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How to fit identities? A systematic review about scientific education from a gender perspective

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Abstract

Addressing the gender gap in science, technology, engineering, and mathematics (STEM) education has become a critical focus in recent years, emphasizing the need for gender-sensitive teaching approaches from the early stages. We conducted a systematic literature review of studies published up to September 2022, focusing on methodological guidelines for incorporating a gender perspective in primary science and engineering education. A total of 104 articles were analyzed, identifying six emerging topics: the formation of student identity and their perceptions of scientific-engineering fields, students' attitudes towards science and engineering, potential differences in science skills between girls and boys; emotional performance in learning scientific-engineering subjects, and factors influencing the non-election of scientific-engineering subjects and studies. The findings show that implementing activities based on engineering practices in primary education has great potential to enhance the interest, participation, and self-concept of students of both genders, thereby promoting diversity and addressing the gender gap in STEM fields.

Keywords: STEM identity, gender identity, systematic review, primary education

INTRODUCTION

The field of science and engineering education is currently facing a significant challenge involving the widespread lack of interest among students, particularly girls, in pursuing careers related to science, technology, engineering, and mathematics (STEM) subjects (Archer et al., 2020; Bamberger, 2014; Eccles & Wang, 2016; MEFP, 2021; Ro & Knight, 2016; Sáiz-Manzanares et al., 2020; Vázquez & Manassero, 2008; Zhou et al., 2019). This issue is evident in the low representation of women in these fields, especially in engineering and technology (UNESCO, 2021; Simarro & Couso, 2022; World Economic Forum, 2023). Despite institutional efforts to promote gender equality in education, the gender gap persists globally, with a more pronounced disparity in developed countries (Jackson et al., 2020; Stoet & Geary, 2018).

In this context, teaching STEM disciplines from a gender perspective has become an educational imperative, necessitating early intervention strategies (Avraamidou, 2023; Ayuso et al., 2021; Ribarić & Novoselić, 2025; Santos et al., 2025), as girls tend to have less stimulation and exposure in these areas (Hewitt & Forcino, 2025). In response, gender mainstreaming in STEM education involves creating learning environments that align with girls' interests, highlighting contemporary female role models, and fostering emotional engagement to enhance learning (García-Durán et al., 2023; Martín-Gámez et al., 2022; Torres-Torres et al., 2024).

Current research indicates that the decline in vocational interest in STEM degrees, which begins in early adolescence, is related to identity issues, as the image of these disciplines is laden with stereotypes and disconnected from students' interests (Archer et al., 2020; Drymiotou et al., 2024; Harnischfeger & Stahl,

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Contribution to the literature

- This study provides a comprehensive synthesis of 104 articles, highlighting a series of methodological guidelines for teaching science and engineering subjects from a gender perspective to address the gender gap.
- This systematic review reveals the need to align students' personal identities with perceptions of STEM fields and professionals, promoting a more realistic and inclusive image that counteracts gender stereotypes.
- The results demonstrate the importance of acting from primary school onward, as gender differences in perceptions of STEM subjects begin to emerge at an early age, and provide information on how these differences can be addressed.

2025; Quintana, 2023; Sakellariou & Fang, 2021; Toma & Meneses, 2019). During this time, students begin to perceive science and engineering as male-dominated fields, which may deter girls from pursuing these disciplines (Zhou et al., 2019). This lack of interest is often rooted in gender stereotypes and biases perpetuated by society and the education system (Bian et al., 2017; Kerkhoven et al., 2016; Zúñiga-Mejías & Huincahue, 2024). These stereotypes contribute to the perception that STEM subjects are not suitable for girls, leading girls to avoid these fields (Alfred et al., 2019; Christidou et al., 2016; Tam et al., 2020). Therefore, it is necessary to eradicate those notions traditionally attributed to the image of the sciences that are stereotyped and associated exclusively with the male gender (Scholes & McDonald, 2022; Uluçinar, 2012; Vázquez & Manassero, 2008).

