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Developing Pre-service Teachers Conceptualization of STEM and STEM Pedagogical Practices

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Science, Technology, Engineering, and Mathematics (STEM) integrated curricular approach has become the leading type of education reform worldwide. This paper presents a STEM integrated collaborative activity to enhance STEM knowledge among pre-service mathematics and chemistry teachers. Well-structured and planned on-site workshops on STEM activities were delivered to pre-service teachers while growing mathematics and science content knowledge and pedagogical practices. The qualitative content analysis research methodology was used to identify relevant topics related to post reflective questions regarding pre-service teacher perspectives on the experience gained through the collaborative practices at the STEM workshop. The results show that the workshop had a positive effect on pre-service teachers' conceptualization of STEM—through collaborative, participatory practices, an effective learning environment while bringing attention to teacher professional development and education policymakers. Key elements of this study approach included: (1) collaboration between university professors to teach and incorporate STEM in higher education; (2) unique partnership among mathematical and chemistry pre-service teachers; and (3) professional development, which is devoted and adopted into a study course.

Keywords: STEM, mathematics pre-service teachers, chemistry pre-service teachers, professional development, higher education

INTRODUCTION

Science, Technology, Engineering, and Mathematics (STEM) has received a great deal of attention in recent years and is growing every day. Considering that STEM education is not a new concept and that it has been discussed for the past two decades, in recent years it has received considerable attention (Sanders, 2009; Bybee, 2010; Breiner et al., 2012; Kennedy and Odell, 2014; English, 2016). Many pre-university schools offer STEM courses starting from preschool and elementary education, whereas universities offer STEM degrees. STEM education encourages science literacy, innovation, and critical thinking (Siekman, 2016). Yet many countries, most definitely developing countries, are still lagging behind the growth of STEM educational skills among their students (Clark, 2014; Blackley and Howell, 2015; Kelley and Knowles, 2016). This could be because the nature and development of STEM skills in different countries are diverse and need to be enhanced in future research (English, 2016).

The development of skills through STEM education is linked to economic growth and the country's environmental and social impact (Kelley and Knowles, 2016). Global economies and

societies need to integrate knowledge and skills into STEM to solve problems on an ongoing basis. The trend of future employment opportunities leads to the increasing need for at least a basic understanding and incorporation of mathematics and science. Through STEM activity practices, pre-university and university students have the opportunity to learn how to design and prepare, develop, and implement project ideas. The theory behind STEM education is that academic concepts are translated into real-world lessons when integrating STEM, representing a multidisciplinary and interdisciplinary approach to learning (Hoachlander and Yanofsky, 2011; Chalmers et al., 2017). Through STEM, students can make connections between school, community, and work (Tsupros et al., 2009). STEM implementation involves integration into teaching and learning, including one or more teachers and more than one class of students, and may have a specific time to completion (Isaacs et al., 1997; Roehrig et al., 2012).

There are multiple definitions of STEM integration (Sanders, 2009; Moore and Smith, 2014). According to Sanders (2009), STEM integration explores teaching and learning between two or more STEM subject areas. Sanders (2009) suggested that results should be deliberately designed to learn at least one of the STEM subjects, i.e., mathematics learnings in science, technology, or engineering. Moore and Smith (2014) described integrated STEM education as an attempt to unify a single course with all STEM disciplines, a lesson centered upon linking subjects and real-world problems. Moor and Smith further add that STEM integrated curriculum could include STEM content learning objectives focused on one subject, but context can come from other STEM subjects. For many years STEM education concentrated on science and mathematics as separate subjects, with little overlap and focus on technology or engineering (Breiner et al., 2012). High-quality STEM learning involves engaging students in engineering design complexities, learning from mistakes, and taking part in reconstructing, using relevant contexts to address the engineering challenges that can be directly related to student's needs. STEM learning involves studying and using correct science and/or mathematics content, engaging students through student-based pedagogies, and encouraging communication skills and teamwork (Moore et al., 2014).

The integrated STEM inquiry task of teaching and learning is even more challenging in cases where traditionally, the learners are used to guided step-by-step instructions to successfully engage in completing a task (Sergis et al., 2019). An inquiry learning in science and mathematics is considered one of the best pedagogical approaches to engage students effectively and through self-directed investigation in the learning process (Lazonder and Harmsen, 2016). Overall, using STEM integration teaching and learning approaches within the curriculum are primarily to develop the ability to live and work in a society of the 21st century and improve learning outcomes in all curriculum areas. It will be difficult for teachers who have never encountered such activities in their learning to introduce them to their classrooms (Quinn and Bell, 2013, p. 26). Teacher knowledge development does not begin or end in teacher education, but it is influenced by it (Milner-Bolotin, 2018). For this purpose, the incorporation of STEM in classrooms requires the preparation of pre-service teachers of STEM education, both for conceptual meaning and for STEM teaching practices.

