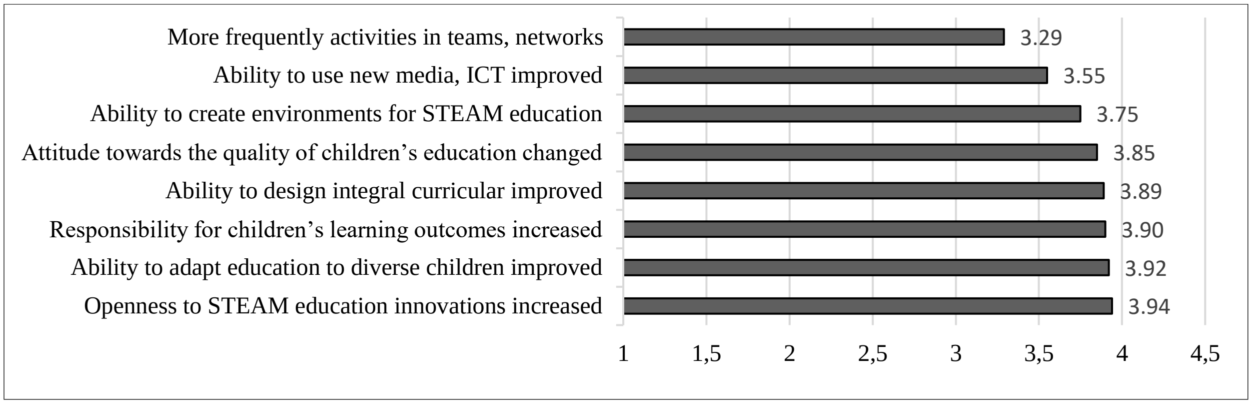

Figure 4. Mean values of influence of applying practices of STEAM education on teacher professional development in a 5-point scale (teachers' opinion)

Impact of innovative practices of STEAM education on development of children's competences

The Description of the Achievements of Pre-school Age Children was prepared in Lithuania (IAVPA, 2014). The Description provides for 5 competences: health, social, communication, cognitive and artistic ones and they embrace 18 areas of achievements. The authors of the article aimed to evaluate the impact of STEAM education practices on development of all competences of children because the majority of previously conducted research focused on revealing the influence of STEAM on 3-6 year old children's achievements only in the fields of STEAM disciplines (Kazakoff et al., 2013; Park et al., 2017). The research results are presented in Fig. 5.

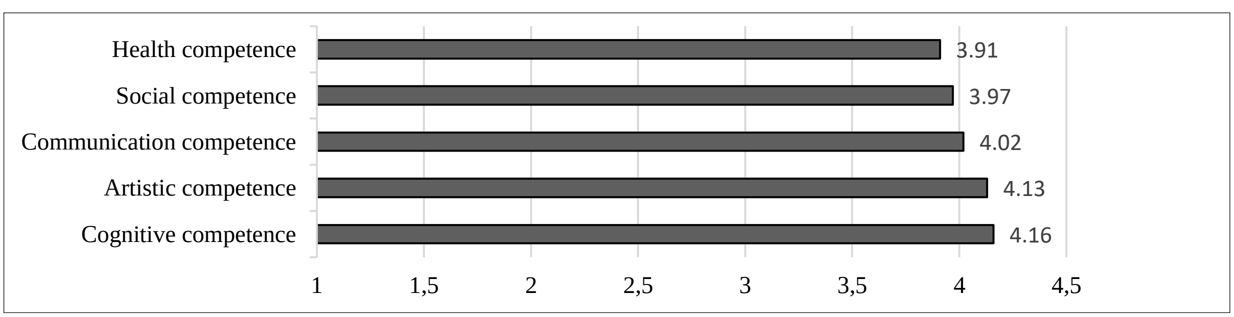

Figure 5. Mean value of influence of applying practices of STEAM education on development of children's competences in a 5-point scale (teachers' opinion)

The obtained research data allow stating that the teachers notice significant influence of applying innovative practices of STEAM education on development of all the competences of children. The values of impact on development of cognitive and artistic competences are slightly higher, whereas the values of influence on health and social competences are lower. Thus, broad and integral impact on all the achievements of children may be assumed.

