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What are we talking about when we talk about STEM education? A review of literature

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Abstract

The aim of this study is to examine how science, technology, engineering, and mathematics (STEM) education is implemented in the published literature. To accomplish this, the educational experiences published in indexed magazines in the main Web of Science collection during the 2013–2018 period were examined, with special attention paid to (a) The STEM concepts defined in the theoretical frameworks; (b) the STEM disciplines that intervene; (c) the possible benefits of STEM education; and (d) the key aspects for the success of the educational intervention. The results indicate that the theoretical frameworks used normally focus more on the variables that are the object of the study than on STEM education, and that there are multiple interpretations of what STEM education is, and these interpretations do usually involve the integrated appearance of the four disciplines that make up the acronym.

KEYWORDS
engineering education, mathematics education, science education, STEM education, systematic review, technology education

1 | INTRODUCTION

The STEM movement came about at the beginning of the 1990s. Although the National Science Foundation began using the acronym "SMET," it decided to change it to STEM (science, technology, engineering, and mathematics) for phonetic reasons. According to Friedman (2005), it was not until the creation of a "degree in STEM education" at the Virginia Tech University in 2005 that the movement began to enjoy success, and was an occurrence that meant the gradual international expansion of STEM until it became widespread (M. Sanders, 2009). This was all in response to the social needs stated by the US National Academy of Sciences, National Academy of Engineering, Institute of Medicine (2007), which stated that the STEM competence of US students was less developed than other countries, and the National Governor's Association (2009), which pointed out that it was necessary to develop a STEM identity to maintain economic competitiveness. Following this, it was transferred to the sphere of education, which is considered an essential tool for covering the growing demand for human capital in STEM (Chiu & Duit, 2011) and, as such, demonstrating that the provision of solid STEM training is necessary in current times (Caprile, Palmén, Sanz, & Dente, 2015).

In light of relative recency of the STEM movement, we were able to place STEM education at the stage of initial development. Reviews along this line of research are scarce, although there are some deep reviews of the literature. By way of example, Bybee (2013) brings together a series of perspectives on STEM education from the review of a number of works; the National Academy of Sciences (2014) contributes a reference framework to justify the integration of the four STEM disciplines. As another example, Atkinson and Mayo (2010) emphasize the characteristics of the implementation of STEM education, concluding that there is a current contrasting efforts—one to incorporate science, technology, engineering, and mathematics into the same educational experience, and another that opts to afford protagonism to science and mathematics. Recently, Thibaut et al. (2018) reviewed 23 educational interventions that clearly set out an integrated STEM approach, to determine which learning theories and teaching practices were used therein.

With regard to these precedents, the aim of this article is to explore how the educational interventions that claim to be STEM have been implemented, based on their final research reports. In this current effort, we hope to afford clarity to the subject from the contributions made by the scientific community, guided by the following questions.

(1) What STEM concepts are defined in the theoretical frameworks of the articles?
(2) Do STEM educational interventions work on the disciplines of science, technology, engineering, and mathematics in an integrated manner? What discipline tends to be dominant? How are they normally integrated?
(3) In integrated STEM education, are STEM disciplines related to the content being studied?
(4) What benefits of STEM education are highlighted by interventions?

Which aspects appear to be key in a STEM intervention?

To accomplish the task, first, a terminological clarification had to be addressed to identify the conceptual position from which this literature review has been undertaken.

1.1 | STEM literacy and identity

The evolution of the STEM movement led the Washington STEM Study Group (2011) to create and define the term "STEM literacy," the capacity to identify and apply content from STEM knowledge areas to understand and resolve those problematic situations that cannot be concluded from a mono-disciplinary approach. For the development of this new literacy it is necessary for each of the disciplines involved in STEM to include a series of essential conceptual, procedural, and attitudinal contents in such a way that, although the command of each of these STEM disciplines is necessary, so is the capacity to recognize and appreciate the connections that exist between them. This integration of knowledge areas involves obtaining a final product greater than the sum of its individual parts. Thus, the Washington STEM Study Group (2011) proposes that a student will be STEM-literate when he or she achieves an understanding of how the world works through these four disciplines and is able to apply this understanding to improving social, economic, and environmental conditions in all social spheres.

Zollman (2012) continues with the evolution of this academic approach and to do so introduces a definition for STEM literacy focused on the educational sphere and orientated towards problem-based learning. According to this author, STEM literacy requires the ability to understand and apply content (conceptual, procedural, and attitudinal) from the disciplines that comprise STEM to solve real problems, with particular attention drawn to the need to develop a series of specific affective and procedural STEM skills to consolidate this literacy.

STEM literacy is creating the development of "STEM curricula" based on practical skills that aim to eliminate the gap between theory and practice, as well as improve problem-solving skills. The development of these curricula arises from proposals such as that of Dufresne, Gerace, and Leonard (1997) based on problem solving. To achieve it they consider three essential elements: conceptual knowledge (CK), operational or procedural knowledge (PK), and problem-solving knowledge. Practical STEM skills include CK and PK, it having been recognized as a central competency for technological education, defined as the capacity to use engineering skills, techniques, and tools in the field of technology (Barlex, 2007). Furthermore, the praxis of science should promote learning transfer via a cognitive development that allows the realization of abstract concepts, makes the creation of mental structures on the part of students possible via kinesthetic participation and increases their motivation and commitment (Flick, 1993; Klahr, Triona, & Williams, 2007). STEM curricula should also summarize proposals such as those made by Clough and Kaufman (1999) in which students are encouraged to make "connections" between content and skills in a wide variety of contexts to develop their problem-solving skills.

Another aspect to consider within STEM literacy and its curricular development, according to the National Science Foundation (Gonzalez & Kuenzi, 2012), is that it should include a wide range of "STEM subjects" in the fields of chemistry, computers and information technology, engineering, geoscience, life sciences, mathematical sciences, physics and astronomy, psychology, social sciences, educational research, and STEM education.

With this educational approach it is hoped that a "STEM identity" will be reached, in which students feel part of STEM through their interests and skills, regardless of their race, gender or culture (Brickhouse, Lowery, & Schultz, 2000; Carlone & Johnson, 2007; Polman & Miller, 2010). To do so it is necessary for there to be a STEM integration, in which different combinations of the STEM disciplines can be included, one discipline can be emphasized over others, it can be presented in a formal, neutral, or informal environment and a variety of teaching strategies can be involved (National Academy of Sciences, 2014). To be able to reach this integration, Moore, Miller, Lesh, Stohlmann, and Kim (2013) propose using engineering as a context or catalysing concept for students to develop representations of the real world and thus develop scientific and mathematical concepts in an interdisciplinary manner, via the use of multiple portrayals (specific models, images, language, and symbols) and provide translations between them, supported by technology.

1.2 | STEM education: Is it equivalent in integrating science, technology, engineering, and mathematics?

The STEM approach has been undergoing a continuous evolution since its beginnings. As an indication, for STEM education, far from there being a consensus, there are almost as many definitions as authors who have touched on the subject. In addition, there are great differences between them, with some authors asserting that the disciplines can be dealt with individually, whereas others consider them to be an integrated group (Bybee, 2013).