This study provides STEM instructions through a series of STEM activities and shared learning experiences to pre-service mathematics and chemistry teachers. Only the effects of the post-reflective questions were discussed in this article. The goal of this study was to improve teachers' conceptualization of STEM and introduce them to STEM pedagogical practices. The need to enhance pre-service teachers' preparation to teach STEM-integrated subjects is combined with the need to investigate the effectiveness of such collaborative practices in improving teacher education programs. The study provides insights and ideas on how pre-service teachers perceive STEM education, shaping their teaching practices, beliefs, and the challenges they experience when implementing STEM education practices. Information received as needs assessment from the pre-service teachers will lead to future STEM education research and provide insight into integrating integrated STEM education in specific curriculum practices in pre-service education and continuing professional development.

STEM PEDAGOGICAL PRACTICES AND PROFESSIONAL DEVELOPMENT

Content knowledge focuses on the subject knowledge, and pedagogical knowledge focuses on practical implementation in the classroom. Ozden (2008) defines content knowledge as "the concepts, principles, relationships, processes, and applications a student should know within a given academic subject," whereas pedagogy as "the science of teaching, instruction, and training" (pedagogical practices). They are the two crucial areas of teacher knowledge that are often stressed (Shulman, 1987). The blending of the two (content and pedagogical knowledge) is called pedagogical content knowledge (PCK). PCK refers to understanding how specific topics, problems, or issues are structured, interpreted, and tailored to learners' varied interests and abilities. In recent years, technology was also added to the combination as a requisite for teachers' expertise for the 21st-century classroom (Chai, 2019). When teachers already have difficulties in their content knowledge, they are likely to experience new knowledge gaps and face challenges in pedagogical practices of integrating STEM education (Stinson et al., 2009). Stohlmann et al. (2012) suggest that what is learned from research into efficient science and mathematics instructions gives insight into effective practices in applying STEM. Walker (2007) finds that connections (*between topics, students' in-, and out-of-school knowledge, and procedural and conceptual knowledge*) and representations (*of concepts, problems, and solutions*) can also help the pedagogy of teachers. Many of these teaching approaches benefit from integrating STEM and naturally lend themselves to integrated STEM activities.

Science, Technology, Engineering, and Mathematics education practices also have the potential to shape pedagogical practices. Hands-on activities in the educational context while integrating STEM subjects is "an innovative way to reimagine education" (Peppler and Bender, 2013). According

to Harlow et al. (2018), teacher support is needed to develop appropriate skills to promote STEM learning experiences, as many teachers do not have pedagogical practices to teach STEM education. Milner-Bolotin (2018) notes that it is essential to review available research evidence on teacher knowledge development during teacher education and better understand how to educate STEM teachers. Additionally, it is critical to recognize that teacher knowledge development and competencies are highly dynamic concepts. A teacher's growth is affected by many factors such as content knowledge, learning experiences, reflection, practices, and opportunities for professional development, learning attitudes, the teacher's belief in teaching as a career, and peer collaboration. Belland (2009) and Nadelson et al. (2013) explain that many teachers teach their science classes similar to how they remember them when they were students. The science content introduced mimics teaching methods of how they were taught. Belland (2009) then concludes that if accurate science-based teacher instruction is not offered correctly, teachers are likely to teach STEM in a lecture-based fashion.

As per Shernoff et al. (2017), teachers who incorporate STEM education into their teaching require several courses and workshops that show them how to integrate STEM subjects while attempting to solve real-world problems collaboratively. While there are many education reforms and research that does center upon integrated approaches to teaching STEM, there is insufficient information around STEM-specific teacher preparation programs that primarily prepare pre-service teachers for STEM implementation (Shernoff et al., 2017). Besides, because of the inequality between conventional teacher education programs and everyday life, teachers encounter difficulties in finding real-life examples to create a STEM teaching context and implement a flexible STEM curriculum. The primary responsibility for overcoming these problems rests with teacher preparation programs (Aydin-Gunbatar et al., 2018). According to Shernoff et al. (2017), teacher education programs need to improve their courses and teach those courses while preparing their pre-service teachers with the knowledge of STEM, effective pedagogy for implementing STEM, and knowledge on STEM literacy, skills, and abilities. Kelley and Knowles (2016) state that STEM teacher education programs need a thorough overview of core theories of learning, such as design thinking, computational thinking, and scientific inquiry. Pre-service teachers may also lack sufficient training to teach relevant scientific investigation, technology, design, and engineering practices. Thus, integrating integrated STEM education and engineering design processes and improving teachers' STEM content knowledge are crucial measures for introducing any STEM reforms. Teacher education programs should provide STEM courses to pre-service teachers during their study programs and professional development to support in-service teacher planning and STEM teaching implementation (Shernoff et al., 2017). Teachers' conceptualization and preparation for STEM education may be the critical factor determining STEM reforms in education (Bissaker, 2014; McDonald, 2016).

