STEM IN CHILDHOOD EDUCATION: A LITERATURE REVIEW

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Abstract

Scientific research has followed the impact of the use of more active and participatory methodologies in the teaching and learning process. Among these methodologies, the STEM (Science, Technology, Engineering, and Mathematics) approach has shown high efficacy when used in the daily lives of children and young people. Considering this the Project "Oleachain: Skills for sustainability and innovation in the value chain of traditional olive groves in the Interior of the North of Portugal", was designed, under the responsibility of the Polytechnic Institute of Bragança and developed through its research centers (CeDRI, CIMO, UNIAG, and CIEB), in close liaison with organizations, associations, schools, and producers. This project arose from the need to value traditional olive groves, olive and olive oil and is realized in different dimensions. In this sense, CIEB is committed to working on sustainability and the STEM approach among children in primary schools and kindergartens in the region, promoting teaching and learning experiences that lead to a clear understanding of the processes, scientific, technological, technical, and mathematical in the production of olive oil, from planting to the sale of olive oil and its by-products. This study aims to analyse the approaches of this approach, trying to understand what kind of work is developed in the context of childhood education and basic education, which profile reveals teachers who use this type of approach and what learning and involvement results, the children demonstrate. This is a systematic review of the literature for data collection and content analysis for their interpretation. The investigative process followed the following steps: (i) search databases by keywords; (ii) selection of relevant articles; (iii) reading the texts, organizing them in a diachronic way; (iv) elaboration of categories of analysis; (v) textual elaboration, performing the intersection between pedagogy based on rights and participation. The data point to the importance of educators and teachers revealing positive attitudes and favourable to the need for interdisciplinarity in the work developed with their children, establishing relationships of collaboration and partnership with other educators and teachers, and rethinking their strategies and actions in the classroom.

Keywords: basic education; STEM approach; educators; teachers; innovation.

1 INTRODUCTION

The world is constantly changing and therefore society must keep up with this transformation. Schools become key elements in this process and should seek to keep up with all advances, whether scientific, technological, social, or environmental. Educational institutions should consider and weigh all the challenges associated with this evolution, so that, at the same time as children face these challenges, educators and teachers can keep up with them [1]. Children need to react and find strategies to overcome challenges when changes occur. These strategies, which imply a great investment by schools, may enable them to be equipped to think about the future, always bearing in mind that we live in a democratic society, which must be taken into account [1], [2].

To accompany this process there is increasing investment in studies that focus on the potential of active methodologies in education and their approach from childhood. These studies reveal significant impacts on the daily lives of children and young people. Education for the 21st century requires integrating STEM (Science, Technology, Engineering and Mathematics) skills. This approach, which originated in the United States of America in the 1990s [3]is becoming increasingly prominent in the wider world and is proving to be an ally in today's education. This approach seeks to develop children's interest in several areas, approaching them concomitantly. This integrated and holistic thinking present in the STEM approach allows one or more problem issues present in the children's immediate circle or even challenges presented at a global level to be overcome (Kelley & Knowles, 2016).

Different studies mention the importance of addressing these issues from early childhood [4], [5]. Hadani and Rood [5]carried out a study on the relevance of the STEM approach in education and advocate six key aspects that are described below: i) STEM thinking can come from early childhood; ii) play can develop active thinkers in the STEM approach; iii) using the STEM approach promotes the development of language, which in turn facilitates STEM thinking; iv) the active learning process develops STEM

skills, increasingly promoting interest in these areas; and vi) the role of the adult as support and supporter of children is fundamental to the development of abstract thinking in children.

This combination of factors indicates that an investment in teacher training in STEM areas is necessary to achieve an integrative approach. The same authors [5] also point out that the adult should assume the role of i) asking open questions; ii) diversifying the vocabulary they use with children; iii) giving more than one opportunity for children to explain and argue their reasoning; iv) offering materials that help thinking, and v) encouraging problem solving by using their whole body. To these ideas is added the role of the adult in helping children to fully understand the problem question they want to be solved and how they can solve it [6]. Having these ideas present in their daily practice, children will assume a central role in the development of the work, creating, reflecting, preparing and presenting conclusions, seeking support from the teacher only when necessary [7]. Recent studies by [8] show the need for educators and teachers to innovate their practices, seeking to implement activities that integrate the STEM areas, favouring *hands-on* activities. This line of thinking also promotes reflection on the learning environments that still prevail in educational contexts.