The model of influence of innovative STEAM education practices on teacher professional development and children's competence development

Since the sample of the present research was large, the Exploratory Factor Analysis was used to identify correlations of factors. On the basis of correlations, the EFA helps to divide the analysed variables into groups that are linked by latent factors eliminating insignificant variables (Fabrigar & Wegener, 2011). The conducted EFA allowed distinguishing 8 latent factors that include 70 variables:

Factor 1: Innovative methods of education.

Factor 2: Influence of STEAM education practices on teacher professional development.

Factor 3: Practices of mathematical education and promotion of deep learning.

Factor 4: Practices of promoting problem-solving, creativity and ability to learn.

Factor 5: Practices of engineering-technological education.

Factor 6: Influence of STEAM education practices on children's competences.

Factor 7: Development of communication skills that include practices of applying new media and ICT tools.

Factor 8: Practices of science-technological education.

Factorability of STEAM practices and their impact on teachers' professional development and children's competences was examined by measures of sampling adequacy (Kaiser-Meyer-Olkin test - KMO = 0.973, <.0001; Cronbach's Alpha=.971). The data of *Total Variance Explained* show that eigenvalues of the above-mentioned 8 factors are above 59.66 % of the *Cumulative Variance*.

The factors make up several logical groups. Five factors include practices that are applied by teachers for development of hard (pre-academic, disciplinary) and soft (personal, social, strategical) abilities of children. The factors "Practices of science-technological education (within and outside an institution)" reveal integrity of development of hard abilities. As it can be seen from the available data, practices of technological education at early age do not form a separate factor but are integrated into engineering and science education. Moreover, practices of science-technological education in early childhood institutions contain two obvious components: education in an institution and outside it (explorations in the real natural environment, in educational centres for natural explorations, trips to specific places (bakery, artists' workshops and others), where children are able to observe technological processes). The factor "Practices of promoting problem-solving, creativity and ability to learn" discloses integrity of soft abilities development. The factor "Practices of mathematical education and promotion of deep learning" shows that innovative practices ensure integral development of hard (mathematical skills in this particular case) and soft (personal skills: deep learning in this particular case) abilities. The factor "Development of communication skills including practices of applying new media and ICT tools" also evidences development of soft (personal skills: communication) and hard (technological) abilities. *The factor "*Innovative ways of education" can form a separate logical group, which embraces all the ways of education applied by teachers. Two factors of influence of STEAM education practices on teacher professional development and children competence development make up one more logical group.

Later attempts were made to identify correlations among the distinguished factors and the model of impact paths was designed (Fig. 6). To this end, Structural Equation Modelling (SEM) analysis was undertaken. The conducted SEM allowed identifying the reliability indicators of the model. The value CMIN/DF (*Minimum Value of Discrepancy Divided by Degrees of Freedom*) of the model equals 2.455 (the acceptable range: 1≤CMIN/DF≥3); the value NFI is 0,995 (a model is appropriate if the value is not lower than 0.95), the value of GFI (*Goodness of Fit Index*) is 0.993 (a model is appropriate if the value is not lower than 0.95); the value of IFI (*Incremental fit index*) equals 0.997 (a model is appropriate if the value is not lower than 0.95); the value of TLI (*Tucker-Lewis index*) is equal to 0.994 (a model is appropriate if the value is not lower than 0.95); the value of CFI (*Comparative fit index*) is 0.997 (a model is appropriate if the value is not lower than 0.95); the value of RMSEA (*Root Mean Square Error of Approximation*) is 0.034 (an acceptable value is not lower than 0.05) (Schreiber et al., 2006). The SEM established that the devised model embracing 8 latent factors with 70 indicators is complete and fit.

