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STEM Education As A Transdisciplinary Practice In Secondary And High School Education

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Abstract

In the current scientific moment, as stated by Caro et al. (2020), despite the large amount of disciplinary research being carried out, different forms of supradisciplinary research are also emerging, such as multidisciplinarity, interdisciplinarity and transdisciplinarity.

Today's societies go forward very quickly, and education systems do not always evolve at the same rate, which leads to the relevant difficulties in the implementation of new curricula that try to respond to the demands of societies related to these advances. Education must prepare citizens to face future challenges and provide an efficient response to the resolution of complex problems that may arise. Therefore, this article presents a literature review to address STEM education as a transdisciplinary practice in secondary and high school in the classroom. For this purpose, different databases have been used during the years 2015-2023, specifically WOS (Web of Science) and SCOPUS. This review aims to answer the question of whether the STEM experiences carried out in the classroom have really been designed from a transdisciplinary approach.

Keywords: transdisciplinarity; secondary education; high school education

1. Introduction

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In the current scientific moment, as stated by Caro et al (2020) , despite carrying out a large amount of disciplinary research, different forms of supradisciplinary research also emerge, such as multidisciplinarity, interdisciplinarity and transdisciplinarity.

These supradisciplinary terms can be defined according to the same authors as follows:

• Multidisciplinarity will be understood as the research practice where the juxtaposition of both theoretical and methodological models from different disciplines occurs, to answer a research question where each specialist works in their discipline.

• Interdisciplinarity will be understood as the practice of research where a juxtaposition of models will also occur, but unlike multidisciplinarity, in this case the research question will be addressed through dialogue, coordinated collaboration and transfer. of models and methodological tools between different disciplines.

• Transdisciplinarity will also be the practice of research, but taking a step further in the integration of the different disciplines, so that these will be articulated in such a way that they will generate new plots of knowledge, thus exceeding the limits of the disciplines that form part of the investigation.

Considering the aforementioned definitions, it can be seen how a gradual integration of the terms has been carried out, which also implies the gradual integration of the different disciplines.

With the integration of the different disciplines, a whole series of educational interpretations of the term STEM (Science, Technology, Engineering and

Mathematics) have taken place. Despite more than thirty years having passed since the appearance of the term in the National Science Foundation (NSF), it is with the integration of these disciplines that the term STEM is given an integrative approach, calling it integrated STEM education, as Kelley and Knowles (2016) , assuming this is the beginning of a line of educational research and practice. Art has recently been added to the disciplines included in the STEM acronym, giving rise to the term STEAM as stated by the authors Ortiz-Revilla et al (2021) .

Authors such as Herro and Quigley (2017) understand that the problems that society faces cannot be solved in an isolated manner from one discipline, but rather there must be an integration of these, with transdisciplinarity taking on special importance in this integration.

Despite the use of the term transdisciplinary to refer to STEM/STEAM education by some authors, there is still a mixture of supradisciplines when working with this type of education. Authors such as Lin and Tsai (2021) create a pedagogical model whose objective is to implement interdisciplinary study plans where science, technology, engineering, art and mathematics come together. For their part, Chu et al. (2019) propose in an intercultural context a theoretical foundation for teachers to develop a STEAM program aimed at improving the learning and teaching of science, integrating multidisciplinarity, interdisciplinarity and transdisciplinarity.

The mix of this amalgamation of terminologies in the different educational stages makes clear the need to deepen the study of the use of transdisciplinarity in STEM/STEAM education, since, as Tovar and López (2021) point out, this will help obtain a multi-complementary understanding . of the people who make up organizations that undergo transformations and adaptations, depending on the context in which they find themselves. For this reason, it is also worth highlighting the importance of higher education in this context, with its participants being the ones who will form and direct future organizations with the evolution and changes that are generated along this path.

Authors such as Bernate and Guativa (2020) , carry out a study of the trends and challenges of educational systems, placing them in a context of what they call the fourth industrial revolution. They propose, citing Piña and Senior (2020) , that societies can take revolutions as crises or opportunities, having to prepare citizens for all the necessary changes in these situations, and that it is STEAM education that is implemented in different training institutions. for the structuring and orientation of the educational system.

