STE(A)M APPROACH: DISTINGUISHING AND DISCUSSING MEANINGS

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Abstract

The STE(A)M approach has been recognized by several authors for its potential in assisting teaching and learning, and several curriculum standards already value its application in the classroom [1]. This approach is based on the articulation between different areas, the clarification, and the deepening of the concepts being studied. Although there are different approaches, according to the fields involved, STEM and STEAM are two among the most often mentioned in the literature. STEM is based on learning that integrates the following areas of knowledge: Science, Technology, Engineering, and Mathematics. The conceptualization of the STE(A)M approach is not consensual and uniform. There are different models focusing on problem-solving based learning, project-based-learning, design-based learning, and engineering models. Still, different authors [3] [4] [5] present different conceptualizations of this approach. In this paper, we relied on the existing literature to discuss the different understandings of the STE(A)M approach. We will also pay attention to mathematics and how different authors see the disciplines' role within a STE(A)M approach and discuss the evolution of the mentioned authors' positions throughout time. Thus, methodologically, we undertook the following steps: (i) literature search based on the selected keywords; (ii) selection of the texts, considering the authors and time gap, in order to analyze the evolution of the research and (iii) collection and organization of the relevant topics for the study. This study aims to present the meanings, conceptualizations, and possible influences present in different models and for understand the evolution of the STEM and STEAM approaches over time. The main findings suggest a focus on the interdisciplinary or transdisciplinary approach as opposed to the primeval years of investigations in STEM and STEAM when many authors advocated a multidisciplinary approach. This change in thinking is due to the need to train students in an integral and holistic manner, developing citizens with transversal knowledge and skills prepared for the current societal challenges.

Keywords: STEM, STEAM, interdisciplinarity, transdisciplinarity, Mathematics.

1 INTRODUCTION

The STEM approach is based on learning that connects Science, Technology, Engineering, and Mathematics. The addition of the arts gave rise to the acronym STEAM. These can boost student motivation and engagement, as mentioned by Quigley, Herro, and Jamil [6, p. 1]: "STEAM-based curricula increase motivation, engagement, and effective disciplinary learning in STEM areas". The plural name "arts" arose from the intention of valuing the most varied aspects of art: music, theater, painting, and performing arts, among others. Moreover, the addition of the arts to STEM has been described as especially suitable for early childhood education since young children are believed to have "built-in art elements within them" [7] [8]. Art has a very particular role. It is pointed out as a means for students to develop creative solutions to problems and to make connections between scientific knowledge, and the arts, and the humanities [2]. It is a way to improve social coexistence, build up creativity and even learn about different perspectives. Increasingly, it makes sense to provide teaching directed to the students' needs, as individuals capable of living in society, and acquiring broader skills, "it is possible to say that learning is motivating when it involves: learning creatively (...), as active citizens, (...) [providing the student] with reflection on [their] own learning" [3, p. 24]. The STEAM approach, then, is one that seeks to put the student at the center of learning. The process involves relating the different areas mentioned. This relationship between areas must happen in a structured way. For this to happen, it is necessary that the teacher is prepared and thoroughly familiarized with the subject. "It is necessary that the mathematics teacher who intends to use the STEAM approach develop means to make his classroom management break with traditional methods" [3, p. 118]. It is proposed that the students' competencies be developed, such as reasoning and problem solving and scientific and technological knowledge.

2 METHODOLOGY

This study consists of a review of the literature. A narrative literature review, on its part, refers to a comprehensive narrative synthesis of previously published information [9] [10]. “The literature review consists of an intertwined combination of searching, evaluating, selecting, pre-analyzing, and reading the literature” [9, p. 1]. Thus, methodologically, we undertook the following steps: (i) literature search based on STE(A)M models (interdisciplinarity; transdisciplinary; mathematics); (ii) selection of the texts, taking into account the authors and time gap, to analyze the evolution of the research. Regarding time, it is relevant to present recent articles (we present an article with more years so that people can understand the evolution of the concept); (iii) collection and organization of the relevant topics for the study.

3 STE(A)M

The STEAM approach has numerous meanings and conceptualizations, and there is no consensus about it in the scientific community. “Literature debated discipline knowledge as an entry point or focus to STEM education. Views varied, ranging from emphasizing discipline knowledge through to interdisciplinary project-based approaches” [11, p. 12]. Among the conceptual framework, we have authors who advocate different strategies of disciplinary articulation: multidisciplinarity, interdisciplinarity, and transdisciplinarity, because “integrating learning is known to increase student interest” [12]. In the literature, STEAM approaches can be characterized as interdisciplinary, focusing on several disciplines under a common theme but as discrete areas; cross-disciplinary, focusing on one discipline as a lens into another discipline; transdisciplinary, where all disciplines are fully integrated focused on a central inquiry or problem; and multidisciplinary, which explores the relationships between two or more discipline area” [5]. The idea of disciplinary integration can be traced back to Dewey (1859-1952) and has been recurrent in educational reform debates and movements since the last century, in which psychological, epistemological, and pedagogical arguments have been used [13]. It is necessary to know the concepts and nomenclatures.