Considering the above aspects and to promote a change from transmissive methodologies to active methodologies, namely the implementation of the STEM approach among educators and primary school teachers, the project "OleaChain: Skills for sustainability and innovation in the value chain of traditional olive groves in the Interior of Northern Portugal" was born. This project, developed at the Polytechnic Institute of Bragança, arose from the growing need to enhance the value of olive oil and the traditional olive groves that give rise to it, in the Trás-os-Montes area of Portugal. All the research centres of the Institute (CEDRI, CIMO, UNIAG and CIEB) are involved in the project, establishing a close communication and partnership. The present study, which is developed in the Basic Education Research Centre (CIEB), intends to promote the STEM approach in the school context and strengthen partnerships between schools and companies linked to the olive grove. The commitment is made to work on the process of transforming olives into olive oil, using the steps in a STEM approach. Learning experiences for children and training actions for teachers to implement the STEM approach in their daily practices in a more conscious way are promoted in schools and kindergartens.

2 METHODOLOGY

This research aims to determine the role and desirable skills of educators and teachers to become drivers of a STEM approach in early childhood education and primary school, understanding the impact on children. This is a qualitative study, based on a systematic literature review for data collection and content analysis for data interpretation, in line with Higgins et al. [9].

The investigative process followed the following steps: (i) searching databases by keywords; (ii) selecting relevant articles; (iii) reading the texts, organising them diachronically; (iv) elaborating categories of analysis; (v) textual elaboration, making the intersection between rights-based pedagogy and participation.

After defining the analysis question, data were collected through a systematic literature review. The SCOPUS, ERIC and SPRINGER platforms were used to collect the theoretical references. The following terms "teacher role" STEM and children" were used to limit the search to the topics under study.

At first, the following number of documents was obtained as a result of the search: 241 SCOPUS, 35 ERIC and 915 SPRINGER. Subsequently, the results were refined by limiting the search to open access articles, in English, Spanish and Portuguese. The search for the last twelve years was also limited to the social sciences and the levels of early childhood education and the first cycle of basic education, obtaining 43 results (21 SCOPUS, 12 ERIC, 10 SPRINGER). The articles were cross-referenced between the selected platforms, and those which were repeated were excluded, as well as those which were not related to the topic under study and those which did not address the contexts of early childhood education or primary education. Thus, 21 documents were read and analysed.

Data were organised in a table with the following columns: year of publication; author(s); title; objective(s); methodology; results; and conclusions. The documents were thoroughly read, followed by content analysis and data organisation. From the analysis of the 21 documents, categories and subcategories emerged, as shown in Table 1.

Table 1. Categories and subcategories of analysis.

Study Topic: STEM approach in basic education context	
Categories	***Subcategories***
(a) Role of the adult in the STEM approach	Characteristics of educators/teachers
	Strategies to implement the STEM approach
(b) Enabling environments to develop STEM learning	Space areas and materials
	Innovative ways to inspire children
(c) Challenges in the STEM approach	The pre-service and in-service teacher education
	The teachers' knowledge

Considering the objective defined for this study, and analysing the texts resulting from the research, three major categories were identified. For each category, two subcategories of analysis were found. Category (a) Role of the adult in the STEM approach is divided into two subcategories: (i) Characteristics of educators/teachers; (ii) Strategies to implement the STEM approach. From category (b) Enabling environments to develop STEM learning, two subcategories emerged: (i) Space areas and materials; (ii) Innovative ways to inspire children. Also, the category (c) Challenges in the STEM approach is divided into two subcategories: (i) The pre-service and in-service teacher education; (ii) The teachers' knowledge. Having determined the categories and subcategories of analysis of this study, the results of each one are presented below.

3 RESULTS

Given that this study aims to analyse the development of the STEM approach in primary education, the learning environment created by the teacher determines the level of possibilities offered to the children. It is emphasised that the personal and professional characteristics of educators/teachers, as well as the strategies used to promote STEM activities, become key elements in the realisation of this approach. It is also recognised that there are contextual challenges for teachers and educators and that solutions need to be found.

3.1 Role of the adult in the STEM approach

Educators and teachers should assume critical thinking when reflecting on the STEM approach, on their role, on their personal and/or professional characteristics that might facilitate the use of the approach and reflect on the methods and strategies to be implemented. Different studies show that the educator/teacher has a central role in developing this approach in kindergarten and primary school.