An example of the former is Shaughnessy (2013), who defines STEM education as the solving of problems based on science and mathematics concepts and procedures that incorporate applied engineering strategies and use of technology. At the other extreme, M. Sanders (2009) defines it from a different approach that attempts to understand all STEM disciplines as a cohesive entity, whose teaching is integrated and coordinated via the resolution of real-world problems, a definition similar to that established by Merrill (2009), who conceives it as a meta-discipline based on learning standards where teaching has an integrated teaching and learning approach, and where specific content is undivided, contemplating a dynamic and fluid instruction. The definitions provided by M. Sanders (2009) and Merrill (2009) are supported by Bybee (2013), who considers STEM education as a spectrum that has an "interdisciplinary nature" in its nucleus, focused on the solving of real problems. The terminological review brings us to more modern definitions, such as that established by Baran, Bilici, Mesutoglu, and Ocak (2016), who understand STEM education as an interdisciplinary teaching method that integrates science, technology, engineering, mathematics, and other knowledge, skills, and beliefs particular to these disciplines.

The evolution of the term STEM education has led some authors to create the concept of “Integrative STEM Education” to identify that STEM education that integrates the different disciplines in an interdisciplinary manner. M. E. Sanders and Wells (2006) define “Integrative STEM Education” as teaching approaches based on technology or engineering design that intentionally integrate the concepts and practices of scientific and/or mathematical education with the practical concepts of technology and engineering education. In addition, they subscribe to the recommendation for improvement, specifying that “Integrative STEM Education” can be improved through greater integration with other scholarly materials, such as the arts of language, social sciences, art, and so forth. The debate also continues with the use of the term integration, with M. Sanders (2012) and Wells (2013) arguing, for example, that “Integrative STEM” and “STEM Integration” are different, the first term implying an integration with a teaching and learning process in constant development that is dynamic and focused on students, in contrast with the latter, which suggest a more static process overseen by the teacher.

The ideas of curricular integration derive from real-world problems in which the disciplines are not isolated. However, we find ourselves confronting an inconsistency, due to the fact that in most traditional educational approaches the disciplines are presented separately, offering little more than a disconnected and inconsistent variety of facts and skills (Beane, 1995; Czerniak, Weber, Sandmann & Ahern, 1999; Jacobs, 1989). The type of learning resulting from this isolated approach to the disciplines fails to present a set unity and, therefore, lack sense when viewed from outside the academic context. It is as if students, when facing a problematic situation, are expected to stop to ask themselves which part they can resolve with science, with mathematics, with art, and so forth (Beane, 1995). In contrast, an interdisciplinary learning approach integrates the disciplines and diffuses their limits, passing through different levels of cognitive ability in pursuit of developing a holistic thought process. In this manner, students can make meaningful connections that allow them to process knowledge to produce an interdisciplinary understanding that is applicable to reality. Boix Mansilla, Miller, and Gardner (2000) define interdisciplinary knowledge as the capacity to integrate knowledge and the modes of thought of two or more disciplines to produce a cognitive development, such as explaining a phenomenon, solving a problem or creating a product in a way that would have been improbable via just one of the disciplines involved. This approach is considered to be a great leap in all of the spheres and is increasingly attracting greater attention (Czerniak et al., 1999). Satchwell and Loepp (2002) mark out an integrated study plan such as that, which assimilates concepts from the perspective of more than one discipline. Notwithstanding, although these new approaches are transferred to curricular proposals or are argued and defended by education researchers, in educational centers there continues to be a development of the “separate topics” or “layer cake” approach for the teaching of knowledge and skills (Furner & Kumar, 2007). This reticence to adopt the integrated approach may be due to its radical departure from most current teaching practices (Mikser, Reiska, Rohtla & Dahncke, 2008). Unfortunately, failure to adopt the integrated approach keeps students from developing the skills needed to solve real problems because they fail to understand the context in which the problems are situated (Frykholm & Glasson, 2005).

M. Sanders (2009) and Ritz and Fan (2015) favor an interdisciplinary approach, and to support this they argue that STEM education approaches should require students to apply knowledge of mathematics, technology, science and engineering, design and carry out investigations, analyze and interpret data, and communicate and work with multidisciplinary teams. STEM integration offers students one of the best opportunities for experiencing learning in a real-world situation, instead of learning fragments and then having to assimilate them at a later moment (Tsupros, Kohler, & Hallinen, 2009). Students, via STEM integration, will

(1) gain a deeper understanding of each discipline contextualizing concepts,
(2) widen understanding of STEM disciplines via exposure to socially and culturally relevant STEM contexts, and
(3) increase interest in STEM disciplines as channels are increased for students to enter STEM fields (Moore, 2008).

It is argued that true STEM education establishes connections between the academic context in which it is taught and the real context in which we live (Erdogan, Navruz, Younes, & Capraro, 2016). Biasutti and EL-Deghaidy (2014) opt for the generation of an interdisciplinary philosophy, a deep conceptual understanding, and so-called 21st-century skills. However, following Bybee (2013), ideas about how to carry out STEM integration vary. The National Academy of Sciences (2014) argues that it is necessary to work in contexts that imply complex phenomena or situations via tasks that require students to use knowledge and skills from multiple disciplines, in a manner that context should be the backbone of STEM education. In contrast, Bryan, Moore, Johnson, and Roehrig (2015) puts forward three different paths for the integration of STEM content working with units or activities that

(1) simultaneously develop multiple learning objectives from the diverse STEM knowledge areas;
(2) significantly cover content from some areas as support for developing the learning objectives involved in the main area to be worked on;
(3) start out from a specific context from an area of knowledge for locating learning objectives of others.

Yet another area of contention is the diverse conceptualizations established for the integration of the disciplines. In this regard, we find concepts such as (a) "Integrated STEM," in which different combinations of the STEM disciplines should be included, one discipline should be emphasized over another, presented in formal or informal contexts and involve a variety of teaching strategies (M. Sanders, 2009); (b) transdisciplinarity, which mentions the lack of correspondence between knowledge and the resolution of social problems (Hoffmann-Riem et al., 2007); (c) interdisciplinarity, which is associated with the capacity to solve problematic situations that require the tools and theories of multitude disciplines, developing student skills (Klein, 1990); (d) supradisciplinarity,
which implies involving diverse disciplines to transgress the knowledge of one of them (Balsiger, 2004); and (e) multidisciplinarity, which implies involving various academic disciplines, without integrating them, to solve a problem and reach multiple disciplinary objectives (Tress, Tress, & Fry, 2005). Thus, we find ourselves for the third time facing the paradox established by Bybbe (2013), due to the fact that multiple conceptualizations exist, something that speaks to the lack of a consensus between the scientific community.

1.3 | STEM teaching and learning

The definition of "STEM learning" is not well-established in the literature, so we are obliged to specify one from diverse conceptions on learning. Dreyfus, Jungwirth, and Eliovitch (1990) and Houseal, Abd-El-Khalick, and Destefano (2014) describe that for successful STEM learning to take place we must adequately attend to the conceptualization and application of ideas on the part of students. Drake, Land, and Tyminski (2014) and Rahm (2014) affirm that any learning must be founded on the acquisition of knowledge and skills through students' experience. Drawing from these conceptualizations, and from those already presented (STEM literacy and STEM education), we define STEM learning as the integration of a number of conceptual, procedural, and attitudinal contents via a group of STEM skills for the application of ideas or the solving of interdisciplinary problems in real contexts. To achieve this learning, "STEM teaching" must be based on the standards of STEM curricula, creating experiences for students that allow them to develop STEM proficiency. These experiences should include participation in research, logical reasoning, and problem solving. Yet again we face the problem of not having an adequate conceptualization of terms, as there is no adequate and consensual conceptualization of the term "STEM learning."

From what we have outlined thus far, it is clear that there is a little consensus amongst the scientific community on what STEM education is. Therefore, we believe it is necessary to delimit the term to avoid the terminological amalgam that has led authors like Bybee (2013) to question whether its use is even appropriate.