In order to have interdisciplinarity and a consensual STEAM model, it will be crucial to deepen the knowledge and connection of the areas, to emerge in a more fluid and organic process that makes sense in articulation. Hence the importance of bringing together teachers from the various fields and establishing connections and interconnections in the development of the STE(A)M approach. We focus on mathematics, although when applied it should be linked to all other areas. Mathematics plays a fundamental role in education. “Mathematics is recognized as the fundamental basis of other disciplines; however, many students still perceive it as a difficult subject and abandon it” [14, p. 1137]. However, if skills such as reasoning, problem-solving, personal development and autonomy, and critical and creative thinking were developed from a young age, they could decrease difficulties in mathematics. The STEAM approach can demystify this situation and help students and teachers to learn from real problems, based on an interdisciplinary approach, helping them to work the content proposed in the curriculum and official documents, based on connections and hypotheses. Some authors argue that mathematics becomes invisible in the STEM approach, however, “the mathematics dimension captures the extent to which this discipline is emphasized and how the connections among procedures, concepts, and contexts are addressed” [14, p. 1139].

3.1 A Framework for Education

In the model presented in 2011 by Yakman, the "S-T-E-M" approach is approached as being the more traditional form, as it features the initials (subjects) separated, unlike "integrated STEM education". The strands of each subject area are defined, and “cooperation among disciplines provides realistic dynamics and influences that allow students to learn how to accommodate to the real world” [15, p. 4]. Technology is seen as something man-made, synonymous with change, innovation, or alteration [15]. Science is attributed to what exists naturally. Engineering, on the other hand, is linked to research, development, and design. The arts are in the author's view: language arts; physical; liberal and social; and plastic arts. Mathematics is the study of numbers. Mathematics is the primordial language that cuts across all other field’s boundaries, which is the closest the world has to a common language that can be currently used to provide structure for the other silos. This study talks about multidisciplinary disciplinary integration and the importance of emphasizing the discipline to be worked on, but without excluding the others. “Teams of teachers can work together to provide in depth coverage of their areas of expertise while reinforcing what students are learning in other specific areas” [15, p. 7]. The author is of the opinion that full implementation of STEM education would be beneficial, although studies and research should be done a priori. Yakman's goal with the implementation of the STEM approach in the classroom is to motivate students and to see if the effects on their disciplinary assessments are evident. In addition to developing the skills, abilities, and knowledge valued in the STEM approach, such as problem-solving, critical thinking, and creativity, developing functional literacy is also valued by Yakman: “Functionally literate people are more effective because of how to think across the spectrum of topics and understand the connections between the disciplines” [15, p. 4]. The STEM approach is improving personal and cultural success as it makes society more competitive.

3.2 STEM Literacy Framework

The STEM literacy framework for K-12 STEM education by Fallon, Bower, Hatzigianni, Forbes and Steven was published in 2020. The authors refer to the difference in STEM perspectives and have selected four key concepts to address the topic: 1) STEM skills, abilities, and dispositions; 2) STEM curriculum and pedagogy; 3) STEM disciplinary knowledge; 4) STEM literacy. The fourth topic “represented the ‘aim point’ for STEM education and was minimally contested as a principal outcome from STEM curriculum” [11, p. 12]. It is seen as an urgency for curricula, and consequently for the evolution of countries. The skills, abilities, and dispositions to be developed in the STEM approach are consensual among the authors: communication, critical thinking, collaboration, flexibility, problem solving, creativity (...) [11] [16] [6]. STEM curriculum and pedagogy focuses on the student as the central agent of his or her learning, and the importance of the teacher supporting his or her students by guiding them towards their goals, without ever making any pre-judgments or assumptions about their acquired knowledge. In the literature there are many references “about the role of design thinking principles in K-12 STEM education. The importance of authentic, ‘real world’ projects focused on modelling or designing solutions to problems, needs, wants or opportunities” [11] [3] [17]. In STEM discipline knowledge, the authors argue that the STEM approach, is considered interdisciplinary, however, they acknowledge the deformity of views, regarding the integration of disciplines. “This challenges teachers who are expected to reconsider often strongly-held beliefs about teaching and learning located in individual STEM disciplines, to move towards multi or interdisciplinary approaches that involve solving problems or realizing opportunities, located in ‘real world’ contexts” [11, p. 3]. The authors also refer to the difference in views regarding the positioning and ranking of subjects in the curriculum, “different perspectives exist about how it should be planned, taught and assessed, that can cause confusion amongst those responsible for its implementation” [11, p. 2]. “Interdisciplinary STEM education challenges this approach, requiring more collaborative methods that combine multiple disciplines and different pedagogical skills” [11, p. 3]. Interdisciplinarity, can also take different approaches or forms of integration, due to “varying according to different school levels, how schools are organized, and educational priorities” [11] [18] [19]. Situations arise from problems, needs, opportunities, disciplinary orientations, interdisciplinary orientations, intentions, design process. “Interdisciplinary approaches provide opportunities for students to critique and evaluate the implications and effects of both their own and others’ STEM endeavours” [11, p. 7]. STEM has been driven by political, economic and educational factors. Companies are calling for skilled professionals and “to fill current and emerging positions, particularly in innovation-based enterprises” [11, p. 2]. The importance of the STEM approach is linked to the development of society and the demands made on professionals who wish to enter the job market. In this sense, one of the concerns of the educational community is focused on the development of innovative teaching and learning methodologies.