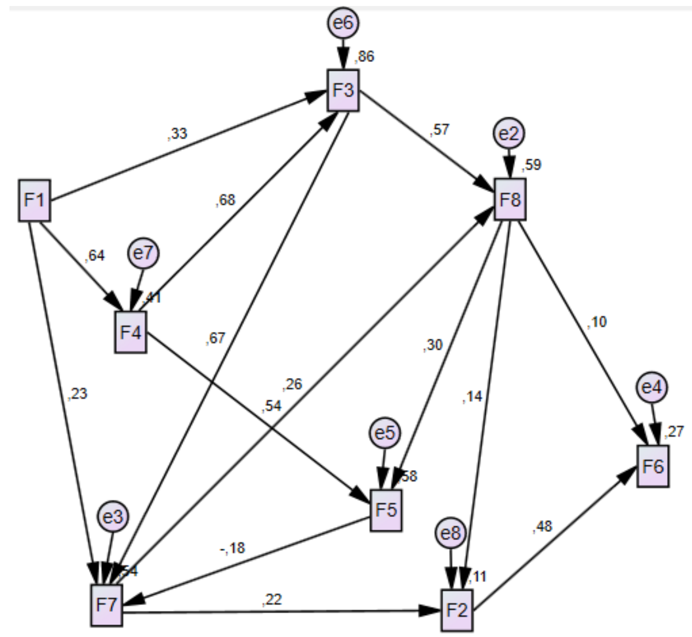

Figure 6. Standardised SEM model of correlations among latent factors

The model shows that application of innovative methods (Factor 1) has direct and significant impact on practices of promoting problem-solving, creativity and ability to learn (Factor 4) and through the latter factor influences practices of engineering-technological education (Factor 5) and those of mathematical education and promotion of deep learning (Factor 3). The application of innovative methods (Factor 1) has a direct effect on the practices of mathematical education and the promotion of deep learning (Factor 3) and through the latter has considerable influence on practices of science-technological education (Factor 8) as well as on development of communication skills that include practices of applying new media and ICT tools (Factor 7). Application of innovative ways (Factor 1) directly influences development of communication skills (Factor 7) and through the latter has impact on practices of science-technological education (Factor 8). Thus, application of innovative ways of education has direct or indirect impact on STEAM education practices with integral relationships. Only the development of communication skills that include practices of applying new media and ICT tools (Factor 7) and practices of science-technological education (within an institution and outside it) (Factor 8) influence teacher professional development (Factor 2). The model also shows that the majority of STEAM education practices do not have any impact on children's competence development (Factor 6) with exception of practices of science-technological education (within an institution and outside it) (Factor 8). This is slightly unexpected as a direct impact of practices of all the fields on children's competence development was forecasted. The model discloses that the impact of STEAM education practices on children's competence enhancement occurs through teacher professional development (Factor 2), which is under influence of separate groups of STEAM education practices.

Discussion and Implications

The research study sought to find out how often pre-school teachers apply practices of different fields of STEAM education. The research results show that early childhood teachers in Lithuania traditionally prioritise science education, i.e. one of the five STEAM fields. Practices of science education are applied more often compared to those of mathematical, engineering, technological, art education. The developed model of impact of STEAM education practices shows that practices of science-technological education, which are joined into one latent factor, where the weights of science education practices are bigger, have a direct influence on professional development of early childhood education and 3-6 year old children's competence development. Other STEAM practices have no such effects. A more considerable attention to science education compared to other fields of STEAM has been observed as a global tendency. Bers et al. (2013) draw attention to a similar trend stating that the natural world plays the most considerable role in early childhood curriculum, whereas human-made world (technologies, engineering) lacks attention. The overview of conducted research presented by Somerville & Williams (2015, p. 109) reveals that a *global tradition of environmental education* can be observed among early childhood teachers, which targets at enhancement of the link between the child and the natural world as well as to adopt values of environment protection because it is thought that children distance themselves from the nature due to rapid technological developments. Even a certain conflict among practices of creativity education and practices of using new media and ICT practices can be noticed. The present research evidences a negative relationship between the practices of engineering-technological education (Factor 5), which are based on imagination and creativity, and communication education that involves use of new media and ITC tools (Factor 7). The research results also show that early childhood teachers do not have a full integral STEAM education conception as well as conception of modern sustainable development based on ideas of biocentrism.