Furthermore, Chai (2019) states that the gaps in teachers' STEM knowledge and STEM teaching skills lead to STEM teacher professional development. With the introduction of new curricula to teachers, professional development often focuses on curricular training, targeting the curriculum's organizational or practical needs instead of subject content or teaching based on content objectives (Walker, 2007). It was grounded in Desimone's (2009) recommendations for teacher professional development programs to emphasize coherence, content focus, active learning, collective participation, and a substantial duration. Borko (2004) argues that teachers' professional development in many countries is insufficient, inconsistent, shallow, and does not consider how teachers learn. Many studies (Borko, 2004; Desimone, 2009; Opfer and Pedder, 2011; Fore et al., 2015) state that developing effective professional development programs, awareness of local environmental characteristics is essential. Professional growth affects teacher practices and educational programs, attitudes and behavior, performance, and productivity. However, Chai (2019) claims that teacher educators need to consider the context in STEM teacher professional development workshops or activities.

Guskey (2002) defines professional development programs as efforts to change teacher practices and beliefs. These changes are often influenced by the teachers themselves trying to find new resources and teaching strategies that best fit the students' needs. Therefore, it is essential that teacher professional development programs, both pre-service and in-service, include the most advanced practices and the most appropriate for society's needs. Educational reforms and professional development programs in Kosovo are continuously evolving. The educational reforms must receive information on how pre-service teachers in Kosovo see STEM education, conceptualize STEM and pedagogical practices. Thus, according to Yıldız et al. (2019), establishing the STEM centers in cooperation with universities will significantly contribute to creating well-educated individuals and societies in science, technology, mathematics engineering.

Context of the Study

A new pre-university education curriculum was developed in Kosovo to meet the population's needs and the wider challenges of the 21st century, creating new skills for the global labor market (MEST., 2016). The primary focus of the Kosovo curriculum framework (KCF) is to develop a *knowledge-based society*, integration in the *Digital Age*, an increase in *interdependencies, and mobility* as a result of globalization, inclusion in the European Union through *Learning to live together*, and *Sustainable development*. The development of knowledge, skills, routine, behavior, attitudes, and values form the main objectives of the framework.

Kosovo offers a competency-based curriculum. The KCF aims to promote integrated learning across broad areas and strengthen interconnections across different fields of learning, thus enabling students to understand the relations between all aspects of their learning. Kosovo's curriculum includes knowledge and skills, attitudes, and values to address real-world issues, integrate emerging-market curricula, and discuss new developments in society, economy, culture, or technologies. Furthermore, the curriculum gives a lifelong perspective, ensuring that the curriculum should prepare students to address daily challenges and concerns in a learning and understanding society effectively.

Creative skills, such as learning to learn, active and responsible analysis, and processing information, e-learning, along with use of digital technologies, are the focus of the curriculum approach (MEST., 2016).

According to Kennedy and Odell (2014), the current state of STEM education worldwide has developed into an immersive meta-discipline, reducing traditional barriers between STEM subjects and relying instead on developing design solutions for complex contextual problems through the use of modern tools and technologies. The Kosovo Curriculum theoretically promotes the intentional convergence of subject areas by offering more in-depth connections between science fields (MEST., 2016). However, the teachers are trained to teach one subject only, and STEM has not been mentioned in the curriculum. Similarly, initial teacher training focuses on distinct subject disciplines, as observed by Blackley and Howell (2015). In such cases, there are significant difficulties for educators and administrators in fostering integrated STEM teaching (Shernoff et al., 2017). Because of the integrated nature of STEM, it is not feasible to offer isolated courses of STEM disciplines and hope to train successful STEM teachers (Sanders, 2009). Sanders (2009, p. 22) states that introducing pre-service teachers to "the foundations, pedagogies, curriculum, research, and contemporary issues of each of the STEM education disciplines, and to new integrative ideas, approaches, instructional materials, and curriculum" is essential. This will help build pre-service teachers' STEM content knowledge and pedagogical content knowledge. For some teachers, education programs may help integrate initial training in STEM pedagogical practices (Yip, 2020). Teacher practical knowledge (Verloop et al., 2001) and educational background (Kennedy and Odell, 2014) substantially impact the teachers' integrative STEM approaches.