2 | METHOD

We carried out a qualitative and intentional review (Randolph, 2009) of the articles published in the 2013–2018 period in the database of the main Web of Science (WOS) collection, by Clarivate Analytics. The review process stages, adapted from those established by Bennett, Lubben, Hogarth, and Campbell (2005), are detailed in Table 1.

Then we designed a search key that used the keywords "STEM education," "STEM literacy," "STEM learning," "STEM teaching," and "STEM competence," linked by the Boolean OR operator, refining the search via the AND Boolean operator, and the Education and Educational Research category, restricting it to the 2013–2018 period. We also established the following inclusion criteria: (a) works that are of the magazine article type; (b) the magazines in which they are published must have an impact index in Journal Citation Reports (JCRs); (c) articles that specify keywords; and (d) studies that state a STEM education intervention developed in any educational context in which preschool, elementary school, middle school, high school, or university students participate. The quality of the articles was guaranteed based on the requirements that the magazines indexed in WOS with a JCR impact index must fulfill. Regarding the review protocol, this was designed from the research questions put forward; in this way, we defined the different analysis units and procedures to follow for collecting the data from the works selected. This protocol can be consulted in Appendix A. Furthermore, the descriptors used to decide the STEM disciplines are shown in Appendix B.

The search was carried out in the first week of April 2018, in such a way that the search key for the main WOS collection generated a volume of 312 works. Once the search results were saved, two of the authors began sifting them, which consisted in the independent application of the inclusion criteria from the reading of the title, abstract, and keywords of the works found. In this task, which reduced the number of works to 32, an 84% degree of agreement was obtained. Subsequently, the valuation of their suitability for definitive inclusion (via the complete reading of the articles) was carried out by the same authors together, who selected a total of 27 articles.

To contextualize the results from the analysis of the studies selected, these have been gathered in Table 2, in which the following information is collected: (a) the first author; (b) year of publication; (c) country where the educational intervention is implemented; (d) methodological design; and (e) the educational stage to which the students participating in the intervention described in each of these studies belong.

TABLE 1 Stages of the review process

Stage	Actions
Clarification and approach	Analyze the why and for what of the review Create a theoretical framework Formulate research questions Establish search key and inclusion criteria Design review protocol (define categories considered for article analysis)
Search, sift, and select	WOS database search Sift articles Assess appropriateness for inclusion
Analyze and interpret	Analyze research characteristics In-depth understanding of included works Descriptive analyses, present in tables and figures Interpret and discuss results obtained
Draft report	Structure information Present results and discuss Submit implications and conclusions

Note. WOS: Web of Science.

TABLE 2 Main characteristics of the selected studies

First author	Year	Country	Study design	Educational stage
Abdullah, N.	2014	Malaysia	Quantitative	Elementary school
Abrahamse, A.	2015	United States and Bolivia	Qualitative	University
Aladé, F.	2016	United States	Quantitative	Preschool
August, S.E.	2016	United States	Quantitative	High school and University
Barak, M.	2016	Israel	Mixed methods	High school
Barrett, T.J.	2016	United States	Quantitative	University
Beckett, S.H.	2016	United States	Mixed methods	High school
Blustein, D.L.	2013	United States	Qualitative	University
Caglar, F.	2015	United States	Qualitative	High school
Castellanos, J.	2017	Spain	Quantitative	University
Chang, S.H.	2015	Taiwan	Quantitative	High school
Duran, M.	2014	United States	Mixed methods	High school
English, L.D.	2017	Australia	Mixed methods	Elementary school
Evans, M.A.	2014	United States	Qualitative	Middle school
Hughes, R.M.	2013	United States	Mixed methods	Middle school
Kim, C.	2015	United States	Mixed methods	University
Lamb, R.	2015	United States	Quantitative	Preschool and Elementary school
Lou, S.J.	2017	Taiwan	Mixed methods	High school
Marle, P.D.	2014	United States	Mixed methods	High school
McLurkin, J.	2013	United States	Not specified	University
Pietsch, R.B.	2015	United States	Not specified	High school
Rogers, M.	2015	United States	Qualitative	University
Shahali, E.H.M.	2017	Malaysia	Quantitative	Middle school
Toma, R.B.	2018	Spain	Mixed methods	Elementary school
Toth, E.E.	2016	United States	Mixed methods	University
Tseng, K.T.	2013	Taiwan	Mixed methods	University
Won, S.G.L.	2015	United States	Mixed methods	Middle school

The main characteristics of the selected studies are shown in Figure 1.

2.1 | Data encoding and analysis

The coding of the data, which involved the application of the designed protocol, was carried out by the authors together to bring the increase the comprehension of the works and collect the data based on agreed decisions. Thus, the aspects of each work that were coded and analyzed were as follows: (a) characteristics of the study, attending to the year of publication, methodological design, and educational stage of the students participating in the intervention; (b) theoretical foundation of the study; (c) identification of the STEM disciplines and contents tackled during the intervention described; (d) discussion and conclusions of each work, to extract the benefits and key aspects for STEM education. Only that information shown explicitly in the written documents was coded, in a way that in the cases in which the data that was the object of analysis did not appear, it was identified as "nonspecific" only in the case of the coding and analysis of the STEM disciplines were inferences drawn by the

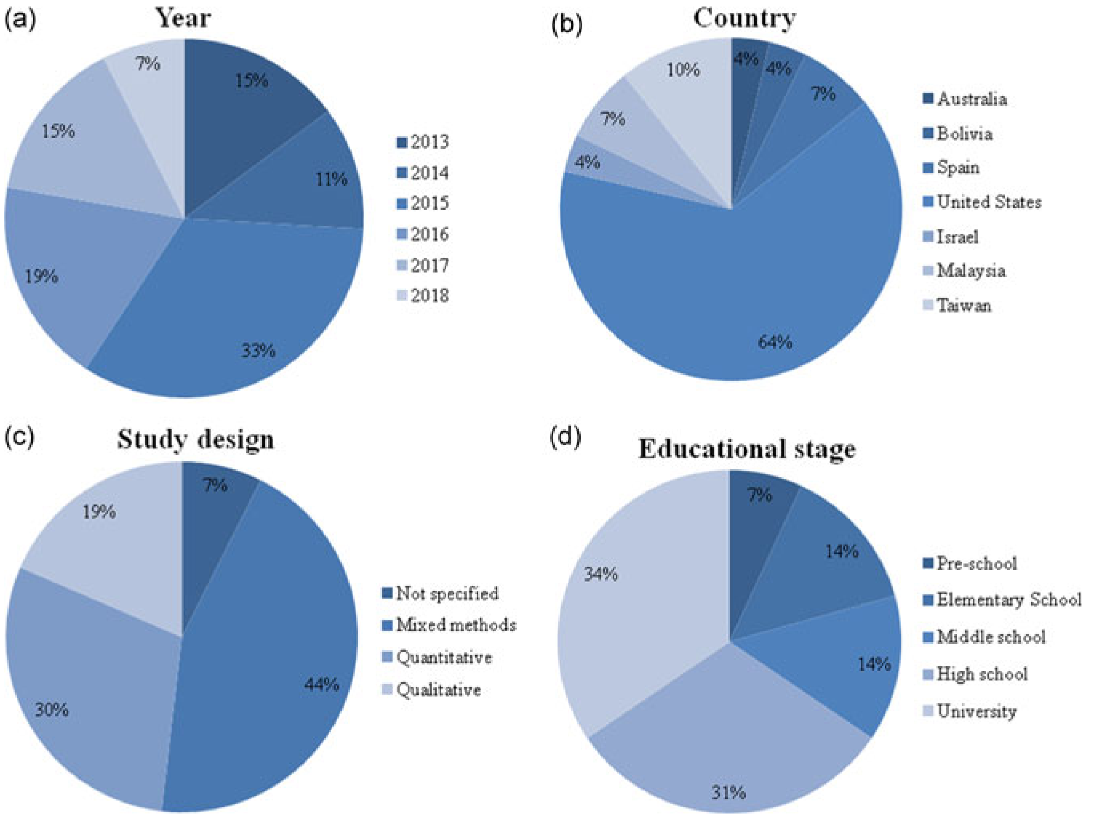

FIGURE 1 Graphic representation of the study characteristics [Color figure can be viewed at wileyonlinelibrary.com]

authors, and always from the data specified in the articles analyzed, in a way that in the cases in which STEM disciplines were not identified, attention was paid to the specification of underlying branches of knowledge or, failing these, the description of contents, procedures, and skills specific to each STEM discipline. Furthermore, in those cases in which explicitly described information was not identified, it was understood that only those STEM disciplines specified were studied.

