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Professional Competence of Teachers in the Context of STEM Education

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Abstract

Introduction: The article deals with the quality of technical education at the kindergarten level, in context of the kindergarten teachers' professional competence and the training programs they graduated from. The main research question is how the relevant university programs are prepared to educate the teachers for the STEM concept.

Methods: On the one hand, using the method of content analysis, the authors examine in detail the study programs of pre-primary education at three universities in Slovakia, which provide training programs for the profession of a work-based education teacher for kindergarten. On the other hand, by means of a questionnaire the authors investigated preschool teachers' awareness of the concept of STEM and their competence to implement this education in their practice.

Results: Results of the content analysis have revealed inconsistencies manifested in the structure of bachelor's study programs, which only partially follow the topics of technical education in kindergartens. Results of questionnaire investigation point to insufficiencies in professional training of teachers to apply STEM as well as on their weak general information in the given field.

Conclusion: Based on the above-mentioned findings, the authors point out potential strengths and areas for improvement in teacher training at the respective higher education institutions.

Keywords: pre-primary education, technology education, STEM, professional competence of teachers.

1. Introduction

The STEM educational model belongs to the modern means of innovation at all levels of education. The basic principle of STEM education is based on integrated inter-subject teaching (Science, Technology, Engineering, Mathematics), thanks to their natural continuity (Lutkevich, 2022). Since the beginning of the 21st century, this concept has attracted a lot of attention all over the world and is considered one of the main points of education and curriculum. The need to

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integrate STEM education is an up-to-day requirement that is stated by various authors and studies (Bybee, 2006; Kim, Kim, 2016; Nuangchalerm et al., 2020; Samara, Kotsis, 2023) due to the demand for STEM skills to solve different economic challenges is becoming more and more serious (English, 2016; Marginson et al., 2013; Wei, Chen, 2020).

STEM attracts attention of people of all ages because it increases motivation, interest, curiosity and desire to learn (Amiruddin et al., 2019). It improves the way of engaging in the process of own learning (Razi, Zhou, 2022), uses innate curiosity, what leads to recommendations to familiarize already pre-school children with the given concept (Aktürk, Demircan, 2017). STEM is a modular field of education, the purpose of which is to develop possibilities to engage a child's intellectual abilities into scientific and technical creativity (Abdumajitova, 2022). As the teacher is one of the most important implementers of STEM education (Siekmann, Korbel, 2016), therefore it is important that s/he understands this concept, is sufficiently informed about it and is relevantly prepared to apply it in practice. As argued by Rifandi et al. (2019), teachers are expected to be able to design for children (pupils, students) learning process that is fun and of high quality to achieve valuable learning goals. Teachers need at first knowledge on the integrated subjects, and secondly knowledge on the relevant pedagogical content to be able to deal with this (STEM) concept in classes they teach or will teach (Kurup et al., 2019). However, the concept of STEM is not a fixed curriculum. It is not intended to replace national curriculum frameworks or state curriculum standards (Wei, Chen, 2020). The role of the teacher in teaching in the 21st century is expected to shift from an expert to a facilitator, and the focus of teaching moves from knowledge to the ability to use and apply information in a relevant way. Bell (2016), and Harris & Sass (2011) therefore emphasize that the training of qualified teachers is a principal necessity to implement STEM education.

Teacher Training in Slovakia

As it has been already above-mentioned, we are facing an ever-increasing demand to implement the STEM concept into education at almost all levels of education. However, for teachers this can be a hard task, requiring from them cross-disciplinary work, increased workloads, and an understanding of the nature of STEM integration (Boice et al., 2021). The undergraduate system of education has the task to equip future teachers with the necessary competencies so that they can handle this task as best as possible (Anisimova et al., 2020). In Slovakia the undergraduate teacher training is characterized by a high level of autonomy of universities, what causes that each of the universities has its own model of practical teacher training (Ďurjaková, 2019). Education of teacher trainees in the field of science, technology, engineering and mathematics has received increasing attention in the last decade, and there are calls to increase emphasis given to these fields, and to increase quality of training in them. Qualified teachers are essential for teaching STEM (Polgampala et al., 2017). They must be adaptable in their teaching strategies and respond to the needs of children during the teaching process (Ejiwale, 2013), they must be flexible and open to innovations in education (Nagdi et al., 2018). Educational institutions that provide teacher training must therefore constantly adapt their teaching modules, courses, seminars, in order to achieve the practical sustainability of their programs in accordance with current socio-economic requirements (Oraison, et al., 2019). Teacher training in Slovakia is regulated by the Ministry of Education, Research, Development and Youth of the Slovak Republic and is subject to certain standards and regulations. Currently, future students – teacher trainees can choose different fields and specializations according to their interests and future career goals.