There is still a great deal of confusion among Kosovo teachers about STEM education and how it is best translated, applied, and implemented in practice. Kosovo teachers need professional development and experience to change STEM views as something revolutionary and distant from learning outcomes and curricula. Likewise, there is still a great deal of confusion in other nations about STEM education and how it is best applied and incorporated (Breiner et al., 2012; Blackley and Howell, 2015). When countries worldwide increase their potential in STEM education, they will have to work together to develop scientific research and build the capacity to provide quality education to students (Clark, 2014).

METHODOLOGY

The study took place at the University of Prishtina, Faculty of Education, during the academic year 2017/2018. A total of 40 (22 mathematics and 18 chemistry) pre-service teachers engaged voluntarily in the professional development workshop organized and structured by mathematics and chemistry university lecturers (authors) associated with the needs provoked during the Teaching and Learning of subject-specific courses at Master-level studies. The lecturers replicated

the module developed by Dr. Sevil Akaygun and Dr. Fatma Aslan-Tutak from the Bogazici University (Akaygun and Aslan-Tutak, 2020) with their collaboration and organized STEM workshop activities to introduce practices that support STEM education.

Initially, pre-service teachers were asked to reflect on STEM knowledge they might have and STEM conceptualization. The pre-reflection was meant to enable researchers (authors) to learn how much STEM knowledge and STEM awareness pre-service teachers had. For 5 weeks in a row, the STEM professional development workshop was attended by pre-service teachers on Saturdays. In the eighth week, pre-service teachers presented and discussed their group STEM projects. During the workshop, participants had a dual role: as learners-involved in the learning process while engaging in the STEM workshop and as teachers-involved in discussions and perspectives on pedagogical processes. **Table 1** outlines the weekly activities for the STEM professional development workshop based on work of Akaygun and Aslan-Tutak (2020). All activities were completed in groups (mainly two mathematics and two pre-service chemistry teachers). After the professional development workshop, open-ended, post-reflective questions were emailed to all participants to inquire about their experiences. In response, the understanding, knowledge, and pedagogical practices gained during the collaborative practices and the benefits/challenges they faced during the STEM workshop were acquired. A total of 26 responses were collected from all participants in the workshop (incomplete responses were not considered).

A well-prepared STEM professional development workshop deepens and broadens teachers' subject matter knowledge and broadens and improves their teaching STEM practices. In this study, the STEM workshop was in alignment with the background contextual knowledge of the pre-service teachers' educational training and pedagogical strategies of teaching, the curriculum in practice, and instructional methods. The contextual information about the pre-service teachers, the educational system, and their complexity helped the researchers offer adequate resources and supporting materials for implementing and facilitating an effective teacher practices STEM workshop. The integration of their teaching subjects' curricula and teaching practices was very important. The organization of activities in small groups has enabled pre-service teachers to reflect and deeply consider integrating their fields of study with pedagogical aspects and provide them with valuable experiences that will help them and their future students.

The qualitative content analysis research methodology (Cohen et al., 2007, p. 475) was used to identify relevant topics related to open-ended reflective questions regarding pre-service teacher perspectives on the experience gained through collaborative practices in the STEM workshop. The inductive approach for data analysis was used to grasp and analyze the data from the reflective questioners. Both lecturers (authors) "diving into data details and specifics to discover important patterns, themes, and relationships starts by exploring them first and then confirming them" (Patton, 2002, p. 453). Therefore, each researcher read the answers separately and, at the same time, performed initial coding. The authors discussed the experience and results of

TABLE 1 | The activities for the STEM professional development workshop (Akaygun and Aslan-Tutak, 2020).

Week	Schedule
1	Pre-reflection on STEM knowledge
1	Activity 1: *Introduction to STEM education*
	Lecture on STEM education
	Two scientific articles on STEM education were shared with the pre-service teachers for reading and reflection (Dugger, 2010; Laboy-Rush, 2011)
2	Activity 2: *Poster of STEM Student Club Logo*
	Visioning of STEM through drawing (students were given A3 paper size and crayons)
	Reflection on the activity
3	Activity 3: *Edible Car*
	Guided worksheet instructed for planning, designing, and testing the speed of movement of the "Edible Car."
	Different foods were provided
	Reflection on the activity
4	Activity 4: *Ocean Color*
	Guided worksheet through QR code reader for planning, designing, testing ocean colors
	Reflection on the activity
5	Activity 5: *Building a boat*
	Guided worksheet for planning, designing, testing if the ship will sink or float
	Recycling materials provided
	Reflection on the activity
8	Activity 5: *Build your Project* and lesson worksheets for planning, designing and testing
8	Post-reflection questions on STEM

the first coding exercise and decided on the methodology to be followed as the final coding method. Analysis of the codes followed and constant comparative analyses were used to prevent research bias (Patton, 2002, p. 492). Patterns and themes have been reported as a list in a separate table as a useful tool for the researcher to explain each theme.