Not only are there studies in formal STEM/STEAM education, they have also been carried out in the field of non-formal education, such as the one carried out by Zapata and Carmona- Mesa (2021) , where they carry out a documentary analysis of the developments and challenges of non-formal Ibero-American STEM/STEAM education. The authors affirm the existence of little discussion related to the integration of STEAM education disciplines in the non-formal sphere, and citing Domènech-Casal et al. (2019) affirm that the discussion that may exist around interdisciplinarity is complex, situating their research around monodisciplinarity and multidisciplinarity, prioritizing the sum of disciplines rather than their connections.

Once again, the elusive and complex nature of the terms can be seen when used not only in relation to formal education, but also extends to informal education when it comes to STEM/STEAM education.

In the new Organic Law 3/2020, of December 29, which modifies Organic Law 2/2006, of May 3, on Education (LOMLOE), a competency learning model is promoted, being one of the eight competencies that proposes the Mathematics and Science and Technology competition, called STEM competition. The inclusion of this competence implies the grouping of subjects by areas with the complexity that this entails, especially when it has to be implemented in the classrooms. And not only because of the existing literature on the terminologies used, but also because of the new legislation on education, which is why this work studies the relationship or connection of the reality of the classrooms with the implementation of STEM education in the stage of Compulsory Secondary Education and Baccalaureate from a transdisciplinary approach.

2. Research objectives

For all the reasons stated in the previous lines, the research carried out aims to achieve the following objective:

• Develop a bibliographic review to detect the application in the classroom of STEM experiences designed from a transdisciplinary educational approach in the Compulsory Secondary Education and Baccalaureate stage, and learn about the evaluation of their application in students, as well as the authors' conclusions in the development of experiences developed from this perspective.

Next, the methodology carried out to develop the objective set out in the previous lines is described.

3. Methodology

To carry out the bibliographic review, the recommendations of the PRISMA statement (Preferred Reporting Items for Systematic reviews and Meta-Analyses) have been taken into account, a resource created to improve quality that will provide the study with greater clarity and transparency (Urrútia and Bonfill, 2010).

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In the same line as Gil (2002) , the work carried out contains a series of steps such as the choice of the topic, preliminary bibliographic study, formulation of the problem, preparation of the provisional thematic plan, search for sources, reading of materials, organization of the topic and writing of the research. And following the scheme used by Sánchez and Martínez (2021) , where the steps mentioned in the previous lines are summarized, Figure 1 shows the steps followed to carry out the present study.

Figure 1. Defined steps for bibliographic analysis. Own elaboration

Source: self made.

The steps followed to carry out the bibliographic review presented in this work are described in detail below.

Step 1. Topic and keyword selection. The topic selected to carry out this study has been the detection in the literature of STEM education as a transdisciplinary practice within the framework of Compulsory Secondary Education and Baccalaureate, using the following keywords to search the databases: STEM and transdisciplin* in the topic field, thus selecting all the documents that have the terms indicated in the title, or in the abstract, or in the keywords defined by the authors.

Step 2. Selection of databases. The databases chosen to carry out the study were the following: Web of Science (WOS) and SCOPUS. These databases allow us to have a high-level view of the level of research production in all scientific fields.

The reason why the WOS was chosen to work is the high scientific level that its composition provides, since it is composed of the basic collection Core Collection that covers the indices of Sciences, Social Sciences and Arts and Humanities, in addition to the Proceedings of both Sciences as Social Sciences and Humanities along with tools for analysis and evaluation, such as the Journal Citation Report and Essential Science Indicators. It also has the complementary databases included in the license for Spain: Medline, Scielo and Korean Citation Index.

The SCOPUS database has been selected for the same reason, it is a database of bibliographic references and citations belonging to the Elsevier company, of peer review literature and quality web content, with tools for monitoring, analysis and visualization of the high-level research production.