Moreover, another of the causes that appears to be the origin of the failure to choose STEM studies is the lack of examples or models to follow in these branches of knowledge, with the invisibility of female scientists being especially significant (Bamberger, 2014; Hughes et al., 2020; Valdés-Argüelles et al., 2024). All of the foregoing contributions contributes to students not wishing to continue with these types of studies due to the feeling of insecurity and frustration when facing something new, and to which many barriers and prejudices exist that make them difficult to achieve (Archer et al., 2020). An example of this is the belief, in the event of continuing with studies of a scientific and engineering nature, that it is incompatible with raising a family (Bamberger, 2014; Wang & Degol, 2017).

Despite the existence of important research on this subject, there is still a gap in how to teach scientific and engineering areas from a gender perspective in primary education. Therefore, it is essential that educational proposals promote a broader perspective, which allows nurturing an environment linked to the knowledge of the characteristics of the professions, without delimiting or marking gender stereotypes when defining whether they fit into male or female grades (Macías-González et al., 2019).

This study aims to conduct a systematic literature review guided by the following question: What methodological guidelines could be extracted from the literature to incorporate a gender perspective in primary education science and engineering?

Through this systematic review, we explore the literature to rethink teaching methodologies in STEM education, with the aim of providing guidelines that can transform primary education into a catalyst for change (Toma & Meneses, 2019). Hence, the purpose of this study is to deconstruct false beliefs (Dapia et al., 2019; Fleer, 2021; Martín-Gámez et al., 2022; Zhou et al., 2019), create accurate identities in science (Clark & Kajfez, 2023), and remove stereotypes (Avraamidou, 2022). This involves "not just teaching these subjects, but also teaching 'around' them, that is, presenting them in their social context, as forms of knowledge, cultures and instruments with their own contexts, roots and social impacts" (Vázquez, 2013, p. 28), to promote equal opportunities between men and women (Jackson et al., 2020).

METHODOLOGY

The systematic review presented in this work was implemented following the preferred reporting items for systematic review and meta-analysis (PRISMA) protocol, which establishes a series of concrete guidelines for the creation thereof (Moher et al., 2009). The specific aim of this article is the construction of a qualitative analysis of the topic related to the consideration of aspects of gender in science education within compulsory stages, especially primary education, for discovering the current state of research. The search was carried out selecting all studies published up to September 2022, using the international database Web of Science (WoS) as the main data source.

The initial selection of documents followed the criterion of inputting a code in the advanced search of this database, filtering appearance by title, abstract and keywords. The search string inputted was: (STEM study*) OR (STEM education*) OR ("science*education*") OR ("attitude*toward*" science*) AND (Primary Education) OR (Primary School) OR (Elementary School) AND (gender*role*) OR (gender*difference*) OR (gender*stereotype*) OR (gender*gap*) OR (gender*issue*) OR (gender*identity*)