In Slovakia, there are 35 universities that offer a number of specialized programs and fields of study, which rake them among the highly recognized institutions providing professional education for various areas of life. However, none of them provides systematic STEM education or teacher training for this education concept. Only the study programs in teaching mathematics, natural sciences, technology, or informatics are available. Gradually, only new teaching materials and courses providing this education are created, but not comprehensively. For the most part, these initiatives address STEM subjects separately. Our goal was to examine whether, at least in individual fields, students are informed about the STEM concept. We focused on the training of teacher trainees for kindergartens, in relation to the part of their preparation for insurance of technical education in their future profession. The preparation consists in the acquisition of theoretical expertise in the field of pedagogy, psychology, and in scientific fields of technical school subjects. The goals and tasks of this education should reflect the emphasis that is placed on the development of competencies necessary for performance of these teacher trainees' future

profession (Bahodirovich, Romilovich, 2021). The concerned pre-gradual education is carried out at 3 universities in Slovakia, namely at the Constantine the Philosopher University in Nitra (CPU), at the University of Prešov in Prešov (UP), and at the Matej Bel University in Banská Bystrica (MBU). Inclusion of technical education into the university study program for teacher trainees for pre-primary education is carried out at the given universities in frame of the study branch Teaching and pedagogical sciences in the study programs Preschool and elementary pedagogy (bachelor's degree).

2. Methodology

For each part of the research another methodology was used.

On the one hand evaluation of the professional training of preschool teacher trainees was done by means of the content analyses (Crowe et al., 2011). The aim of the content analyses was to compare subjects included in the study programs of the study branches of preschool and elementary pedagogy (PEP) at the concerned three Slovak universities (CPU, UP, MBU). Subsequently, the achieved results were confronted with the content and goals of the State Educational Program (SEP) in the educational area Man and the world of work. The stated means that the whole analysis was done in two stages context.

As the object of our content analyses were austere official documents of the given higher education institutions (basically curricula of the compulsory and optional subjects included into the study programs of the given study branches), the content analysis used by us was of thematic kind (thematic analysis). The thematic analysis of the stated documents followed occurrence, in meaning of presence, of lexical units related to the content and goals of the State Educational Program (SEP) in the educational area Man and the world of work. Based on the occurrence of the relevant lexical units our goal was to identify whether some STEM education elements are or are not integrated in the pregradual teacher training. There was no need to quantify the numbers of the particular lexical unit occurrences (i.e. to use the content analysis of qualitative kind, qualitative content analysis), as the question was whether the particular issue, or the particular component of some issue is included in the study program or is not.

On the other hand, the evaluation of the in-service preschool teachers' awareness on the STEM concept was done by means of a questionnaire. The purpose of the questionnaire, which we designed, was to answer following three research questions:

– What is the level of teachers' awareness of the STEM concept,

– Whether and to what extent teachers apply STEM education in their educational work with children,

– What would contribute to increase applications of STEM concept in teachers' activities.

As the questionnaire consisted of only three questionnaire items, there was no sense to analyse its reliability or test suspiciousness of its items. However, what was checked was its validity. For this purpose, a group of several in service teachers (participants of a further education of primary and lower secondary school teachers) were asked to express their opinions to the given three items (to verify comprehensibility and clarity of their formulation).

A research sample of 300 kindergartens all over Slovakia was addressed to take part in an online form of the questionnaire survey. The addressed kindergartens were chosen on basis of a random choice. Based on the obtained returned questionnaires the total number of the teachers who responded to our questionnaire call was 372 respondents. At this point it is necessary to mention that the presented study has served as a pilot (with a pilot research sample), for a more complex one, in frame of which all kindergartens in the whole Slovakia have been planned to be involved in (i.e. 3326 of these educational institutions of all kinds, either public or private or church ones). In case of this planned more complex research there are planned also more detailed analyses of the collected data.

After processing both sets of the above-mentioned collected research data, the findings resulted from both of these investigations were compared.

Results of the Analyses of the Study Programs of Preschool Teacher Trainees

The educational area Man and World of Work incudes in itself a broad range of work activities and technologies based on a creative team cooperation. By means of the technical education the pupils are led to acquisition of basic user's skills in different areas of human activities and elementary technical thinking. The stated area creates a space for technology and engineering implementation of the STEM concept.

At first, the technical subjects included in the teacher trainees study programs, their content focus (curriculum) and learning outcomes (performance standards) were examined. Subsequently, we compared them with the educational area's objectives and its content focus (sub-areas). The stated was done in relation only to compulsory subjects of a technical nature at all three concerned universities (Table 1).