The information gathered from each article was exported to Microsoft Excel 2013, where it was coded according to the established protocol guidelines, and a descriptive analysis (absolute and relative frequencies) was applied from which tables and figures were created.

2.2 | Bias control

The selection and coding biases were controlled for this review. Thus, on the one hand, we controlled the selection bias on carrying out the search and sifting of the articles independently. The two authors responsible for this task obtained, as mentioned, an agreement percentage of 84%. Specifically, the reviewers selected 30 and 29 articles, respectively, following the application of the inclusion criteria, in a manner that they identified 27 coinciding articles and five different ones. On the other hand, the coding bias was controlled from the design of a protocol that indicated the guidelines to follow for the data collection. In addition, the fact that the authors coded the data together contributed to the consensus, with the benefits that this affords to the coding bias control.

3 | RESULTS AND DISCUSSION

We analyzed those interventions that refer to themselves as STEM education, STEM teaching, STEM learning, and STEM literacy. We present the results and simultaneously discuss them according to the research question they respond to.

3.1 | Research question 1. Analysis of the theoretical frameworks

The analysis of theoretical frameworks of the interventions (Figure 2) reveals the findings of National Academy of Sciences (2014), which states that it is common to find inconsistent language, a lack of definition of terms and, as a result, a theoretical framework that makes it difficult to understand STEM education. In this sense, we found that 55% of the studies selected (n = 16) fail to explain a single STEM concept. However, it is frequent for authors to contextualize the origin of the STEM movement, although they do not define STEM concepts in their theoretical frameworks. Furthermore, the same authors deal with STEM terms without explaining them, which unavoidably leads to a diffuse projection of STEM education.

Those articles that define STEM concepts employ a wide range of terms for clarifying the nature of STEM education. We thus find studies that define such concepts as: STEM curriculum (S.-H. Chang, Ku, Yu, Wu, & Kuo, 2015; Lou, Chou, Shih, & Chung, 2017), STEM literacy (Abdullah, Halim, & Zakaria, 2014; Marle et al., 2014), STEM subject (Duran, Höft, Lawson, Medjahed, & Orady, 2014), STEM identity (Hughes, Nzekwe, & Molyneaux, 2013), STEM learning (Lamb, Akmal, & Petrie, 2015), STEM teaching (Lou et al., 2017), and STEM integration (Shahali, Halim, Rasul, Osman, & Zulkifeli, 2017) to refer to and/or complement the concept of STEM education, although it is true that the term STEM education is the most defined amongst the selected articles; it is defined in the theoretical frameworks of Barak and Assal (2018), English, King, and Smeed (2017), Lou et al. (2017), and Toma and Greca (2018).

On the one hand, Barak and Assal (2018) and Lou et al. (2017) elect to provide a definition of STEM education that advocates the integration of content and skills specific to science, technology, engineering, and mathematics in the teaching–learning process, which despite not being grounded on any of the frameworks of reference that have existed up to now, can be linked to the definition that M. Sanders (2009) contributes to STEM education. On the other hand, in their theoretical frameworks the authors English et al. (2017) and Toma and Greca (2018) emphasize the debate that revolves around the term STEM education, with both opting to understand it as a teaching approach that integrates the knowledge and skills of the four disciplines, but using different frames of reference

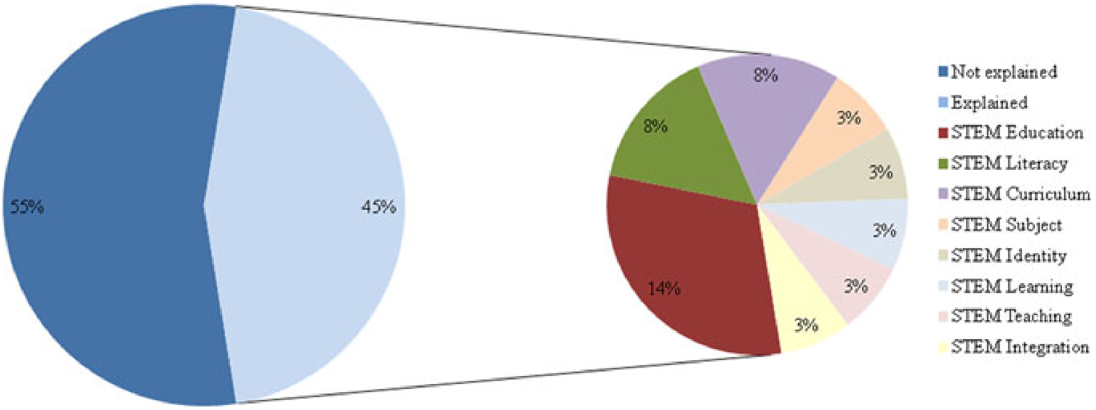

FIGURE 2 STEM concepts defined in the theoretical frameworks. STEM: science, technology, engineering, and mathematics [Color figure can be viewed at wileyonlinelibrary.com]

(National Academy of Sciences, 2014 and M. Sanders, 2009, respectively). In the same vein, Shahali et al. (2017) and Lamb et al. (2015) use, respectively, the terms STEM integration and STEM learning alluding to STEM education, with both understanding it as a process that integrates concepts and skills originating from the four disciplines that comprise STEM.

Finally, it is interesting to observe that amongst those studies that explain the term STEM education, we find five of the six most recently published articles (2017 and 2018). This fact could be interpreted as progress in those demands made by National Academy of Sciences (2014), given that the educational interventions developed are framed within a specific perception of STEM education, affording cohesion and consistency to the work carried out. Despite not all of them using the same frame of reference to explain the term STEM education, with it even being nonexistent in two cases, the six studies in question adopt a similar understanding of it.

3.2 | Research questions 2 and 3. STEM disciplines

The existing debate on STEM education does little more than echo different concepts of this teaching approach and, in consequence, on a wide spectrum of didactic models that range from the teaching of one of the disciplines that make up the acronym STEM, to it being considered as a discipline in itself. This has been addressed and developed by Bybee (2013) who, in light of the existing debate, has established nine perspectives of STEM education from an inclusive idea that attempts to categorize all of those didactic interventions that are normally referred to as STEM education. Notwithstanding this, if we adhere to the rejuvenating essence with which the STEM movement arose in the National Science Foundation and carry out an analysis of the educational interventions from the definition that M. Sanders (2009) makes on STEM education (one of the most referenced), or that contributed by Zollman (2012) to define STEM literacy, categorizing the adjustment to STEM education interventions (Figure 3) becomes an easier task, in which it is necessary to distinguish between integrating or not integrating the four disciplines during the implementation of the educational intervention analyzed. Therefore, the intention is not to describe all of the existing perspectives on STEM education as flawed; rather, it is to delimit each personal understanding of STEM education to the implication it brings to the use of the acronym. As such, the freedom to understand and implement STEM education in the classroom would be limited to the capacity, need, or convenience of integrating science, technology, engineering, and mathematics into the same educational experience.

