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STEM Education: Future and Current Challenges for the Preparation of STEM Educators

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Abstract

Several studies have shown that the combined education in Science, Technology, Engineering, and Mathematics (collectively known as STEM) is fundamental in preparing knowledgeable and technology savvy individuals who will become active citizens. As a result, STEM education is receiving increased attention and interest in recent years and the interest in STEM design models is literally exploding across the education landscape, leading to curriculum reorganization through STEM initiatives. In these models, the role of teachers is one of the most important factors in ensuring excellence in STEM education. A STEM savvy educator needs to show both deep content knowledge in STEM subjects and mastery of all the required skills and competences to teach these subjects well. As a result, professional development of educators is critical for designing and implementing STEM education concepts and programs. In this paper, the current trends in Teachers Professional Development for STEM education are identified and a brief overview of the state-of-the-art is given. In addition, challenges and potential future areas of research are identified, proposing a research methodology, which aims to identify skills and competencies for STEM educators, while taking advantage of the European Framework for the Digital Competence of Educators (DigCompEdu).

Keywords: *STEM education, teacher professional development, skills and competences, DigCompEdu;*

1. Introduction

STEM (Science, Technology, Engineering, and Mathematics) education constitutes a learning approach, which integrates the content and skills of different disciplines, aiming to introduce into the teaching of Mathematics and Natural Sciences, which are vital for a basic understanding of the universe, Technologies and Engineering Sciences, which are the means of interaction for human with the universe. This interdisciplinary approach promotes a learning environment for individuals to acquire not only 21st century skills, but also to have the opportunity to create new skills, using real problems and situations in order to address global challenges that citizens must understand [1].

Over the past years, there has been a growing interest in STEM education, due to the lack of student achievement in STEM subjects [2] and thanks to innovations on economic growth of nations and the importance of individual preparation to work in the technologically advanced world [1]. As a result, interest in STEM design models is literally exploding across the school-based landscape, supporting curriculum reorganization through STEM initiatives [3]. These initiatives include a shift from teaching students to remember and execute isolated facts and skills, to learning students to experiment as scientists, engineers and mathematicians [4].

However, these kind of educational reform movements require remodeling of the educational process. Based on the innovations that the STEM approach promotes, several challenges have created in order to be supported; educator preparation is one of them [5]. Additionally, since the role of educators (trainers, teachers and tutors) is of strategic importance, especially when it comes to acquiring technical and behavioral skills [6], there is a greater need for well-qualified STEM educators who understand what is needed and how to teach relevant and high-quality STEM courses.

Towards this direction, the purpose of this paper is to present the current trends concerning Teachers Professional Development for STEM education and the emerging research challenges. In addition, a proposed research framework for mapping skills and competencies for STEM educators is presented, aiming to facilitate the design of effective Professional Development Programs for STEM education.

2. Professional Development for STEM Educators

Over the past years, Teacher Professional Development has emerged a recognised area of research, due to its importance for the learning process and its influence on student achievement [7]. In the professional development literature that is specific to science, inquiry-based approaches that

emphasize on subject-matter content knowledge to deepen educators' content skills are suggested for high quality teacher professional development [4][8].
Furthermore, studies have shown that experiences in informal learning environments increased teachers' confidence and positive attitude toward science [9]. In addition, although student achievement in STEM teaching is more effective when teacher develop learning communities in their schools, in most teacher preparation programs offer limited experiences in such informal settings [10].
In the recent literature, the research efforts that exploit Teacher Professional Development for STEM education focus on different areas based on specific needs. For example, in [11], a model called s.t.e.m. (support, teaching, efficacy, material) was used, providing useful information for the teachers, focusing on the teaching category, the content knowledge of the teachers. In [4], a professional development program was designed, aiming to improve secondary science and mathematics teachers' competence in using a problem-based approach in the teaching of STEM, while in [5], a professional development program for teachers was developed, focusing on improving teachers' confidence towards knowledge and efficacy for teaching inquiry-based STEM. In iQUEST project [12], which aimed to promote student interest and attitudes toward careers in STEM, a professional development model was also designed and implemented, with the aim to train middle school science teachers the use of the technology as a critical part of student learning through integration of innovative technology experiences in formal science settings. In [13], a professional development series for STEM teachers was also developed focusing on the effective use of technology combined with engineering.
As we mentioned, all the above-mentioned research efforts enlighten different aspects of the topic under consideration. However, as the effective use of technology in education and the development of effective educational learning environment require comprehensive expertise in technology, pedagogy and content knowledge [14], none of them offer an integrated view of what an educator needs to know in order to be an effective STEM educator. Thus, there is a need for further research and discussion on the knowledge, experiences, attitudes and competences that educators need in order to effectively teach integrated STEM courses [11].