We begin by looking at studies that focus on the characteristics of the educator/teacher. A 2018 study by Lieberman et al. [10] in a project that took place in five US states, aimed to increase the professional skills of educators and teachers in the area of technologies to improve their daily practices. The authors mention that a central point of this programme was to convince and show education professionals the value of continuous training and professional learning in the implementation of this type of programme. These authors state the importance of establishing relationships of trust between all stakeholders, and of investing time so that professionals can create a culture of professional learning so that it is easier for them to reach the children. Following this thought, in the study by McClure et al. [11] supported by a literature review, they state that one of the characteristics of educators and teachers that promote children's development is the sensitivity and awareness of the needs presented by the group of children with whom they work. According to the authors, this understanding of the individuality of children's trajectories will allow a continuous accompaniment of children in the discovery of new learning. In the article by Sumpter and Hedefalk [12] whose objective is to study the teachers' roles in helping children's mathematical reasoning (they studied 3 groups), they conclude that the teacher needs to know, needs to know what to do and when to do it, to be able to help in the resolution, at the same time as determining and evaluating when key questions are asked. This line of intervention of the adult and his/her interaction with the children is also present in the study by Hollenstein et al. [13], conducted in 15 kindergartens, whose focus is to understand how children solve digital problems in adult-guided play. The conclusions reached by these authors reveal that when the kindergarten teacher participates in make-believe play, it can enable the understanding of the digital problem-solving process, making it more complex and, consequently, longer. In Clark and Andrews' exploratory study [14], which analyses the perceptions of

engineering teaching in primary education in the UK, the authors conclude that, for children, exposure to engineering issues depends on the individual interests of the teacher, his or her management of the curriculum to be presented to children and on his or her motivation to help develop long-term projects. This line of thought also fits with the findings of the study conducted by El Nagdi et al. [15] whose aim was to explore the characteristics and roles of eight STEM teachers, randomly selected to have a diverse group in terms of gender, experience, background and age, in two schools using this approach in the United States. The results of this study reveal that the construction of a STEM teacher's identity is not simple and should be seen as a dynamic and evolving process. This process involves several factors, including the interaction of personal and professional traits. This study found four core characteristics of STEM teachers: collaboration, flexibility, awareness of students' needs and promotion of equity and inclusion. The teachers in this study refer to the need to be a continuous learner, to be receptive to change and to take every moment as a learning opportunity. These characteristics are also present in a study by Kim and Keyhani [16] who analysed a teacher's progress in the STEM approach from her lesson plans and records.

Another idea, very present in the studies analysed, refers to the teaching-learning strategies that the educator/teacher can use to be able to fit a STEM approach more easily into their practices. They also refer to strategies to provide educators and teachers with specific knowledge of each area, as well as didactic knowledge. The study by DuBoff [17] with the collaboration of a science teacher, in a primary school for one semester aimed to verify the use of science fiction in a school context. This teacher used different resources with the children, namely science fiction films, short stories, poems, or other literary genres, to motivate the children and generate greater involvement in the activities arising from the STEM approach. This study shows that there is a relationship between the number of strategies used and the children's level of motivation. It is also presented in this study that there should be moments designed for discussion, creation, reflection, and involvement of families to maximise pupils' STEM potential. In the study by McClure et al. [11] the authors explain concretely a sequence of teaching-learning experiences, highlighting, for example, the potential of exploring children's height in a preschool classroom. Likewise, Blackley and Howell in a study supported by the implementation of a project in different schools in Australia, aiming to understand how technologies support teachers and how they use the STEM approach to teaching, highlight that the use of a digital tool used in the project has brought them numerous advantages [18]. They mention that it allowed them to plan and map STEM activities in a purposeful way across all levels of education, as well as to acquire digital skills and recognise that the focus should be on the learning process. Small [19]Small, in a study involving interviews with nineteen primary school children (grades 4-8), studied the relationship between innovative activities and children's motivation and needs, with a focus on the role of the teacher. The evidence from this study shows that children have opinions about this approach, stating, for example, that they like to understand how things work. In this study, teachers were alert to this need to listen to children and establish connections so that children feel comfortable questioning, seeking answers and persist in finding ideas. In addition to these strategies, in the study by Hollenstein et al. [13], the importance of further training for educators and teachers to feel more prepared and confident is underlined.

3.2 Enabling environments for STEM learning

Following on from the above, one of the roles of teachers and educators should be to organise and structure the educational environment. Therefore, they should focus their attention on the space and materials, but also on the various learning opportunities to be offered to children in the different areas of the STEM approach. With these ideas in mind, several studies focus their analysis on this issue as well.