This way, analyzing the selected educational interventions under the perspective described shows that 30% of them ($n = 8$) seems not to correspond to STEM education, despite all of them stating in their title, abstract, or

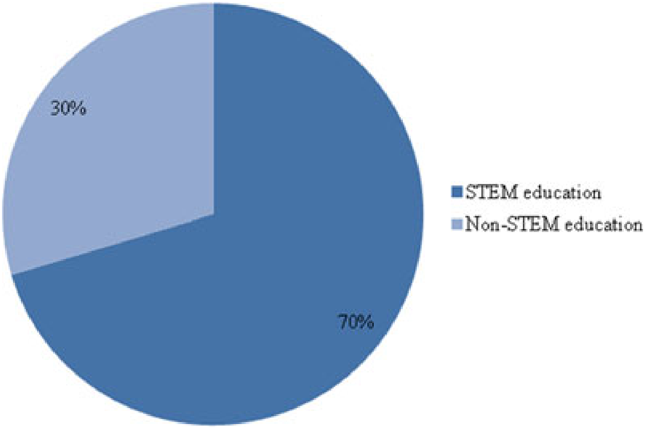

FIGURE 3 Adjustment of interventions to STEM education, so that the four disciplines are integrated (to a greater or lesser degree) into these. STEM: science, technology, engineering, and mathematics [Color figure can be viewed at wileyonlinelibrary.com]

keywords the term "STEM education," or similar (STEM literacy, teaching, or learning). Therefore, following the perspectives of STEM education described by Bybee (2013), Abdullah et al. (2014), and Abrahamse et al. (2015) it is demonstrated that this could be compared with the teaching of mathematics and science, respectively. In this regard, the understanding of Castellanos, Haya, and Urquiza-Fuentes (2017) on STEM education corresponds to the teaching of technology. These authors, therefore, understand STEM education as the teaching of one of the disciplines that comprise it, and in this way, they appear to assume that the isolated study of these disciplines could link the content and skills developed with those of the others. This, however, remains far from occurring if we consider that adopting a teaching approach that isolates the content of a specific STEM discipline contributes to the unconnected perception of the four disciplines that comprise STEM (Shahali et al., 2017), more so if we take into account that students by themselves are incapable of establishing connections between the content and skills of each of the four disciplines (Graesser, Halpern, & Hakel, 2008).

From a perspective that understands STEM education as the teaching of science and mathematics (Atkinson & Mayo, 2010), we can classify the educational intervention developed by Aladé, Lauricella, Beaudoin-Ryan, and Wartella (2016). In this intervention, implemented in the early childhood education stage, mathematical notions are worked on (standardized and nonstandardized measurements) along with scientific ones (animal species), supported by technology. In the same sense, in accordance with a perspective that understands STEM education as the coordination between some of the disciplines that make up this acronym, Rogers, Pfaff, Hamilton, and Erkan (2015), from a multidisciplinary approach, develop an educational intervention distributed into different models where technology, mathematics, and science content are addressed from the main topic, sustainability.

Other educational interventions draw attention to a perspective of STEM education where content and skills from other disciplines (technology and engineering) are incorporated for teaching science. In line with this, Pietsch, Bohland, and Schmale (2015), from an interdisciplinary approach, implement an educational intervention in which content and skills from science, technology, and engineering are integrated for studying the anatomical structures of biological species capable of flight. Hughes et al. (2013) frame their intervention within various scientific contexts (laboratory, science museum, etc.), in a way that they work on multiple scientific contents (electricity, renewable energies, recycling, etc.) from which others originating from technology and engineering are incorporated, as well as developing skills from the three disciplines studied. Likewise, Barrett and Hegarty (2016) study molecular structure in their educational intervention, incorporating technological tools (software for creating two-dimensional [2D] and 3D models), and engineering knowledge and skills to complement the teaching of the scientific content described.

In relation to the above, we understand that the eight educational interventions described should not be considered as STEM education for different reasons, such as the following.

(1) The authors rename the teaching of science, technology, engineering, and mathematics with the term "STEM education" in an attempt at invoking recognition as a didactic and pedagogical renovation, but they ignore the history of these. Thus, independently and before the STEM movement, authors like McDemortt (1990) point to the need for teaching science under an overall treatment, which integrates knowledge and skills from other disciplines.

(2) The educational transposition of the STEM movement is aimed at a teaching approach that instead of isolating science, technology, engineering, and mathematics in different educational experiences, should integrate them into one (Zollman, 2012). The purpose of this is to contribute to the development of students' ability to solve real-world problems (M. Sanders, 2009) and, in turn, facilitate the understanding of existing connections between these four disciplines (Tsupros et al., 2009).

(3) Finally, 4 as the successful attainment of STEM education, we must consider STEM as a meta-discipline created from the integration of the four disciplines (Kaufman, Moss, & Osborn, 2003), in a way that the total is much more than the sum of its parts (Zollman, 2012). We also consider it more appropriate to assume that STEM education can promote and improve the learning of each of the disciplines it refers to (Toma & Greca, 2018), not the other way round.

TABLE 3 Dominant disciplines in STEM interventions

Discipline	Frequency (%)	E.g., (only first author cited)
Science	4 (21%)	Beckett et al. (2016); Marle et al. (2014); Toth (2016); Won, Evans, Carey, & Schnittka (2015)
Technology	3 (16%)	Caglar et al. (2015); S.-H. Chang et al. (2015); Duran et al. (2014)
Engineering	11 (58%)	August et al. (2016); Barak and Assal (2018); English et al. (2017); Evans et al. (2014); Kim et al. (2015); Lamb et al. (2015); Lou et al. (2017); McLurkin, Rykowski, John, Kaseman, and Lynch (2013); Shahali et al. (2017); Toma and Greca (2018); Tseng, Chang, Lou, and Chen (2013)
Mathematics	0	–
Not identified	1 (5%)	Blustein et al. (2013)

Note. STEM: science, technology, engineering, and mathematics.

This all brings us to consider that the teaching of science, technology, engineering, and mathematics has traditionally led to using contents from other disciplines, whose role was to complement and allow the acquisition of the content from the discipline that was the teaching object. We believe, however, that when we speak about STEM education it should involve a simultaneous study of the four disciplines, where they abandon the role of tool, support or complement to take on protagonism in themselves during the educational experience. In this sense, the rest of the educational interventions selected could be classified, which represent 70% of the total (n = 19), as they all integrate science, technology, engineering, and mathematics. Given this, we paid attention to which of these disciplines was dominant during the intervention (Table 3), how they were integrated (Table 4) and to the details given relating to the established links between the disciplines and the content studied (Figure 4).