3. Research Challenges

Taking into consideration all the above, as STEM approach is being increasingly used and based on the innovations that promotes, several challenges emerged that require further investigation concerning the preparation of STEM educators. Based on the literature, more integration of content is taking place in teacher education programs in mathematics and science methods courses [11]. Although, the research on teaching integrated mathematics and science provides a good basis for teaching integrated STEM education, the biggest difficulty, is that many educators do not know how engineering skills are used in industry, so they cannot relate them to their students or deploy them properly as part of an effective STEM strategy [15].
In addition, STEM educators may have different academic background; as a result, the prior content knowledge may different. Thus, the curricula of the Professional Development Programs for STEM educators may differ based on the specific needs of the group of educators. Towards this, a creation of a competence profile for STEM educators may facilitate the design and development of such training programs. Different Competence Frameworks have been developed describing competence profile for educators, such as the European Framework for the Digital Competence of Educators (DigCompEdu) [16], which describe a set of digital competences specific to educators' needs. However, the focus is on digital competences, aiming to make an educator able to exploit the digital technologies for enhancing and innovating education, without focusing on technical skills, which is an important factor for a STEM educator.
In contrast, studies have shown that educators lack confidence in delivering science materials and encounter difficulty in gaining students' interest to study science subjects; there is also evidence for a similar association between confidence, anxiety, and efficacy with teacher effectiveness [5]. Thus, there is also the question of the use of STEM approach in educational practice and the appropriate preparation of educators not only for the required technical knowledge and skills, but also for the design of appropriate educational activities that take advantage and feel confident with the STEM integrated approach.
Studies have shown that educators who work in strong learning communities are more satisfied with their careers and are more likely to remain in teaching long enough to become accomplished educators [17]. Additionally, since many studies refer to active interaction and engagement within informal settings as a positive impact for STEM educators effectiveness [9], [18], the research on how active interaction and engagement within communities or online communities may enhance STEM

educators' professional development could be an interesting research topic and could bring innovative pedagogical approaches for Professional Development for STEM educators. Thus, future research areas concerning Professional Development of STEM educators should focus on both critical and practical questions. Such questions could be the following: *What are the skills and competencies influencing educator effectiveness? What difficulties does an educator face in his/her attempt to teach STEM related courses? In what ways do educators develop their skills and competences? How does a community of practice affect the educator's competence development?.*

4. Research Approach

Based on the aforementioned sections, there is an interest in the educational community towards STEM approaches and as a result the effective preparation of educators is a core issue. Thus, there is a need for systematic research in order to answer the emerged research questions, such as:

"What are the specific skills and competences, which are needed in order for someone to be an effective educator of STEM related courses and how individuals can acquire these competencies in informal learning environments such as communities of practice?"

Mapping the required skills and competences a STEM educator needs and investigating how he/she may enhance these skills and competences through informal settings, will lead to more structure training programs in the broader aim to enhance scientific and technological dexterity in fighting exclusion in the forthcoming technology-intensive society and to develop technologically savvy citizens.

As this research aims to investigate a new phenomenon, it is necessary to adopt an approach that would allow exploratory research [19], which would improve and extend qualitative findings based on quantitative data through a tool, develop a typology or classification, and identify procedures for experimental intervention from qualitative findings [20]. This is going to be a sequential exploratory design, as it will try to define the variables and qualities of an unknown phenomena and the first phase of the research will be used to build the second stage of the research design.

Moreover, it is worth mentioning that the European Competence Framework of Educators (DigCompEdu) will be exploited, aiming at commonly recognizable research results and developing a competence profile of STEM educators alongside with a training outline. Participants will be STEM tutors and as ethical issues may arise and need to be addressed during all steps of the research process, participants will be will be informed for the purpose of this research and how they will be involved in the research data [21].

The data analysis process includes three stages. The first stage is the primary qualitative stage, where semi-structured interviews, a concept mapping assignment and document analysis will be used. The next stage is the secondary quantitative stage, where a survey and statistical qualitative analysis will be performed. Finally, there will be the integration phase, in which the two strands of data will be connected and will extend the initial qualitative exploratory findings. The final joint display will be included to integrate data focused on the main research question. Fig.1 illustrates the two phases of the research, describing the methods and the data collection for each phase.

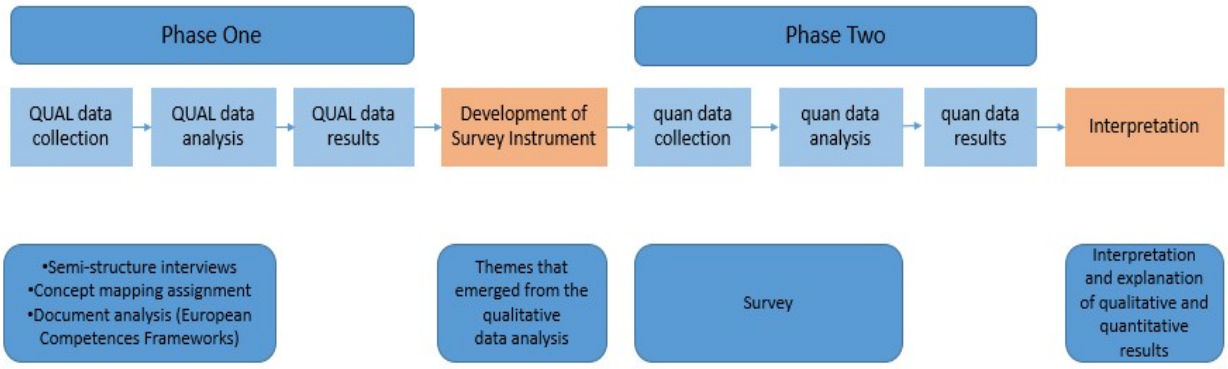

Fig.1. Exploratory sequential mixed methods design

5. Conclusions

In this paper a brief overview concerning Professional Development for STEM educators was presented, in order at first, to identify the current and future research challenges within this topic and then to provide an research framework regarding the required skills and competences of a STEM educator. This framework included the research questions, the research methodology and the proposed method of data collection and analysis. Finally, we believe that the results of this research are intended to contribute the research and educational community.

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