RESULTS AND DISCUSSION

The need to enhance the pre-service teachers' preparation to teach STEM integrated subjects is combined with the need to investigate the effectiveness of such collaborative practices to improving teacher preparation educational programs. In this paper, only the findings from the post reflective questions were analyzed. Our intention was not to investigate changes in knowledge before and after the workshop. Yet, we wanted to learn as many ideas and insights as possible from pre-service teachers' experiences and integrate them into our curricula. Nevertheless, it ought to mention that there were minimal and limited answers from the pre-reflections (most of which said that STEM is only a new approach to integrating science, technology, engineering, and mathematics). The coded data from the post reflective questions were organized in a table to identify themes that reflect all the issues identified in the open-question answer. Data from the questionnaire were the starting point for identifying patterns.

The data analysis for responses to the post reflective questions, *What is STEM? How do you understand STEM education? How does STEM influence the enhancement of your pedagogical practices? What are the benefits/challenges of applying and implementing STEM education?,* led to the creation of five themes (**Table 2**): (1) STEM is an instructional method for solving real-life problems; (2) STEM helps in developing 21st century skills; (3) STEM encourage the creation of positive values and attitudes, (4) STEM enables the advancement of teacher pedagogical practices; and (5) it is challenging to implement STEM in schools.

STEM Education and Real-Life Problems

The results obtained from the analysis of the data collected characterize STEM education to identify and apply concepts and content from different disciplines to solve challenging problems. Most pre-service teachers seem to agree that STEM is about preparing the best teachers and students at all levels and enabling them to compete in fast-moving science and technology. According to pre-service teachers, STEM is about involving different fields for implementing projects that need to be related to the learning outcomes envisaged in the curriculum. Others assume that STEM is a teaching method or an activity for developing the different skills necessary to solve real-life problems. The STEM education, as stated by the pre-service teachers:

> *Is a program that promotes the understanding of knowledge by interrelationships between different subjects and appropriate learning strategies that are essential to solving real-life problems.*

> *is a method that links various fields such as science, technology, engineering, and mathematics to perform a task or an activity that is compatible with the curriculum's learning outcomes. I would define STEM as an activity that integrates different fields to make teaching and learning as productive and successful as possible.*

Furthermore, the pre-service teachers stated that the:

> *benefits of STEM are many. The implementation of STEM in education brings benefits for students, teachers, and the community.*

TABLE 2 | Summary of Patterns and Themes that emerged from the responses of the reflective question: *How do you understand STEM education? How does STEM influence enhancement of your pedagogical practices? What are benefits/challenges of applying and implementing STEM education?*

Patterns (open coding)	Themes (Axial Coding)
STEM: - is a curriculum for the understanding knowledge through the interrelationships of different subjects; - an appropriate learning method; - a method for addressing real-life problems; - focused on improving learning outcomes; - an evolution to teaching method to meet the needs of students.	STEM is an instructional method for solving real-life problems.
STEM helps: - to gain new knowledge and skills; - tp develop critical thinking and creativity; - logical reflection and argumentation; - tp work together and share ideas on problem-solving; - to be a researcher; - to work together with colleagues.	STEM helps for developing the 21-st century skills
STEM: - motivates you for work; - it is a driving force for creativity and innovation; - it encourages you to grow perseverance; - it stimulates you to share ideas freely; - it enhances teamwork.	STEM encourage creating positive values and attitudes
STEM: - enables the advancement of knowledge for pedagogical practices; - had twofold benefits, training of pedagogical practices and expanding knowledge in various fields; - allowed the use of the new teaching approaches in coherence with developments in the field of education; - influences the fulfillment of curriculum requirements; - develops knowledge and skills for working in the projects	STEM enables the advancement of teacher pedagogical practices
- the encouragement, professional preparation, and institutional commitment; - teachers are not enough prepared; - lack of resources (inappropriate texts, insufficient technological equipment, lack of budget) - the management of the projects in a classroom with a large number of students; - a lack of collaborative culture among teachers of different fields; - the integrated of the disciplines of STEM can be challenging.	*STEM is challenging*

These benefits can be instantaneous during faster acquisition and exchange of cross-curricular knowledge. They can also benefit from long-term information to be used to raise awareness among all actors involved in teaching and learning. STEM helps to ensure that the knowledge gained in the classroom is applied in practices in real life.