The integration of the STEM disciplines is usually accompanied by different combinations between them and the adoption of a dominant role for one of them (National Academy of Sciences, 2014). Along this line, the useful aspects of engineering as a “hinge” discipline have already been described for connecting the other disciplines (Brophy, Klein, Portsmore, & Rogers, 2008), which can be appreciated in the results obtained, as 58% (n = 11) of the 19 interventions that apply a STEM education give it a dominant role. Specifically, engineering appears as a dominant discipline via the employment of robotics (e.g., Barak and Assal, 2018), the use of engineering design (e.g., Shahali et al., 2017) and engineering-based problems (e.g., Toma & Greca, 2018). In contrast, mathematics appears to be a discipline that, despite having a relevant role for science, technology, and engineering is complex to use as a “backbone” from which the other STEM disciplines begin. Regarding the dominant role that could be exercised by science (21%; n = 4) or technology (16%; n = 3), it is common for them to adopt such relevance from the solving of real-world problems in the case of science (e.g., Marle et al., 2014), or virtual contexts in the case of technology (e.g., Toth, 2016). Moreover, it has been impossible to identify which of the STEM disciplines could exercise a dominant role in the educational intervention developed by Blustein et al. (2013), given that they neither explain the content addressed nor how it was studied throughout the educational experience.

TABLE 4 How the disciplines are integrated, according to Bryan et al. (2015)

Forms of STEM integration	Frequency (%)	E.g., (only first author cited)
Content integration	2 (11%)	Becket et al. (2016); Lou et al. (2017)
Supporting content integration	5 (26%)	Barak and Assal (2018); S.-H. Chang et al. (2015); Duran et al. (2014); Kim et al. (2015); Shahali et al. (2017)
Context integration	12 (63%)	August et al. (2016); Blustein et al. (2013); Caglar et al. (2015); English et al. (2017); Evans et al. (2014); Lamb et al. (2015); Marle et al. (2014); McLurkin et al. (2013); Toth (2016); Toma and Greca (2018); Tseng et al. (2013); Won et al. (2015)

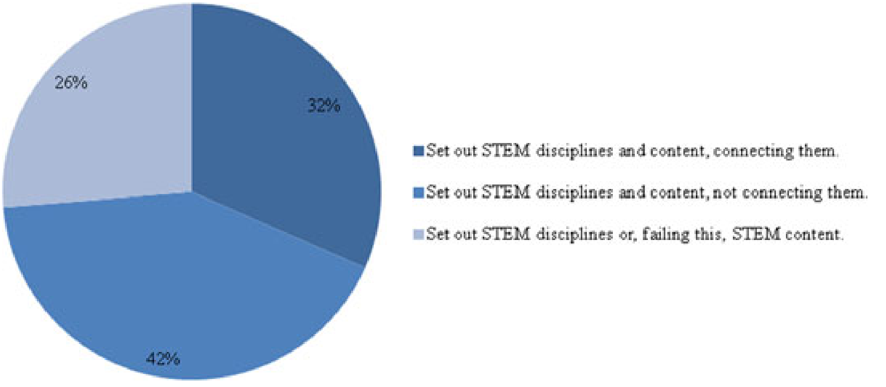

FIGURE 4 Relationship between disciplines and content dealt within intervention. STEM: science, technology, engineering, and mathematics [Color figure can be viewed at wileyonlinelibrary.com]

It is also important to analyze the level of detail that the authors offer on the disciplines and the content studied during the educational intervention. This adheres to the recommendations given by National Academy of Sciences (2014), which recommends that researchers explain the way the disciplines are integrated, and detail the content addressed in each one of them (Figure 4). Given this, the following three categories have been established: (a) those interventions that explain the disciplines and the description of the content studied in each one, favoring the identification of the dominant discipline or disciplines and the way in which they are integrated; (b) interventions that explain the STEM disciplines and the contents addressed in a deficient manner, making the links that could have been established between the different STEM contents and disciplines vague; and (c) educational interventions that explain the STEM disciplines studied or, failing this, the contents addressed, in a way that establishing links between the contents and the STEM disciplines is highly complex.

In relation to the first category, we find 32% (*n* = 6) of the 19 articles that implement a STEM education: Tseng et al. (2013); August et al. (2016); Lou et al. (2017); Shahali et al. (2017); and Toma and Greca (2018). The educational interventions developed by these authors contribute the description of the contents dealt with and framed in their corresponding discipline, as well as establishing clear links between these contents and, as a result, between the disciplines. We could, therefore, state that these educational interventions, for the purpose of a possible response would reduce the difficulties experienced by educators when integrating STEM disciplines effectively at the same time as having to maintain the integrity of each one (English, 2017).

The second category accounts for 42% (*n* = 8) of the educational interventions described as STEM education (cases only quoting the first author: McLurkin et al., 2013; Duran et al. 2014; Marle et al. 2014; S.-H. Chang et al. 2015; Evans, Lopez, Maddox, Drape & Duke, 2014; Lamb et al. 2015; Toth, 2016; Barak and Assal, 2018). Thus, these interventions outline the STEM disciplines and describe the content studied. However, the exposure of these elements appears disconnected throughout the text, generating a certain deficit in understanding of the educational intervention implemented. As such, if this disconnection took place in the classroom, it could have repercussions on the effectiveness of STEM teaching and, as a side effect, on student learning, given that it would increase teacher difficulties in terms of the implementation of STEM education described by English (2017) and reduce the level of understanding of the existing links between the STEM disciplines on the part of students (Shahali et al., 2017).

As regards the third category, we find those interventions whose comprehension is more complex (26%; *n* = 5). These studies reveal series limitations in the description of the teaching intervention, to the extent that we have identified two situations: (a) contents studied in the intervention are not made clear (e.g., Blustein et al., 2013; Kim et al., 2015); and (b) the description of the procedures and other essential details for understanding the

TABLE 5 Benefits of STEM education for students

Referring to	(Only first author cited)
Cognitive benefits	Boosts academic performance (S.-H. Chang et al., 2015). Improves ability to apply STEM knowledge (S.-H. Chang et al., 2015; Lamb et al., 2015; Lou et al., 2017; Shahali et al., 2017). Enriches disciplinary STEM knowledge (McLurkin et al., 2013; English et al., 2017; Lamb et al., 2015; Toma & Greca, 2018). Connects STEM disciplinary knowledge (Lou et al., 2017).
Procedural benefits	Increases technological skills (Duran et al., 2014). Develops creativity (Lamb et al., 2015). Allows the accumulation of practical experience (Marle et al., 2014; Lou et al., 2017).
Attitudinal benefits	Encourages taking of STEM degrees (Blustein et al., 2013; McLurkin et al., 2013; Tseng et al., 2013; Shahali et al., 2017). Predisposes students for learning thanks to the solving of problems, the use of technology and cooperation (Evans et al., 2014). Promotes emotional commitment to STEM subjects, having an effect on cognitive and behavioral aspects (Kim et al., 2015). Increases interest in and curiosity towards STEM subjects (Lamb et al., 2015; Lou et al., 2017; Shahali et al., 2017). Encourages positive attitudes towards STEM disciplines (Tseng et al., 2013; Toma & Greca, 2018).

Note. STEM: science, technology, engineering, and mathematics.

link between the different content studied and, therefore, between the STEM disciplines, is excessively superficial (e.g., Beckett et al., 2016; Caglar et al., 2015; Won et al., 2015). In this manner, these studies project a diffuse image of STEM education that could irredeemably generate more confusion in educational practice regarding this teaching approach.

The manner in which the four STEM disciplines were integrated was analyzed from those described by Bryan et al. (2015) (Table 4), and in this way attention was paid to whether there existed a total integration of the content or whether, in contrast, the way in which the disciplines were integrated was supported by the content or in a context specific to one of the STEM disciplines.