Step 3. Selection of search criteria. The criteria used to search for the information were the following: documents resulting from research work related to the keywords mentioned in step one during the years 2015 to 2023. Those that were also taken into account as criteria for the final selection of the contents were: They could be obtained online and without any payment.

Step 4 . Selection of articles. The articles have been selected following the criteria mentioned in previous lines, the following filters have also been used: document typology and the selected year range, with the selected documents being magazine articles. In addition to the selection of articles that met the established criteria, we also began with the identification of the works that responded to the objective set in this work.

Regarding the search carried out, a total of 211 documents were obtained in WOS and a total of 193 documents in SCOPUS. The first refinement that was applied to limit the number of articles obtained was the document type, selecting only the articles. This refinement reduced the results to 147 documents in WOS and 100 documents in SCOPUS. Subsequently, the next level of refinement was applied, which consisted of including documents published between 2015 and 2023. This step reduced the number of articles to 116 and 80 respectively. Finally, a refinement related to the language of the article was applied, including only documents in English and Spanish. As a result, a selection of 110 articles from WOS and 78 articles from SCOPUS was obtained. Of these 188 articles, 57 appeared in both databases, so, after eliminating duplicates, the selection consisted of 131 articles.

Step 5. The next step consisted of reading the title, summary and keywords of the 131 filtered articles. Of these, 61 were eliminated because they did not belong to the topic under study within STEM education (exclusion criterion 1). The discarded articles mostly dealt with health issues, and there was also a considerable number of research on sustainability and urban planning. Next, 20 articles were discarded for dealing with the STEAM theme (exclusion criterion 2), because the present work focuses on the analysis of transdisciplinary proposals within STEM education, without expanding to STEAM education, an objective that will be addressed. in future research.

In this way, there were 50 documents that addressed transdisciplinarity in STEM education in some way, although 12 of them did so from a generalist or philosophical perspective, not related to the type of article that is intended to be analyzed in this research, focused on observe how a truly transdisciplinary STEM approach can be used with Secondary Education students, therefore, they were discarded (exclusion criterion 3).

The remaining 48 articles were read completely. Of these, 40 constituted research developed at educational stages other than secondary education and high school (exclusion criterion 4). Most of the documents analyzed proposals at the university level, with some also found at the Primary and Postgraduate Education stage.

In this way, with the application of the four criteria mentioned, the selected articles were 8, of which 4 of them were discarded because they were investigations in which the object of study was the secondary and high school STEM teacher, not the students (exclusion criterion 5). Therefore, the articles selected for a final review were 4, as can be seen in Figure 2.