Pre-service teachers indicated that the benefits of STEM education were numerous. Most of them mentioned the main interest, the integration of STEM subjects. They also confirm Chai's (2019) statement that STEM education resulted from the gaps between knowledge and skills. Pre-service teachers see the integrations of subject fields as crucial to developing students' knowledge and skills to address everyday problems and solve them. There are also responses from pre-service teachers who

have defined STEM education as a necessary tool for preparing pre-university students for further studies in science, technology, engineering, and mathematics. According to pre-service teachers, the benefits of STEM are not only for students but also for the teachers themselves and the community. While STEM activities are being implemented, teachers advanced their pedagogical practices (STEM teaching, instruction, and training) and have broadened their knowledge of other STEM fields. At the same time, the community benefits from the innovative ideas that come from developed projects related to real-life problems. Our findings align with the study of Tsupros et al. (2009), which states that STEM practices also involve integrating the school and community.

Descriptions of STEM as an interdisciplinary approach aimed at "translating" academic concepts into life lessons or as an "attempt to unify all disciplines to relate subjects to real-world problems" are also given in studies by Hoachlander and Yanofsky (2011), Moore and Smith (2014) and, Chalmers et al. (2017). Thus, although for many pre-service teachers, STEM was a new concept, the involvement in the workshop enabled them to understand STEM as a multifaceted concept. In particular, STEM is recognized and related as a method for solving real-life problems.

STEM Education Develops Multiple Skills

Science, Technology, Engineering, and Mathematics integration through the implementation of engineering design activities during the workshop enabled pre-service teachers to develop valuable 21st-century skills, including being researchers, communicators, problem solvers, team workers, innovators, and competent users of the technology. They found STEM education to be the promoter of curiosity, logical reasoning, and the development of the other skills needed for problem-solving. They reflect on the fact that the benefits of STEM education are linked to the enhancement of teamwork between peers and the motivation for creative and innovative works:

Working together with colleagues has been very productive. It was challenging as well, but it also gave us a lot of fun. This experience showed us how to engage students in similar projects.

I may freely say that STEM will have a significant impact on the motivation of students. They will become researchers and become more independent. The integration of STEM fields will enable the gaining of general knowledge and skills.

In addition to gaining knowledge from specific integrated subjects, STEM aims to stimulate curious minds, reasoning, logical thinking, and collaboration skills. It is also about developing critical thinking and many other capabilities of 21st-century skills.

STEM is designed to improve learning. STEM education is also a stimulus to the development of many skills, such as the ability to use the technology, search new information, create problems on its own, and work together with colleagues from different disciplines.

In their reflections, pre-service teachers presented STEM as vital and very important for developing 21st-century skills. In their study, Moore et al. (2014) discuss the importance of STEM learning relating it to the teaching of content while developing

skills, especially communication skills and teamwork. Similarly, as it was shown by Bartels et al. (2019) that pre-service teachers' attitudes support the value of collaboratively taught math and science methods courses.

Positive Values About STEM

Working in groups during the activities has made it possible for pre-service teachers to understand that STEM also influences many positive values and attitudes for STEM subjects. During the STEM activities, valuable information was exchanged between pre-service teachers. Pre-service mathematics teachers benefited greatly from working with chemistry pre-service teachers and vice-versa. They said that for the first time, they felt relaxed when sharing their knowledge and that everyone expressed their willingness and excitement to participate in the activity. Even when they have made mistakes (in measuring, selecting suitable materials, or testing the engineering design), they agreed that working as a team has built confidence in them, and they believed that they would complete the activity to the end successfully. According to pre-service teachers, STEM education is an excellent approach that allows knowledge outcomes to be achieved and enables the implementation of several positive values necessary for life.

> During the activities, I realized that STEM education also has to do with the incentive for work and motivation to learn new things that are not only related to our specific subjects. I learned a lot from my chemistry colleagues. Cooperation needs to be the principal if you want to do good things in life.

> Science, Technology, Engineering, and Mathematics is a tool that offers an opportunity for more self-confidence. When our car had broken down while going down the slope, I learned not to give up. We have addressed the engineering design, which was challenging for all of us, but we were perseverant until we did what "was the best."

There have also been responses regarding emotional aspects. They consider their engagement in the STEM workshop as very valuable because the cooperation with colleagues has brought fun and enjoyable times. Deemer (2004) states that teacher attitudes are often transferred to their students. Therefore, pre-service teachers' positive reflections on the STEM workshop experience are quite vital and express their readiness to apply STEM in their classrooms. On the other hand, making the necessary strategic plans for teacher candidates to develop positive attitudes about STEM (Yıldız et al., 2019) is significant for enhancing pedagogical knowledge as a 21st-century skill, and necessary competence for future teachers.