A literature review by Daughrity et al. [20] analysed the implementation and use of maker spaces for the development of problem-solving skills from early childhood education to secondary school. The authors state that in the STEM approach there should be spaces designed for creation, for cross-curricular learning. They should be safe places that allow experimentation, failure and collaboration with peers or other stakeholders to succeed in solving the problem. They reinforce the relevance of these places over the traditional classroom spaces [20]. Small [19]Small, even states that school libraries have or may have a central role in schools, as a physical and emotional space where imagination, and creativity and where children's concerns and wishes are heard and nurtured. According to Costa and Domingues [22] in a study promoting mathematics teaching through context-based learning of 51 primary school teachers from five schools, aged between 35 and 61, they found that *hands-on* STEM experimental activities carried out with teachers and students promote meaningful learning. Carrying out activities in which adults and children have the opportunity to manipulate and create, leads to greater motivation to develop this type of practice [22]. From this study we can highlight the voices of the teachers who

participated in this study, mentioning that the processes are now more important than the results and that the implementation of these tasks leads to more experimental moments [22].

Creating enabling environments for STEM learning, however, goes beyond physical spaces as it is also substantiated by the approaches and methodologies that the educator/teacher adopts. For Daughrity et al. [20]there is a need to find new and innovative ways to inspire future generations. They argue that the world inside schools should be as interesting as the world outside. To achieve this, they stress that critical thinking (of adults and children) needs to be stimulated, problem-solving skills helped to develop, and moments of disquiet and challenge created. According to Lasa et al. [21]in a pilot study carried out in Navarra, Spain, to test STEM projects at different educational levels, from the point of view of mathematics education, it was concluded that a large proportion of STEM activities have the potential of ad-hoc situations, i.e. when children put personal problem-solving techniques into practice, even before teachers formalise mathematical content [21]. This can be an example of the creation of an autonomous environment by the teacher. Another aspect to take into consideration for the creation of a learning environment emerges in DuBoff [23]when exploring the teacher's interest in children's learning in a constructivist STEM classroom or school library, is the need to think about children's assessment: how, when and how is it assessed? [23] Outhwaite et al. [24]in a study mapping changes in support networks for primary school teachers and kindergarten teachers, specifically in the area of science, highlight the importance of innovation. This study involved educators and teachers taking part in a training course and recording their practice. It has shown the importance of collaborative work between adults and the relevance of reflection processes. This work can make it possible to improve or change practices. In the study by Kaygısız et al. [25], which investigated ways to enhance future teachers' competencies in robotics knowledge and its use in educational settings, a training course was also used. The students involved in the research reported benefits gained for their academic development, as starting from their knowledge they believe they can take this knowledge into practice with children. They also state, in their entirety, that robotics coding courses should be inserted into teacher training courses.

3.3 Contextual challenges to developing STEM approach

It can be stated that, although the STEM approach is still relatively recent, it is undergoing a growing development and educators and teachers face many challenges. Thus, from the analysis of the selected articles, it was possible to see that the lack of investment in the initial and continuous training of teachers and the ignorance of educators/teachers about the multiple areas of the approach stand out.

The study conducted by Kurup et al. [1], aimed to investigate prospective primary school teachers' beliefs and knowledge about the STEM approach, and the confidence they felt to teach in this area. It was conducted with 119 trainee teachers (26 male, 83 female and 10 who chose not to disclose their gender) at an Australian university in Melbourne and revealed that the prospective teachers believe in the potential of the STEM approach and intend to use it in their practice. This study reveals that current university courses and in-service training are not adequately preparing their students to teach STEM in primary schools. Trainee teachers report that they have never experienced any STEM-based programmes during their experience in schools. Wei and Maat [26], in a study conducted to determine the level of teachers' attitude towards STEM education, used the questionnaire administered to 310 mathematics teachers to obtain the data. This study reveals that in the Malaysian education system, teachers still receive specialised training in STEM subjects separately. Anagün et al. [27] conducted a case study with 41 3rd year primary school students, which demonstrates how the teacher candidates experienced problem-based STEM application. This study reveals that primary school teachers may not be sufficiently familiar with this approach as it is not in the curriculum. However, it is found that the students in this study showed creativity and teamwork. These are skills that they mentioned they wish their students to acquire. Akran and Aşiroğlu [28] conducted a study with 105 teachers (40 primary school teachers, 30 mathematics teachers, 20 science teachers and 15 computer science teachers). They used the interview to understand teachers' perceptions of STEM education and the constructivist approach to education. Mathematics, science, and primary school teachers report positive perceptions of the STEM approach. They emphasise that it is an approach that can enable real-life problem solving, respect for others and a greater capacity for empathy. On the other hand, IT teachers' perceptions are negative. They say that the STEM approach is not suitable for the teaching programme in their country, stressing that it is difficult to prepare technology activities in all subjects (mathematics, science, engineering, etc.). These differences in thinking between teachers of different subjects can become a challenge for the effective implementation of this approach.