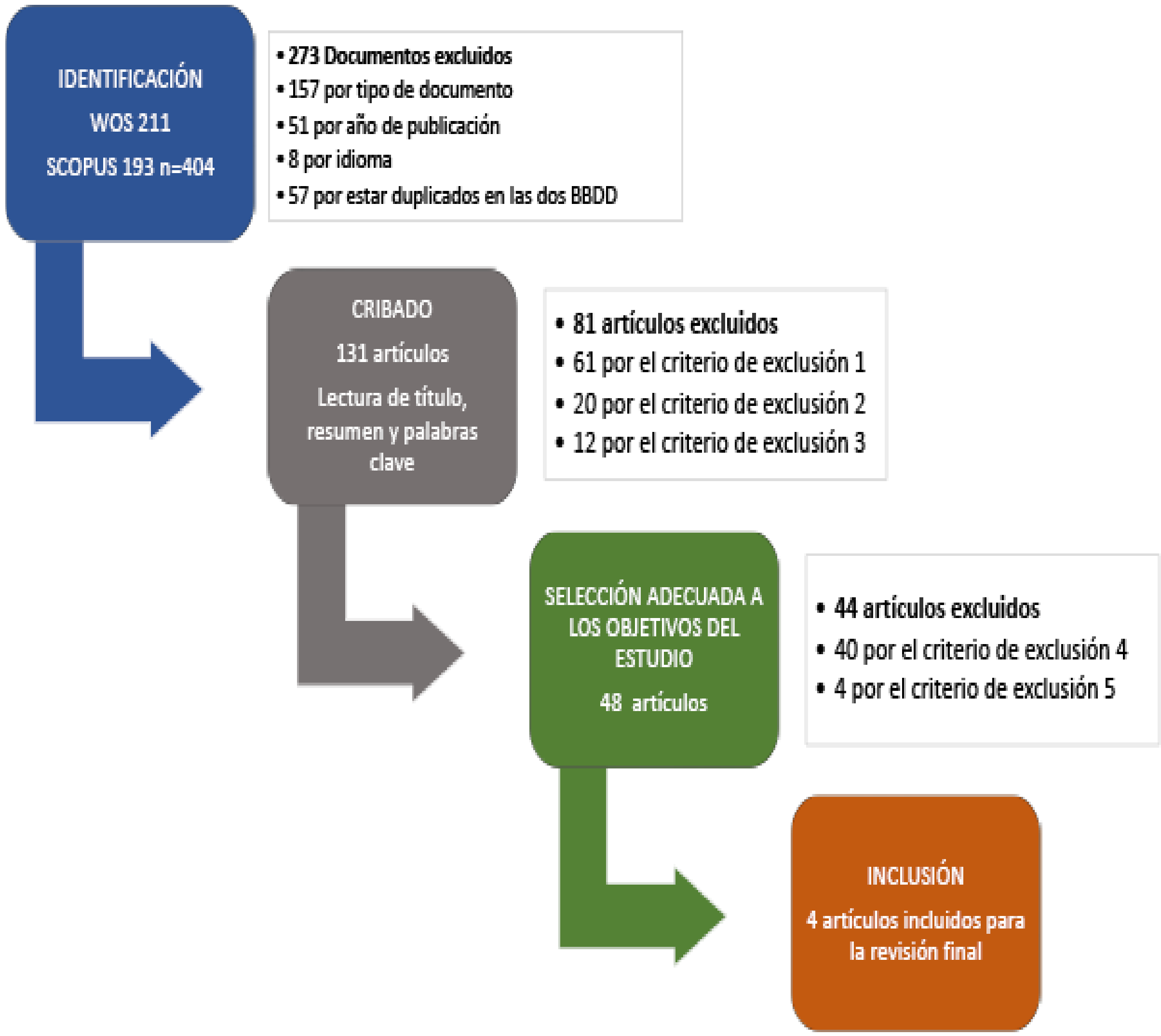

Figure 2. Flowchart of the article selection process. Own elaboration

Source: self made.

To carry out the process described in Figure 2, the documents obtained were organized into folders through the assignment of numerical codes related to the topic and the criteria taken into account for the preparation of this work. A summary of each of these documents was also written, as well as what was included within them also as a summary, the methodology used in each of them and their main conclusions.

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Step 6. Categorization of works. The criteria used to carry out the categorization after reading the documents were the following:

- Analysis criterion 1: Starting from the organization of documents described in the previous step, the years in which the articles were published and the original language in which they were published were identified.

- Analysis criterion 2: Based on the summaries written in the previous step, the areas of knowledge where the STEM practices were brought to the classrooms were identified.

- Analysis criterion 3: In addition to the two previously mentioned criteria, in this last criterion the main conclusions reached by each of the finally selected articles were identified.

Step 7. Writing the report. As a final step of the study, the writing of this article is carried out taking into account the stated objective, the categorizations carried out and presented in the previous step.

4. **Results and conclusions**

As indicated in this study, STEM education takes on an important role in current education, especially taking into account the changes that have occurred in the new legislation related to education in all the stages that make it up in Spain. But these changes not only occur at the national or legislative level, but also occur at the international level, with a constant exchange of information that influences the practices carried out in the classrooms due to existing globalization and scientific exchange. constant.

The main objective of this study is to detect transdisciplinary STEM experiences in the Compulsory Secondary Education and Baccalaureate stage that exist in current scientific literature, with only 4 articles being identified where it is clearly expressed that these STEM practices are transdisciplinary.