Teaching STEM as Pedagogical Practice

Teaching STEM was seen as a new approach to almost all pre-service teachers. During the first week of the workshop, they had the opportunity to read literature on STEM and practically pursued a STEM integrative approach. Pre-service teachers' participation in STEM activities is an excellent opportunity to learn to plan teaching strategies, assist with classroom management, or prepare for assessment to address students' learning needs. Thus, STEM is seen from pre-service teachers'

reflections as a very effective method to develop conceptual knowledge for different subjects and advance their pedagogical practices of STEM teaching and instructions.

Both pre-service mathematics and chemistry teachers said they had theoretical knowledge of the Kosovo Curriculum's integration approach. Still, they did not have the opportunity to see how to plan and design a proper project that integrates and incorporates different fields at the same time. Pre-service teachers, some already engaged in teaching and enrolled in the previous training provided for implementing the new curriculum, have stressed that the interdisciplinary approach is documented in all curricular documents. Yet, practically minimal application there is in the classroom. It was essential for them to experience the combination of the content from different subjects and convey that content, utilizing teaching methods that differ from those by which most teachers were taught (Lynch and Fleck, 2014, p. 174).

> I assume that every useful link of knowledge and information gained from all subjects has a positive impact on student's performance, so I believe that the connection of these four STEM pillars surely makes the students well qualified to work on projects. For me, as a math teacher, the benefit is twofold, the skillful advancement of new pedagogical practices and the expansion of knowledge in other fields besides mathematics.

Almost all pre-service teachers express readiness to implement STEM in classrooms after their experience, despite the difficulties and obstacles they may encounter. They see the value of attempts to continuously improve pedagogical practices through the use of new approaches and in coherence with developments in education and curriculum requirements.

> I think I managed to master some of the primary elements of STEM teaching during the workshop. This experience made me feel confident about implementing this new teaching approach. Although it will undoubtedly be difficult to integrate many subjects into a specific task, with a lot of desire and will, I will do my best to apply STEM with my students.

Pre-service teachers lacked knowledge of other disciplines, and this was also noticed during the workshop. Of course, this lack of knowledge about content affects teachers during teaching. They face challenges in STEM education integration's pedagogical practices (Stinson et al., 2009). Therefore, they see more value, and the opportunity to enrich themselves with new information while collaborating with colleagues:

> Although we are in the early stages and have little experience of STEM implementation, I feel confident to carry out similar projects. Everything I have learned at the STEM workshop is going to be valuable. The collaboration with colleagues is going to increase my teaching skills and knowledge for other disciplines

> As in other countries, such as the United States, Australia, etc., we need to focus on learning outcomes in the curriculum and determine which subject we want to focus more on, for example, using STEM with a focus on developing knowledge and skills for problem-solving in mathematics (STEM).

From the pre-service teachers' answers, we understood that their interest in STEM was great, not only during the workshop

when they were involved in the practical implementation of STEM activities. In their reflections, they expressed an interest in expanding their knowledge of STEM. They have been searching for STEM implementation practices in other countries with advanced education to better conceptualize STEM-based teaching practices.

Challenges of STEM Implementation

In general, provided that there is a lack of collaborative culture among teachers of different fields in Kosovo and that communication between colleagues is not always feasible, pre-service teachers have indicated that the discipline of STEM implementation can be challenging. Preparing for STEM implementation in the classroom is seen as challenging due to the conditions under which most schools operate. The lack of equipment and financial resources necessary for the implementation of various projects may also hinder the introduction of STEM in schools. Even the lack of organizational and classroom management skills is identified as a potential barrier for STEM adoption.

I think the challenges and barriers are of different and diverse natures. For STEM projects, schools need to have a budget to buy the necessary materials, and they should have computers and other tools. The desire of teachers to change and improve is not enough. Still, the encouragement, professional preparation, and institutional commitment are also critical enough to ensure that this approach to education is successfully implemented.

It's hard to think about how I would manage a project in a classroom with a large number of students, especially when the school has neither the means nor space where students can work in groups.

