STEM Program

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STEM (Science-Technology-Engineering-Mathematics) education has received great attention in recent years not only for promoting interest and learning in these areas but also for encouraging children and young people to pursue careers in them.

Keywords: Content Knowledge (CK) ; Pedagogical Content Knowledge (PCK) ; STEM education

1. Introduction

STEM (Science-Technology-Engineering-Mathematics) Education is related to the need to attract students for STEM areas. The development of STEM literacy has become an educational priority[1] to improve the numbers reported by the Organization for Economic Co-operation and Development[2], according to which, in more than half of the OECD countries, the percentage of students who obtain a degree in STEM areas is lower (24% on average) than in other areas.

Even though the advantages of STEM education are well known, there have been numerous obstacles to the dissemination of these practices in the classroom, including a poor understanding about STEM education[3] and scientific concepts[4][5]. Teachers also have shown difficulties in adopting non-traditional teaching strategies[4][5] and integrating content from different STEM areas[6][7]. In fact, the way in which STEM disciplines should be integrated is still the subject of debate in the literature[8][9]. The situation is more problematic in primary education, where most teachers have limited knowledge in STEM areas, particularly regarding Inquiry-Based Learning (IBL)[10]. Research has shown that consistent exposure to IBL is fundamental for preparing future generations of primary teachers to teach using IBL, as well as STEM education[10]. In addition to the already highlighted obstacles to STEM Education, there are others specifically pointed out in the first levels of education, such as the problematic integration of engineering practices[11], the lack of attention to science[12] and technology[13]; the overemphasis on mathematics content and the absence of engineering in the curricula of primary education [14].

Therefore, “consistent exposure to the inquiry may be fundamental for preparing future generations of teachers to teach using inquiry as well as future STEM professionals”[10] (p. 159). Teachers play a decisive role in the successful implementation of STEM Education[1], so they must be supported in the development of their Content Knowledge (CK) and Pedagogical Content Knowledge (PCK)[15] in teacher education. Thus, this study aims to examine the effects of a STEM program on pre-service primary teachers’ CK and PCK.

2. Theoretical Framework

The discourse in the field of science education in recent years has consistently referred to the importance “of cross-curricular 21st century skills such as collaboration, critical thinking, problem solving, design and engineering skills, creativity, and ICT literacy” in early years[16] (p. 89). The combination of an integrated STEM approach with IBL creates an excellent opportunity for the development of these skills, to which communication is added[17]. However, despite the potential of STEM integration for motivating students to pursue scientific careers, studies point to some concerns about how STEM integration is carried out and about the possibility of science content and process learning be lost in a hasty STEM teaching [18].

Nonetheless, research demonstrates that the success of STEM Education depends on the teachers’ self-confidence, their perceptions, the importance they attribute to it, their attitudes, etc.[19][20][21][22]. Several studies focus on this subject. For example, one study [22] with 25 prospective teachers and 21 science teachers, sought to understand the participants’ perceptions about the use of a project methodology based on a STEM approach that combined Project-Based Learning (PjBL) for science teaching. Pre-service teachers and teachers attended an eight-hour continuing education workshop on STEM-PjBL, during which they built toys to address physics topics with students: forces, sound, thermodynamics, electricity, etc. The results revealed that the students’ involvement in this type of activity promoted their motivation for

science classes. However, despite recognizing these benefits, the lack of time, resources, and training in STEM Education was pointed out as impediments to its implementation in the classroom. Kim and Bolger[19] described research in which 119 pre-service teachers (PSTs) developed a lesson plan that included an interdisciplinary STEM approach as part of a course they were attending. The results showed significant gains for PSTs in relation to the perception of their ability to create materials for STEM education, the confidence and commitment to develop such classes in their future practice, and the awareness of the potential of content integration to help students learn in a more interesting and meaningful way.

Thibaut et al.[1], based on an extensive literature review on STEM integration (iSTEM) and social constructivist view on learning, propose a framework containing five key principles (integration of STEM content, problem-centered learning, IBL, design-based learning, and cooperative learning) that describe the practices underlying STEM integration. According to this model, STEM content integration must be explicit to help students develop their knowledge and skills in the different STEM disciplines. In an integrated curriculum, content from more than one discipline is explicitly addressed, and the same emphasis is given to two or more disciplines[6][7]. In this respect, Roehrig et al. [[23]] propose a distinction between content integration and context integration. The first perspective focuses on merging disciplines into a single activity or unit, while the second focuses on the contents of a discipline and uses the others as a context to make the content more relevant.

Regardless of the STEM approach adopted, it is fundamental for its operationalization that teachers have support in the development of their CK and PCK[15] during initial education. Shulman[15] identified CK (or often also called subject matter knowledge or SMK) as the knowledge about the subject matter to be learned or taught and PCK as the knowledge about pedagogy that applies to teaching specific content. The first dimension of teachers' professional knowledge (CK) comprises the body of knowledge and processes that are a prerequisite for the development of the latter (PCK)[15]. Despite its undeniable importance, in research on teacher education, little attention has been paid to how teachers need to understand the content they teach [[24]]. Teaching a subject requires more than Content Knowledge alone. It requires a process of transformation of content into Content Knowledge, and, for that, it is necessary to develop PCK[25]. Shulman defines PCK as a "special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding"[15] (p. 8). Many studies focus dominantly on teachers' PCK, which has resulted in a variety of different models[25]. For instance, for Magnusson et al.[26], PCK is the result of a transformation of other domains of knowledge, which implies being more than the sum of the parts, and is conceptualized as being built through the process of planning, reflecting, and teaching a specific content. For these authors, PCK is determined by the content to be taught, the context in which that content will be taught, and how the teacher uses his/her experience. Although multiple views about the PCK coexist in the literature about these knowledge type, this study aims to shed light on the development processes when PSTs are engaged in a STEM program.

Knowing that Content Knowledge influences teacher confidence and practices[27] and that lack of CK is particularly common in primary teachers[28], initial teacher education programs for early-level teachers should focus on science topics in which PSTs have difficulties and IBL, to produce considerable progress in their PCK[29]. Indeed, research has shown that primary school teachers are not well prepared to engage their students in inquiry and problem-based learning approaches, which makes it essential to support teachers in developing their PCK[29][30]. Literature on STEM practices and the development of CK and PCK in initial education is scarce, highlighting the lack of investment in this field. This research intends to contribute to this gap, studying the effects of STEM activities, according to the IBL methodology, in the CK and PCK of primary PSTs about sound concepts. The sound topic was chosen because it is present in the curriculum guidelines from the first levels of schooling [[31], involving fundamental concepts for the learning of complex physics concepts[32], and numerous studies reveal the persistence of alternative conceptions in students[33][34][35][36][37][38] and future teachers[32][39][40].

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