Table 1. Comparison of the subjects included in PEP study programs corresponding with the educational area Man and the world of work

Man and the world of work		**CPU**	**UMB**	**UP**
		Working techniques in pre-primary education	**Science and technology education**	**Work-technical education**
Themes arising from the SEP	Objectives of the educational area	✓	✓	✓
	Developing skills in working with tools	x	x	x
	Household activities	x	x	x
	Development of elementary technical thinking	x	x	✓
	Development of creativity	x	x	x
	Investigating the properties of materials and objects (trial, error, experiment)	✓	✓	x
Sub-areas	Materials and their properties	✓	✓	✓
	Constructing	x	✓	✓
	User skills	✓	x	✓
	Production technologies	✓	✓	x
	Crafts and professions	x	x	✓

From the comparison of the content of the subjects included in the PEP study programs, with the educational area Man and the world of work resulted following main findings:

– None of the universities has a complete alignment of its programs with the standards of the relevant educational field, there are no differences across the universities in terms of meeting subject objectives. The stated indicates that all universities have the same intent in preparing student, and that s to meet the educational objectives. The themes focused on application of methods of investigation, research and experimentation are evident in the study programs of CPU and UMB. UP forms an exception in developing elementary technical thinking in relation to area Man and the world of work. Further target requirements in the contents of compulsory subjects at the particular universities in comparison with the area Man and the world of work targets were not found out.

– Within the sub-areas resulting from area Man and the world of work, the topic „Materials and their properties“ is consistently included in the compulsory subjects at all universities. According to the information lists of the study subjects, the issue of “Construction” is absent at CPU, issue of “User Skill’s at UMB and issue of “Production Technology” at UP. The area of “Crafts” is absent at CPU as well as at MBU. The analysis also recorded topics beyond the requirements of the area Man and the world of work: at CPU it is the issue of safety and hygiene at work with technical materials; at UMB the topic of strategies and methods of science or technical education; and in UP the topic of work-technical interest activities at school educational institutions. There were recorded no topics nor concepts related to STEM in any of the analysed programs.

– The comparison shows that students acquire basic knowledge about the content of the educational area, the individual sub-areas, and the content and performance standards necessary for teaching. However, insufficient attention is paid to developing strategies for supporting creativity, skills, and technical thinking resulting from the educational area Man and the world of work. Nevertheless, we can assume that the missing components of area Man and the world of work are included in the compulsory elective subjects of the individual universities (CPU – Working skills with materials, Methodology of work-based education; UMB – Working with technical materials; UP – Natural, geographical and technical interest activities, Transport education).

Results of the Evaluation of the Teachers' Awareness on the STEM Concept

Based on the research data collected from the total number of 372 respondents (teachers who responded to our questionnaire call) the hereinafter findings were obtained.

In the first part of the administrated questionnaire, we were interested in awareness of the respondents (kindergarten teachers) of the STEM education concept (whether they have some information about this phenomenon, whether they read or heard something about it). As the results presented in a graphical form in Figure 1 show, even 54 %of the respondents have no information about this concept of education. This proved our assumption that the STEM concept is among the kindergarten teachers in Slovakia relatively unknown phenomenon.

In relation to the professional teacher training, we were interested whether the respondents (pre-primary teachers) have heard about this concept or education already during their higher education studies. The results again confirm our assumption that higher education preparation of teachers dealing with STEM education is insufficient. However, we were surprised by the very low number of the respondents who really met with this concept, or heard something about it, during their university studies (Figure 1 – 5.4 %). Mostly the respondents have obtained some information about this phenomenon from the study of professional literature (22.2 %). More or less equal number of the respondents have obtained some information either within some further education they passed, e.g. some courses or webinars (14.3 %), or from their colleagues (13.0 %).