In light of the results shown in Table 4, we could argue that the authors prefer to integrate the STEM disciplines from a specific context (63%; n = 12). The preferred integrating context is, therefore, framed within the discipline of Technology, as it appears common to use the creation and handling of virtual contexts to achieve the insertion of the rest of the STEM disciplines (e.g., August et al., 2016; Caglar et al., 2015; Evans et al., 2014; Toth 2016; Won et al., 2015). Other contexts used to start out from real-world situations (e.g., Marle et al., 2014) or engineering (e.g., Tseng et al., 2013). These findings, on the one hand, appear to corroborate the potential of technological tools for improving student learning (C. Y. Chang, 2001; Whitworth & Berson, 2003; Williams, Linn, Ammon, & Gearhart, 2004) and, on the other hand, they implement the main objectives of STEM education, which is preparing students for solving real-world problems (M. Sanders, 2009).

3.3 | Research questions 4 and 5. Benefits and key aspects of STEM education

We analyzed the benefits (Table 5) and key aspects (Table 6) of STEM education according to a list of inductive categories, obtained from the reading of the conclusions of those interventions categorized as STEM education (n = 19).

According to the data shown in Table 5, we can argue that STEM education has benefits for students at a cognitive, procedural, and attitudinal level. In terms of cognitive benefits, it has been found that STEM education

TABLE 6 Key aspects of STEM education

Referring to	Key aspects (first author cited only)
Context	Imaginative and interactive atmospheres involve students in STEM learning (Tseng et al., 2013; August et al., 2016). Educational context is a key aspect in the development of interest and improvement of STEM skills in students (Blustein et al., 2013). Informal education could stimulate interest in STEM learning (Blustein et al., 2013; Evans et al., 2014).
Resources	Robotics is a good resource for STEM learning (Kim et al., 2015; Barak and Assal, 2018). Virtual platforms improve the integration and learning of STEM disciplines (Won et al., 2015).
Teaching methodology	Project-based learning is an appropriate STEM teaching method, which permits the integration and application of STEM discipline knowledge (Tseng et al., 2013; Marle et al., 2014; Lamb et al., 2015; Beckett et al., 2016; Lou et al., 2017). Inquiry-based learning contributes to the integration of STEM disciplines (Toma & Greca, 2018). Using real-world examples improves STEM learning (Caglar et al., 2015).
Success indicators	Student race and gender moderate STEM learning results (Blustein et al., 2013). Paying attention to the cognitive and emotional aspects and contents determine the success of STEM education (Lamb et al., 2015). Long-term interventions show better results than more reduced periods (Beckett et al., 2016).

Note. STEM: science, technology, engineering, and mathematics.

strengthens student skills for transferring knowledge acquired to other contexts. This could be due to the recognition that STEM education should normally be aimed at the solving of real problems that students are familiar with (M. Sanders, 2009). Moreover, it appears that a STEM education in which science, technology, engineering, and mathematics are integrated: (a) improves student knowledge in the different STEM disciplines and, in consequence, their academic performance (National Academy of Sciences, 2014); and (b) facilitates the connection between the knowledge that students may have on these four disciplines.

In terms of procedural benefits, STEM education appears to contribute to the development of student creativity (Lin & Wang, 1994), the gaining of experience and technological skills. Such is the case that it appears logical that the experiential learning promoted in STEM education encourages students to acquire and improve skills related to science, engineering, and mathematics as this type of learning stresses the acquisition of strategies and procedures that allow them to solve problems associated with their learning (Kolb, 1984).

As regards attitudinal benefits, we draw particular attention to the value of STEM education for alleviating the lack of interest and commitment on the part of students towards STEM subjects, and this is particularly true during initial school years. In addition, it appears that employing a STEM education approach could increase the future number of STEM degree students, which is essential for economic and social development given the characteristics of current society (Chiu & Duit, 2011; Caprile et al., 2015).

Furthermore, from the results shown in Table 6, a series of key aspects can be established that should be considered when designing and implementing a STEM-focused educational intervention. Thus, attention must be paid to where (context), how (resources and methodology), who (student characteristics) and in what conditions (characteristics of the educational intervention) the STEM education is developed.

The academic and family context surrounding students has commonly been related to their learning results. Therefore, taking into account classroom atmosphere, family and social context are unavoidable. This is all in the hope that the contexts used for developing scientific subjects will motivate students making them feel emotionally positive toward science (Boonprasert, Tupsai, & Yuenyong, 2017) and the other STEM disciplines.

Furthermore, informal educational contexts appear to have a positive effect on student interest in STEM disciplines and subjects (Bultitude & Sardo, 2012), which could find support in the atmosphere created: generally relaxed, familiar to the participant, and entertaining in pursuit of encouraging students' willingness to learn (MacDonald, 2004).

Didactic resources and teaching methodologies are also put forward as one of the key aspects in the development of a STEM educational intervention. Robotics is thus considered as a didactic resource that could improve STEM teaching as it possesses characteristics that facilitate the acquisition of skills such as inquiry, problem solving, creative, and cooperative thinking and, as a result, the integration of the four disciplines (Chung, Cartwright, & Cole, 2014). In this sense, the use of virtual platforms and social networks promotes skills similar to those mentioned above, which makes these an ideal medium for implementing a STEM educational intervention. In terms of the teaching strategies that implement inquiry or project-based learning, it has been observed that they have similar benefits, facilitating the integration of the four STEM disciplines and the application of the knowledge acquired. The reasons for drawing attention to these benefits could respond to (a) the interdisciplinary study approach, which in the case of inquiry-based teaching resembles the form in which scientists carry it out (Martin-Hansen, 2002); and (b) to the teaching approach of the two disciplines, given that both inquiry (Minner, Levy, & Century, 2010) and project-based learning (Bell, 2010) has the objective of demonstrating the transfer of the content studied and knowledge acquired to real-world situations.

Other indicators that may determine the success of the educational intervention are: (a) responding to cognitive and emotional effects, and to the content developed (Dreyfus et al., 1990; Houseal et al., 2014); (b) student race and gender; and (c) its duration, all contrasted via a number of investigations. Abell and Lederman (2006) describe that girls normally show poorer attitudes towards science learning. Sjøberg and Schreiner (2010) place the level of economic and social development of the country of origin of students as an indicator of their attitude towards science learning, in a way that those originating from developing countries could have better attitudes than those residing in developed countries. In relation to the duration of the educational interventions, Weinburgh (1995) argues that with marginal sessions or reduced intervention periods it is difficult for the educational experience to produce positive effects in students.

Finally, it is important to stress that not all of the studies set forth benefits and key aspects of STEM education. We have found cases where the authors highlighted the benefits and key aspects of the STEM intervention (e.g., Blustein et al., 2013; Evans et al., 2014; Lamb et al., 2015; Lou et al., 2017; Marle et al., 2014; Toma & Greca, 2018; Tseng et al., 2013), whereas other authors failed to make them explicit (e.g., Toth, 2016). As such, drawing attention to the benefits obtained from a STEM approach, along with the aspects that have been key to its implementation, is essential to help dispel uncertainties that emanate from educators when they have to face the design or implementation of a STEM educational intervention (English, 2017).

3.4 | Limitations and forecast

The aim of a systematic review paper is to summarize the results produced by the studies considered, accepting that each one of them possesses distinct characteristics, often provided by the context in which they are written. It is also vital to guarantee the quality of the works selected to be able to draw solid conclusions. This way, the reduction of the search to a single database (WOS) has affected the size of the final sample making it the foremost limitation of this study. Thus, we advocate the carrying out of reviews that take in a higher number of databases to increase the study sample. This would also allow the inclusion as a variable of the continent in which the educational intervention was implemented, a study that has not been possible here but that could be relevant for narrowing down what is being talked about when STEM education is discussed in different places throughout the world.