3.3 A Temporal Model

In 2021, the study conducted by Hobbs, Tytler and Prain presents a temporal model of interdisciplinary STEM, where they integrated the disciplines over time, representing three distinct time scales. The authors present “cases of interdisciplinary STEM activity as indicative of the insights the model can provide” [16, p. 5275]. In a school context, they “consider the short-term, medium-term and long-term temporal dimensions of learning discipline-specific, topic-specific and interdisciplinary procedures and processes” [16, p. 5273]. The authors argue that interdisciplinarity does not cancel out disciplinary learning at school. They advocate curricular coherence and more extensive temporal analysis, arguing “that ambiguity exists in the literature concerning the distinction between inter- and transdisciplinarity and suggest that a productive purchase on these distinctions might be gained by considering interactions between disciplinary ideas that may occur at the micro-level, minute by minute temporal scale as they are conscripted in the problem-solving process” [16, p. 5287]. According to the authors, “the challenge of interdisciplinarity can be usefully conceived of through the temporal intersections of the school STEM subjects, re-aligned to reflect their distinctive historical/cultural practices” [16, p. 5285. STEM is seen as an alternative to approaching a subject in isolation, in order to give a context to learning, while still addressing curriculum content, “interdisciplinary practices in STEM are thus not an argument against disciplinary based learning in schools" [16, p. 5273]. The curriculum, the planning and implementation of STEM activities, can be a limitation due to the relationships between teachers of different disciplines, and/or the students' experience of the interaction of the disciplines, how students' cross disciplines and how they incorporate the different ideas and approaches. The study presents quotes from students regarding teaching based on the STEM approach and the answers were very positive and satisfactory, giving meaning to the knowledge acquired, starting from a problem-issue and integrating the disciplines. The authors conducted two case studies, in which the disciplinary integration was carried out differently, as well as the development and implementation of the planning and activities. The teachers showed some difficulty in the development of the activities and referred "if school subjects were more strongly focused on procedural and epistemic knowledge, then there would be a more natural link between interdisciplinary project work and discipline-based curricula" [16, p. 5280]. The authors conclude that for an interdisciplinary method to exist, it is important that it be developed over time, representing opportunities for productive learning.

3.4 Conceptual Model

In Quigley et al.'s 2020 conceptual model, there is connection between the various areas of knowledge and "while the model posits the goal of STEAM as transdisciplinary, the model also looks at variances of discipline integration (single content, multiple disciplines, and transdisciplinary)" [4, p. 502]. The authors address the variety of opinions regarding transdisciplinarity and the intrinsic difficulty in using it. However, they defend the balanced relationship between the various disciplines. The big problem pointed out is the lack of tools that teachers present in their teaching practices. According to the authors, "to address the issue of attracting and retaining a diverse STEM workforce, the way in which we are teaching our students needs to be re-conceptualized to attract and retain alternative perspectives that will assist in solving the world's most pressing issues" [6, p. 1]. The authors demonstrated with their study the importance of PBL to realize disciplinary integration, "teacher facilitation and authentic tasks" [4, p. 512]. The goal of developing a STEAM curriculum in classrooms is rooted in political, educational, and economic motivations that support academic rigor in schools in order to develop students' skills and knowledge "increase motivation, engagement and effective disciplinary learning in STEM areas" [6, p. 1], preparing them to deal with a highly technological world. However, research is still limited "explaining how instructional approaches must shift to enact effective STEAM teaching" [6, p. 1].