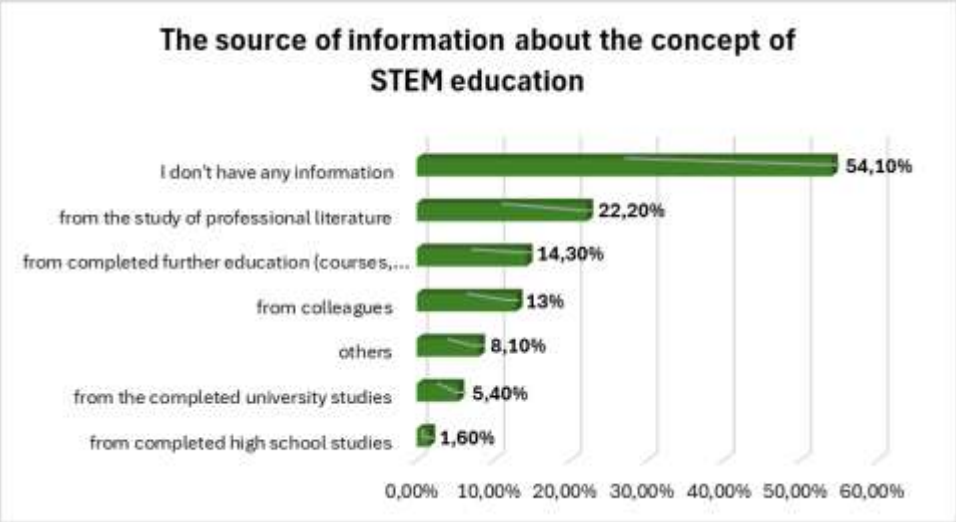

Fig. 1. The source of information about the concept of STEM education

The quality of teacher preparation is key to them applying the STEM education. In the next part, we therefore asked the opinions of the respondents (pre-primary teachers) about their training in relation to STEM. That is, if they encountered the term either during university studies or a course, how do they evaluate their readiness for STEM teaching in frame of the education of the in the children attending kindergartens.

As the results presented in a graphical form in Figure 2 show, only 25 % of the respondents are of the opinion that they are well or sufficiently prepared for STEM learning. However, almost 35 % of teachers could not comment on this question, and almost 40 % of teachers feel that they are poorly or insufficiently prepared for STEM teaching. Several conclusions can be drawn from the above:

– Teachers have a lack of knowledge about STEM subjects;

– Teachers lack information about STEM;

– Teachers have heard about STEM, but have not applied it in practice and therefore cannot assess their training;

– Teachers encountered STEM only theoretically in the framework of various courses, webinars and other education, so they did not have the opportunity to create activities and thus verify their competences or preparation for STEM;

– Teachers received low-quality education.

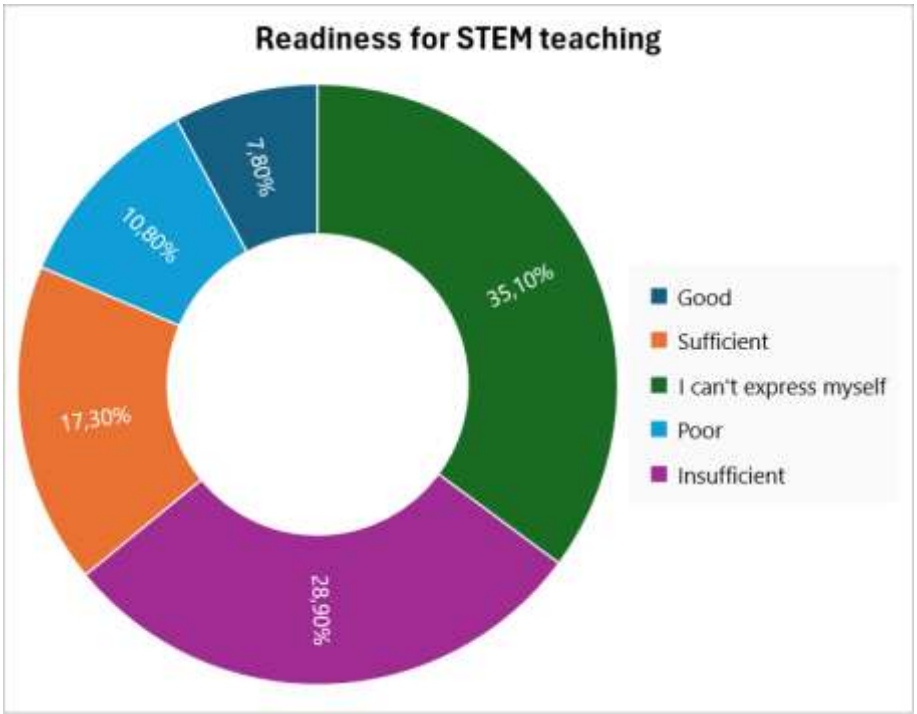

Fig. 2. Readiness for STEM teaching

Feeling insecure about the ability or competence to teach STEM, resulting from insufficient training, could lead teachers to have low self-confidence, what could have a negative impact on their teaching effectiveness in general (Bagiati, Evangelou, 2015; Clark, Andrews, 2010; Holstein, Keene, 2013).