4 | CONCLUSIONS

The objective of this study is to analyze those educational interventions referring to themselves as STEM education, in the interest of offering a vision on what we researchers and educators talk about when we talk about STEM education. In so doing, the analysis of the selected educational experiences points to the existence of multiple ideas on what STEM education is and how to implement it. This said, we can conclude that when STEM education is discussed:

(1) The theoretical frameworks tend to be inconsistent regarding the definition of STEM education, as in the majority of cases no grounds are provided for the term, or other similar ones, in such a way that authors normally focus their frames of reference on theoretically developing the rest of the variables studied. STEM terms, therefore, seem to play a secondary role in the theoretical foundation. This situation could lead to confusion on the part of those researchers and educators who are coming into contact with STEM education for the first time. Nevertheless, it appears that this trend has been changing in recent years, with the term STEM education being the most defined.

(2) It is not simply used for describing an educational experience that integrates the four disciplines in the acronym; STEM education is also used for communicating results from the teaching of science, technology, engineering, and mathematics. Therefore, it appears that speaking about STEM education does not imply that STEM education has truly been implemented.Despite this, the majority of studies use this language. Thus, in the integration of the four disciplines, the role of engineering is normally highlighted, whereas the way of integrating them habitually makes use of a context with real contexts and those specific to technology (virtual contexts) the most used.

(3) The level of detail given on the link between the contexts covered and the different disciplines in the STEM educational interventions is lacking in the majority of cases (68%; $n = 13$). As a result, it is common for there not to be an explicit connection between the different contents and the STEM disciplines in the descriptions of the educational interventions, in such a way that understanding how these are integrated can become difficult and, even, impossible.

(4) Cognitive, procedural, and attitudinal benefits for students are highlighted in much of the research, commonly directed at the acquisition of content and the development of skills related to the STEM disciplines whose goal is the promotion of interest in STEM subjects and degrees.

(5) A series of key aspects is indicated, which should be taken into account during the design and implementation of the educational intervention, these being: where, how, for whom, and in what conditions is this developed.

In short, in light of the debate surrounding STEM education, we must advocate the unification of terms and the adoption of STEM education visions that converge into a simultaneous study of the four STEM disciplines, avoiding points of view that could move veer from their essence. In this manner, conceiving STEM education as “a teaching approach that integrates content and skills specific to science, technology, engineering, and mathematics” could contribute to dispelling those doubts that commonly arise for educators and researchers when they speak about STEM.

4.1 | Implications for educators and researchers

To conclude, we outline a series of implications that could be useful for designing, implementing, and showing the results of a STEM-focused educational intervention.

On the one hand, in reference to the design of the STEM-focused educational intervention, the theoretical foundation of a study that tackles STEM education should establish those STEM terms addressed therein, paying special attention to the explicitness of the STEM perspective adopted. Also, under a logical perspective, theoretically grounded and in light of the most habitual practices, it appears ideal to adopt an approach to STEM education wherein the teaching of the four disciplines that comprise it are integrated into the same educational experience. In addition, it is necessary to make the relationship of the content studied explicitly with a high level of detail along with their link to the different STEM disciplines for the sake of contributing to the understanding of the educational intervention designed. Finally, engineering could be a discipline with a high integrating value, which would contribute to reducing the difficulties that might arise from the design of a STEM-focused educational intervention.

On the other hand, in reference to the results obtained, the benefits of STEM education, paying special attention to the degree of integration of the STEM disciplines, should be made explicit in the article for the purpose of making process in the description of the strengths and weaknesses of the different levels of integration. Furthermore, those aspects that were key for effective implementation of the STEM intervention should be highlighted in the report to aid the design of future STEM educational experiences.

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APPENDIX A. REVIEW PROTOCOL FOR THE ARTICLE

The analyzed aspects and the procedure to follow for the data collection are shown below:

(1) Characteristics of the research: The year of publication, design of the study, and educational stage in which the intervention was implemented are identified. Because these are data in which there is no room for subjective interpretations of the coders, we proceed to identify these in each work. In those cases where none of the data is explicitly stated, it is classified as nonspecific.

(2) Theoretical framework: The theoretical foundation of each paper is analyzed to identify the existence of definitions of STEM concepts if, on the contrary, these terms are not defined or are only named without arguing their conceptualization, these are not considered.

(3) Description of the educational intervention, attending STEM disciplines and contents: The STEM disciplines (science, technology, engineering, and mathematics) and the contents that have been worked on in the educational intervention are collected. Thus, the procedures to collect data are the following:

1. Collect the disciplines and the contents worked out that are referred to in the work.
2. In case of not detailing STEM disciplines, it will be observed if the scientific, technological, engineering, and/or mathematical branches that could allow the identification of the discipline are explicitly mentioned, thereby determining the disciplines worked in the intervention.

3. If neither the STEM disciplines nor the underlying branches of knowledge are explicit, the content, procedures, and/or skills manifested in the work that can be framed within a STEM discipline will be analyzed. These descriptors will be collected to justify the decision made (see annex).

(4) Conclusions:

1. Benefits of STEM education: The benefits of STEM education will be identified for the students participating in the analyzed intervention. In this way, the encoder inductively will establish a category for each identified benefit. Finally, the categories identified by each coder will be compared to establish the final list of categories for this unit of analysis, so that those of a similar nature will be unified in a single consensus and those that differ will be added to the list.

Key aspects in STEM education: The data of this category of analysis will be collected in the same way as the previous one applying the same analysis procedure.

APPENDIX B. DESCRIPTORS ANALYZED TO DEDUCE STEM DISCIPLINES

The descriptors that appear explicitly in those articles that did not identify the STEM disciplines or the underlying branches of knowledge of each of them are shown below. In addition, we must bear in mind that the classification of these descriptors in the different STEM disciplines has been made following the definitions proposed by National Academy of Sciences (2014) for:

a. Science: It studies the natural world, including the laws and theories of nature associated with physics, chemistry, biology, and geology, as well as the treatment or application of facts, principles or underlying concepts of these disciplines. In turn, science is a body of knowledge accumulated in time from a process (scientific research) that generates new knowledge.
b. Technology: It includes the entire system composed of people or organizations, the knowledge, processes, and devices involved in the creation and operation of technological devices, as well as the artifacts themselves. Thus, throughout history, technology has been used to cover wants and needs.
c. Engineering: It is the body of knowledge available to the human being to design and build products to solve problems. Engineering uses scientific and mathematical concepts and it is helped by technological tools.
d. Mathematics: It studies the patterns and relationships between quantities, numbers, and space. It differs from science, because it uses scientific evidence to justify or reject hypotheses, whereas mathematics guarantees these, grounded on logical arguments based on fundamental assumptions. Some of the categories of mathematics are: arithmetic, algebra, functions, geometry, statistics, and probability.

Discipline	Descriptors	
Science	Liquid chromatography	Environmental education and sustainable development
	The principles of movement	Biochemistry
	Electro-mechanics	Climate change
	Energy	Ecosystems
	Structure and composition of DNA	Ecology
	Human genome	Magnets and electricity
Technology	Image editing tools (GIMP)	Work with virtual platforms (virtual laboratory)

(Continues)

	Know and use hardware Employ sensors and other technological tools Wireless communication (Wi-Fi and internet)	Design electrical circuits Robotics 3D models Geospatial technology Programming (software)
Engineering	Build a robot (LEGO) Urban infrastructure Build prototypes	Build electrical circuits Develop hardware
Mathematics	Analysis of bar codes Calculate and apply numerical operations (voltages, concentrations, etc.) Measure variables	Positional numbering systems Visual representation Logical operations Differential equations Probability