In the study carried out by Huang et al. (2022) , upon detecting the need in the scientific world to carry out more empirical tests in order to inform educators and professionals about which educational strategies work and which do not in a pandemic context, designed and implemented a research project where A transdisciplinary STEM curriculum was designed and implemented during the covid-19 epidemic. The results of the pre- and post-tests that were carried out indicated that the students' transdisciplinary knowledge in STEM improved significantly after completing the aforementioned curriculum. Integrating STEM disciplines with social service and writing promoted growth in students' empathy, interest, and self-efficacy.

In the work carried out by Huri and Karpudewan (2019) , integrated STEM-lab activities are proposed in the teaching and learning of electrolysis. The authors state that the activities use real-world contexts as a platform to showcase the transdisciplinary nature of the integration of the four STEM disciplines, as well as that the findings they found suggest that Integrated-STEM laboratory activities are suitable to address the limitation of existing laboratory activities for the construction of knowledge. Furthermore, they affirm that the proposed activities are suitable for integrating the four STEM disciplines into the standard science curriculum.

They conclude all of this in line with the statement that the absence of a specific definition given for integrated STEM, along with teachers' lack of STEM-related pedagogical knowledge, creates confusion among STEM educators to continue STEM education. In this way, the authors assert that STEM pedagogies are effective in addressing conceptual understanding and provide evidence that integrated STEM-lab activities are mental activities that encompass the nature of meaningful learning.

The authors Rupnik and Avsec (2020) explore the effects of a transdisciplinary educational approach on technological literacy, specifically, they design a task that includes several real-life technological contexts and concepts that require knowledge of other disciplines to solve, create and acquire new knowledge while developing positive attitudes towards sustainable technology. They conclude by putting into practice the experience with 242 students that confirms the importance and effects of a transdisciplinary educational approach. A transdisciplinary approach in the technology classroom over a 35-week course affected students' attitudes toward technology and, in particular, the perceived difficulty of the technology was reduced. A transdisciplinary approach taught at a higher cognitive level increases students' interest in technology and their awareness of the consequences of technology, also concluding that students who experience transdisciplinary teaching perceive the subject of design and technology in broader terms through despite the existence of erroneous ideas about what technology includes.

In the last article of those selected for this study, carried out by Seroy et al. (2020) , the starting point is the assertion that, although there are specific resources for each discipline, the transdisciplinary opportunities that integrate engineering education are limited, with few truly transdisciplinary opportunities that integrate engineering education and the development of technological skills to contextualize basic scientific concepts. Therefore, they present an adaptable module that integrates practical technology education and place-based learning to improve students' understanding of key chemistry concepts as they relate to local environmental science.

The module was tested in three different Secondary Education courses, one in Chemistry, another in Oceanography, and another in Advanced Level Environmental Sciences. In their evaluations, students showed a significant improvement in their knowledge of the three courses, also expressing greater confidence in the material, even when their knowledge of the content remained the same.

As can be seen, there are few transdisciplinary STEM experiences implemented in the classrooms described in the literature, as stated by the authors mentioned in the previous lines. But despite being few, it is also evident that the results obtained in the students' learning process are significant.

Also in the studies addressed in this bibliographical research, the authors agree to express the lack of empirical analysis of experiences previously implemented practically in the classroom. In this way, education professionals could obtain information about the practices that work best and those that could bring greater benefit to students, and know if these activities truly integrate the disciplines contained in STEM education in a transdisciplinary way.

Another thing they highlight is the absence of a specific definition of integrated STEM, as well as the lack of knowledge on the part of the teaching staff to carry out the aforementioned integration of the disciplines from a transdisciplinary point of view.

To conclude, and addressing future lines of research, we consider that this work should be expanded by also adding STEAM education to the study. In this way, it could be studied whether the existing research that contemplates STEAM education from a transdisciplinary educational approach is also scarce with respect to the description and evaluation of practices carried out in Secondary and Baccalaureate classrooms, and if learning is obtained with them. significant on the part of the students. Likewise, it would be interesting to know if the same problems are detected in terms of the specific definition of the term STEAM and if the same problems are detected in terms of teacher training to be able to apply it in classrooms.

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