Quigley et al. developed and proposed a conceptual model of STEAM based on classroom observations that had as indicators: a) curriculum integration, b) problem solving skills, c) classroom environment. The model included professional development, observations of STEAM practice, students' activities, and teachers' reflections. It thus covers educational agents and teaching practices. The STEAM conceptual model presents the integration of these three factors mentioned above to result in a learning context, motivating equitable participation and connected learning, between student learning, individually, but also socially, valuing everyday situations as a motto for tasks that can be developed in the classroom.

3.5 STEAM Pedagogical Model

The article published by Lin and Tsai in 2021 presents a pedagogical model with five pedagogical strategies (Scaffolding, Tutoring, Engaging, Argumentation and Modeling) that can be used interactively in the five interdisciplinary subjects of STEAM [20]. The authors also mention that, over the years, STEAM curricula have used the integration of interdisciplinary curricula. In recent years, "many countries around the world have actively promoted the development of STEM (Science, Technology, Engineering and Mathematics) curricula and have utilized the integration of interdisciplinary curricula to enhance students' problem-solving skills" [20, p. 122]. When the arts emerged, a broader interdisciplinary curriculum was formed, thus suggesting that "in schools, such integrative capability could be guided by teachers through interdisciplinary teaching" [20, p. 113]. The authors conducted a study in the context, in which they concluded that "learners were able to acquire diverse knowledge and skills in an interdisciplinary learning environment, which was helpful for developing their project competence" [20, p. 121], also reinforcing the advantages of developing PBL in the context of the STE(A)M approach. The study mentions the positive feedback from students and their perceptions, in which they refer to the lasting acquisition of concepts, due to the meaning they gave in practice and the increased motivation. STEAM has been integrated into American curricula, at all educational stages, according to the authors, confronting the challenges of contemporary education. STEAM curricula are intended to develop students' knowledge, skills and abilities needed to enter into the world of work and to confront everyday problems. The authors address the importance of relating the problems that can be worked on in the classroom, to problems “that humans face in real life usually involve knowledge and skills in different disciplines” [20, p. 112].

Several authors argue that PBL can enhance the STEAM approach by improving student cooperation and student-teacher interaction, promoting an investigative and positive attitude towards science, based on teacher guidance [20] [6] [17]. “Interdisciplinary PBL, learners may not be competent in all disciplines and may therefore require support and guidance, that is, instructional scaffolding” [20, p. 113]. It is very important, for the teacher to understand the limitations of their students, in order to provide the necessary support, to acquire the necessary knowledge and skills.

The authors present the Pirposal conceptual and pedagogical framework that can be used as a practical guide to integrate STEAM education. The strategies in the model are “proposed in this study with the aim of validating its effects on students’ project competence and learning motivation” [20] [21].

4 CONCLUSIONS

In this article, we present some conceptual and/or empirical models and STE(A)M pedagogies, which derive different interpretations and conceptions of disciplinary integration. The STE(A)M approach has been studied by several teachers, psychologists, and educators, but the conclusions are not agreed upon in some aspects, since data in the context is scarce. The oldest article, from 2011, refers to a multidisciplinary approach; the other articles published between 2019 and 2021 advocate an interdisciplinary approach, and one of the selected articles points to transdisciplinarity. The evolution of the times may be following the development in disciplinary integration, since the labor market and society itself, are looking for individuals with broad and integral capacities, capable of dealing with the current challenges. The cooperative work between teachers in educational settings has been the subject of many studies and thus valued by the scientific community, which presupposes advantages for the ease of disciplinary integration.

The most convergent and cross-cutting aspect is the holistic skills, abilities and competences that the STEAM approach is able to enhance, from early childhood education to higher education. Students develop the problem solving, critical thinking, creativity, argumentative power, communication, technological skills, and making connections to scientific concepts. Teaching practices make education transformative. The teacher's role goes from being a transmitter, when the teaching methodology is expository and verbalist, to being a mediator and a guide for the student's learning. The student becomes the center of his learning, building his knowledge so that it is meaningful and effective.

One of the limitations found in the articles for the development of interdisciplinarity or transdisciplinarity, relates to the issue of the workload, the increased workload of teachers and the lack of guidance and help. External evaluation can also be a difficulty, since it is expected to be a curriculum preparation goal. It is important to reflect on the understandings and to find evidence of the STEM/STEAM approach models, through scientific investigations, studies and debates. The ambiguity of concepts, definitions and descriptions, is an impasse to be dissolved but, at the same time, a richness with the potential to promote discussion. The increasingly recurrent and in-depth studies have helped in consolidating and structuring the ideas.

ACKNOWLEDGEMENTS

This work has been supported by FCT – Fundação para a Ciência e Tecnologia within the Project Scope: UIDB/05777/2020.

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