The present research revealed an *imbalance between practices of developing hard* (mathematical, engineering, technological) and *soft* (problem-solving, creativity, learning to learn and communication) *abilities* at early childhood age. Practices of soft-ability development are more frequent than those targeted at enhancing hard abilities. However, a reverse imbalance is observed at other levels of education (basic and secondary education) (Tylor, 2016). More frequently applied practices of developing skills of problem-solving, creativity, learning to learn, communication skills and ways of supporting and extending children's initiatives and interests contribute to education of an actively learning and proactive citizen in a favourable way. However, rarely employed practices of developing hard (mathematical, engineering, technological) abilities and ways of proactive moderation do not ensure balanced STEAM education.

The model for STEAM education at an early age, which was designed on the basis of this empirical research, does not distinguish technological education as a separate field, but integrates it into practices of science and engineering education. In this model practices of mathematical and science education make up the foundation for engineering education. Practices of mathematical education (Factor 3) influence those of engineering-technological education (Factor 5) through science-technological education practices (Factor 8), whereas the latter have a direct impact on implementation of engineering-technological education practices. The situation surprised us, but our model confirms essential characteristics of the model of relationships of STEAM disciplines presented by Wang et al. (2018). Engineering in this model (Wang et al., 2018) is approached as a core field, and science and mathematics are the two cornerstones, whereas arts and technologies serve as additional aids searching for solutions to real-world problems. In the model of Wang et al. (2018) practices of mathematical and science education build up the foundation for engineering education. Thus, general tendencies can be envisaged, although our research was conducted at the level of early childhood education, whereas that of Wang et al. (2018) took place in schools.

The fact that an integral latent factor, which embraces practices of mathematical education and those promoting deep learning singled out in our model, proves why early mathematical knowledge becomes a predictor of later learning (Erbilgin, 2017; Kermani & Aldemir, 2015).

The aim of the research was to determine the impact of STEAM education practices applied by pre-school teachers on teacher professional development. The presented research allows stating that application of innovative STEAM education practices has an effect on teacher professional development, especially through the use of new media and ICT tools for communication. Using internet, social networks, websites (e.g. "eTwinning", "STEAM" and others), the teachers find new ideas, improve own abilities and educational practices. Thus, a two-way direction can be identified: *professional development (training) for STEAM education* (Bers et al., 2013; John et al., 2018; DeJarnette, 2018) and *STEAM education practices for professional development*.

Finally, the research study sought to determine the impact of STEAM education practices applied by pre-school teachers on the development of children's competences. Our research discloses that STEAM education *has an essential influence on the development of children's competences through teachers' professional development*. Only when teachers have sufficient knowledge of STEAM, they apply relevant methods and tools and adequately link them to the development of STEAM competences.

The research results allow changing the attitude towards teachers' preparation to implement STEAM in early childhood. Teachers may improve their professional competence not only in the training courses specially designed for this purpose but also independently searching for innovative STEAM practices and making attempts to implement them. In the process of STEAM education practices, they improve their competences; extend subject-specific knowledge in STEAM areas; develop STEAM pedagogy; design STEAM curriculum; and evaluate children's achievements. Educational institutions should consider the accessibility of new media and ICT tools for teachers and the development of communication networks.

Conclusion

The research revealed that the global tradition of environmental education, which mainly focuses on science and education practices and allocates less attention to mathematical, engineering and technological education, is characteristic of early childhood teachers in the STEAM area. The imbalance between the development of children's hard and soft skills is typical of STEAM education in favour of the latter. Early childhood education teachers more frequently apply methods of support and extension of children's initiatives and interests, whereas methods of proactive moderation of STEAM education are used less frequently. The implementation of STEAM education encourages self-directed improvement of teacher professional competences. Teacher professional development has an essential impact on the development of children's STEAM education.

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