Pre-service teachers also stated that teachers must attend professional development for STEM education because they believe that teachers find it impossible to give up traditional lessons, especially those who are older. The Kosovo pre-service teachers' statements align with the study of Quinn and Bell (2013, p. 26), finding that changes in the classroom culture will not happen without teacher professional development. Other studies also reported a need to develop appropriate skills to promote STEM teaching and learning (Harlow et al., 2018). Since STEM education requires teachers to integrate technology, pedagogy, and content knowledge (Chai, 2019), a commitment to detailed planning and computer-aided design for each STEM-initiated project must be supported by professionals. Thus, it will be beneficial to integrate initial training in STEM pedagogical practices (Yip, 2020) for pre-service teachers and teacher professional development programs. It is difficult for all teachers to use different disciplines while teaching. Some teachers in Kosovo still have difficulties using technology. They are not prepared for this way of teaching. Thus, proper training should be provided and, of course, a forum for the quick exchange of experiences is needed. Challenges that arise during the planning and development of appropriate implementation strategies will be helpful if they are discussed with professionals, especially in the initial phase.

For the STEM to work, in addition to teacher training, appropriate materials and resources must be offered, which are part of the curricula of other countries that already have experience. For starters, texts or pamphlets that may help teachers to be better prepared to work with their students.

Science, Technology, Engineering, and Mathematics implementation will be more straightforward in vocational schools than in high schools, as several similar projects are already underway. Nonetheless, improvements to the curricula need to be made, and more practical examples of STEM applications should be included in the textbooks.

Science, Technology, Engineering, and Mathematics is not a standard that all teachers will obey. It offers different approaches and a wide range of applications. Probably this makes us confused about the things that we need to do during STEM.

Therefore, while pre-service teachers have demonstrated commitment to introducing STEM in classrooms, there is also confusion and reluctance to implement it effectively. Such findings are similar in other countries (Breiner et al., 2012; Blackley and Howell, 2015). Nonetheless, teachers and other educational actors of STEM will be part of the education of young people, and it will be part of the culture of every classroom.

CONCLUSION

For high-quality STEM education programs, countries need to offer a comprehensive curriculum, teacher training, guidance, and assessment, integrate technology and engineering into the science and mathematics curriculum, and promote engineering design pedagogy and scientific inquiry (Kennedy and Odell, 2014). Although the current Kosovo curriculum is theoretically designed to allow for greater integration of subjects, challenges remain, mainly STEM integration education. The education system at all levels, curriculum implementation, and teaching and learning methods have brought the curriculum subject integration into silos, with insufficient integration of science, technology, engineering, and mathematics. Teachers need a lot of work to integrate content across subject areas with a variety of learning activities. However, interaction with other subjects is expected to be relatively broad and varied within the disciplines.

Science, Technology, Engineering, and Mathematics education is of significant importance for preparing pre-service teachers for curriculum integration. According to Bartels et al. (2019), pre-service teachers should be introduced to STEM and allowed to design and teach integrated STEM as early as during their studies. Modeling collaboration while offering integrative STEM activities to pre-service teachers will increase understating of STEM teaching and learning. Future teachers should be guided to consider how STEM subjects can be integrated into meaningful ways for prospective students.

This study found that pre-service teachers effectively conceptualize STEM and STEM pedagogical practices when university professors work together in STEM disciplines. The STEM workshop activities introduced helped the pre-service teachers better understand and reflect STEM concepts and practices. In future publications, we will present the results from

data collected during the workshop on pre-service teachers' ability to apply STEM integration elements, such as planning, designing, preparing, developing, and implementing STEM activities. STEM teaching professional development, which is dedicated and adopted in the course of study for pre-service teachers, has shown that it could be implemented with in-service teaching in the future. The shared learning experience of STEM integration of pre-service mathematics and chemistry teachers is an excellent indication of the immediate need to redesign teacher preparation programs to better enable them to deliver integrated teaching and learning courses.

Similar to the study by Tsupros et al. (2009) and Kelley and Knowles (2016), the pre-service teachers' reflections show STEM to be crucial and related to the development of 21st-century skills and as a connection between school, community, and labor education. Joint efforts by teachers, administrators, universities, businesses, communities, and families can help meet the demand for STEM teacher education development to provide more efficient teaching and meaningful learning for students (Stohlmann et al., 2012). As pre-service teachers have shown, there is a need for more professional development training in STEM education which should be facilitated by professionals so that teachers have the opportunity to play the role of students, and at the same time, to develop the teaching competencies that are necessary for every teacher today. Effective pre-service teacher preparation programs and professional development are the only way to prepare good citizens who serve economic growth and other social developments. The reflections of pre-service teachers will also contribute to the development and adaptation of teacher training programs. Their stated challenges of pre-service teachers advocate discussions with other educational policymakers to implement STEM in schools to fulfill the competencies and development of 21st-century skills, which are the new Kosovo Curriculum's basic principles (MEST., 2016). Besides, the study supports teacher preparation to prepare for STEM teaching and a suitable environment for implementing STEM activities.

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