Al Ali-Mutawah et al. [29] conducted a study, with 10 and 11-year-old children, intending to understand how the mathematics and science curricula can be articulated and what advantages/disadvantages

arise from this articulation. These authors point out that, from the STEM activities carried out in the classroom, teachers presented difficulty in articulating the two areas, and an increase in training in the implementation of the STEAM curriculum was recommended. Similarly, the study by Kurup et al. [1]reveals challenges in terms of knowledge and understanding to be able to articulate the areas of science, mathematics, technology and engineering, using real-life situations as a starting point. They also mention a lack of knowledge of active methodologies that enable the use of this approach. In Lasa's study [21]the results that emerge reveal that some STEM areas are used more than others. For example, there are proposals where mathematics is presented as merely utilitarian, or when geometric content is used to address a technological topic. Teachers have difficulty with this articulation and some activities labelled STEM do not comply with its fundamental principles. The authors even mention that teachers tend to confuse STEM activities with laboratory projects, whether in science, mathematics, technology, or engineering. Clark and Andrews [14]Clark and Andrews also give clear reasons why educators and teachers lack knowledge in one or more areas. In this specific case, the authors refer that, from a pedagogical point of view, children have little or no exposure to engineering in the early years of primary education. They even mention that, in most cases, the first time they have contact with engineering-related issues (if any) is in secondary school. This shows that educators and teachers are neither comfortable with nor awake to this area and therefore do not give it enough emphasis, even when they say they use the STEM approach. In the study by Small [19]Small, there is evidence that there may be disapproval from teachers when students show that they are creative and autonomous in their discoveries.

4 CONCLUSIONS

This study aims to analyse the role and desirable skills of early childhood educators and primary school teachers to use a STEM approach, perceiving the impact on children. This study is characterised by a systematic literature review of 21 scientific documents, searched in the SCOPUS, ERIC and SPRINGER platforms. From the content analysis performed, three complementary categories emerged: (a) Role of the adult in the STEM approach; (b) Enabling environments to develop STEM learning; (c) Challenges in the STEM approach.

From category (a) Role of the adult in the STEM approach emerges the idea that the educator/teacher should be sensitive to the needs of the children in the group. It is highlighted that the adult needs to seek knowledge, to know when, how and where to do it, helping children to define the questions and find solutions to them. To create a relationship with the children, the teacher should sometimes participate in their games, complexifying their thoughts. We highlight different teaching resources, such as digital tools, which can be used in the context to arouse children's interest and generate greater involvement.

There is evidence to support category (b) Enabling environments to develop STEM learning when the studies point out that in the STEM approach there should be spaces for creation. These should be safe spaces that allow children to experiment, fail and collaborate with peers or others involved in the action. It is desirable to create these conditions so that they can be successful in solving the problems they set themselves. The studies show the importance of carrying out *hands-on* experimental activities *and* investing in the close relationship between materials and children. It is also important that adults have these immersive experiences of contact with materials. These activities, which adults and children can explore and create lead to greater motivation to develop STEM activities.

In category (c) Challenges in the STEM approach, barriers related to the ignorance of educators/teachers about the different areas and challenges related to the training of educators/teachers, either in initial or ongoing training, are presented. It is reinforced that the current results underline the importance of providing teachers with more training and that it is available from initial training, based on specific STEM approach programmes.

This research shows that the studies analysed generally mention the need to understand the STEM approach as a process which integrates the different areas, starting from a problematic issue raised by the children and seeking to answer their concerns. However, in the articles read, there is a large number that direct their study objective to only one of the STEM areas, as well as a small number of studies of the approach in early childhood education. For this reason, it would be beneficial for the development and growth of the STEM approach if there were studies focused on the different areas and increased investment in early childhood education.

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