3. Discussion

From the point of view of teachers' awareness, it was found that up to 54 % of kindergarten teachers have no information about the STEM concept and have not even met it yet. On the other hand, the most information for 22 % of the respondents comes from an independent study of professional literature. This suggests a proactive approach by a subset of teachers who took the initiative to learn about STEM through self-directed learning what raises concerns regarding adequacy of the curricula of the teacher trainees' professional development in the area of STEM teaching. Reasons of this lack of teacher training in STEM require further investigation as they may stem from a variety of factors. These findings underscore the need for targeted interventions, professional development initiatives, and a more systematic approach to familiarizing and equipping teachers with the knowledge and skills necessary for effective early childhood STEM instruction. The results showed that STEM education in Slovakia is not sufficiently incorporated in the professional training of future teachers of technical subjects. Lack of special training can affect the process of STEM integration into the education done in kindergartens (Weng, Li, 2020). Absence of the specific professional training can influence implementation of STEM education to kindergartens (Weng, Li, 2020). Well organized and often available possibilities of professional education would support effective application of STEM education in a class (Margot, Kettler, 2019). Necessary is also continuous professional development of teachers, based on participation of a team of teachers who will use the curricula (Nadelson et al., 2012). At this point it is important to stress that it is necessary to enable teachers to gain experiences with STEM concept and to it relevant pedagogy in a meaningful way. Improvement of the professional training could lead to a

higher confidence of teachers in relation to their readiness or competency to teach STEM (Lesseig et al., 2016; Nadelson et al., 2012; Nadelson et al., 2013; Nadelson, Seifert, 2013). A problem is also non-integration of the particular STEM subjects in professional teacher training as well as the lack of information regarding STEM, which is proved also by the foreign studies (Margot, Kettler, 2019). So we need to change approach to the professional training of teachers not only at universities but also in frame of the insurance of the professional and practical development courses focused on STEM education concept: different forms of trainings or webinars (Türk et al., 2018; Shernoff et al., 2017). Teacher's approaches and opinions on STEM education have a strong impact on children's opinions and approaches. Children' motivation to learn the STEM branches depends on the teacher's personality, his/her ways of teaching, interest, opinions (Dökme et al., 2022). Insufficient professional preparation of teachers for STEM teaching was proved by the results of the comparison analysis of the study programs of the concerned universities. Students obtain knowledge on materials, technologies of their processing, options of these materials for the given level of education, and so they will be able at least to apply the acquired knowledge at designing and creating of situational learning tasks for children, corresponding with the educational field Man and the world of work. However, as a problem we perceive absence of any integration of any innovative education strategies such as, e.g. STEM or STEAM, and that into all of the given study programs. The European Union (2016) encourages its member states to better prepare young people for changing labor markets, to develop their STEM competencies and 21st century skills (EU 2016; Dede, 2007). STEM skills and qualified teachers in the given field are seen as the key elements by which these goals can be achieved. Some topics of the bachelor's study programs can be included in the given field (Materials and their properties, Investigation of the material properties – trial, error, experiment, Designing), but they are too general and therefore it is not clear whether universities deal with the issue of STEM integration. It is therefore necessary to ensure that this education becomes an integral part of pre-gradual training of teacher trainees what would enable them to acquire knowledge about the appropriate teaching methodology, and to develop relevant competencies. In order to finalize comprehensive results and for purposes of setting out the consequent research strategy, further analysis will be conducted to specify what in-service teachers actually lack in practice, or what they, based on their in-service experiences, retroactively lack. Complete processing of all of the results of the partial kinds of research will serve as a platform to specify and develop proposed measures of the teachers further education.

4. Conclusion

The presented results show that the preparation of future teachers in Slovakia to apply STEM education in their future career is very weak. There is absence of any preparation in subsequent acquiring of knowledge focused on integrated approach to the STEM education, which is most important for learning and understanding STEM. More connected teaching of the particular subjects of STEM can make STEM concept, as well as the particular STEM subjects, more friendly to both students and teachers (Sarac, 2018), and this in turn can increase the number of students considering careers in a STEM-related field (Schweingruber et al., 2014). In order to develop a generation capable to create innovations, the scope, theory and practice of science, technology, engineering and mathematics education, which is at the center of reforms, STEM should be studied at the school and university level (Cavas et al., 2013; Marculu, Sungur, 2012). STEM education should be included in country national school policies. The mentioned study also encourages further investigation of teaching strategies in the context of technical education of future kindergarten teachers. The presented issue thus paves the way for a further discussion of the complexities of teacher preparation and offers valuable insights into existing and potential areas for improvement within the observed study programs. Results of the presented research can be used as a platform for proposals of innovative study programs reflecting the current social demands regarding the field of technical education at both pre-primary institutions and schools, as well as a platform for creation of practical teacher training methodologies emphasizing STEM education.

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