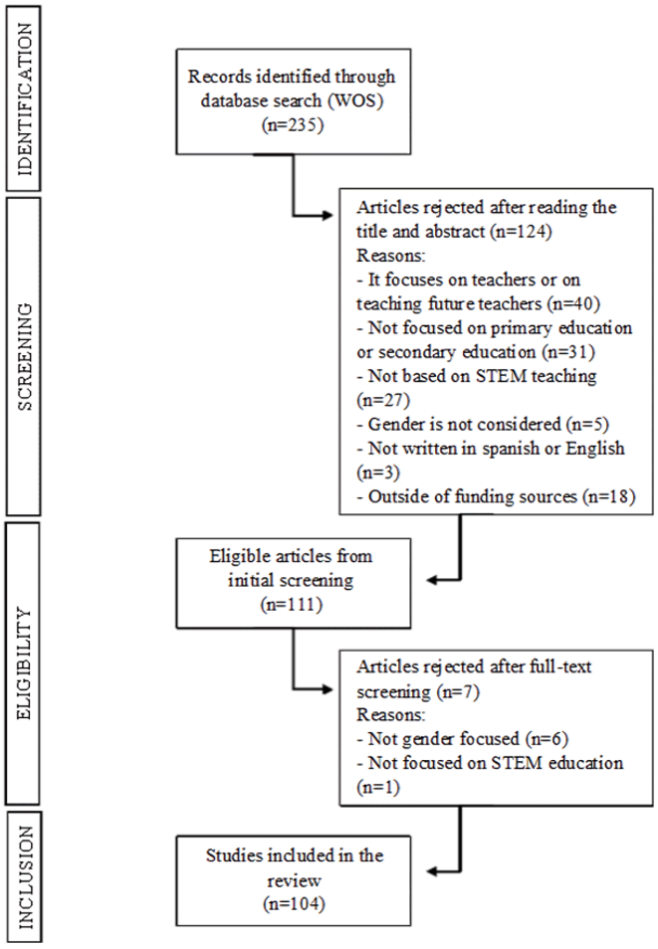

Figure 1. PRISMA flow diagram (Source: Authors' own elaboration)

OR (gender*discrimination*) OR (gender*perspective*). The terms employed were selected with the aim of encompassing those studies that were able to contemplate aspects of gender in compulsory primary education, from the highest possible number of approaches.

In regard to the remaining filters in the initial search, no additional limitations were applied, as both the number of papers obtained, and their publication dates were considered adequate. Most of the studies were recently published within the last five years.

Article Selection

The 235 articles gathered in the initial search (identification phase) were subjected to two phases for refining their selection (**Figure 1**).

The first phase (screening) was done by reading the title and abstract, confirming appropriateness, and selecting those related to STEM learning from a gender perspective in primary education. Moreover, there was no exclusion from those articles that may have focused on compulsory secondary education, as they might have provided notions for a better understanding of the low existing preference for scientific-engineering areas.

Based on this first analysis, we applied the following exclusion criteria: articles focused on a level other than compulsory education or in-service teachers; unrelated to STEM education and gender; written in languages other than English and Spanish; and published in sources outside our funding resources. As a result of this screening phase, 124 articles were rejected from the initial selection, leaving a total of 111.

In the second phase (suitability), there was a complete reading of the text to identify the topics worked on in each article. In this way, 7 articles were rejected with a topic that did not adapt to the subject studied. An example of this is the article by Seals and Smith (2013): "Enhancing K-12 education with engineering outreach", which, despite having an abstract that explained the importance of motivating students of both genders, had a study that neither specifically looked at gender nor analyzed the results of this variable. Thus, 104 articles finally passed the suitability phases, the total number of articles included in this study.

RESULTS

Each of the 104 documents was subjected to a first initial analysis from which general data were extracted, such as the country the research belonged to, year of publication, and objectives sought. A second analysis, focused on the research content, identified what emerging topics were addressed in each study.

General Data

The results of this first analysis show that the articles finally selected are studies carried out in 22 different countries distributed throughout the world (**Figure 2**). As well as the diversity of the places of origin of the studies, attention may be drawn to the fact that more than half of the publications are from the last five years, which shows the emerging aspects within the topic and the current concern that is emerging around STEM education from a gender perspective.

Furthermore, it is possible to observe how the 104 publications analyzed seek 4 different objectives: to carry out interviews, questionnaires or projective tests (n = 58) which permit the gathering of data on student characteristics related to STEM topics (perceptions, attitudes towards science, etc.); to value the potential of specific educational resources in these areas (n = 2); to develop meta-analyses or reviews of the literature (n = 4) with emphasis on specific forms of teaching and in their potential when favoring the choosing of STEM degrees on the part of the female gender; and to analyze the design and implementation of educational proposals (n = 40) to help develop skills or improve attitudes towards science and engineering.

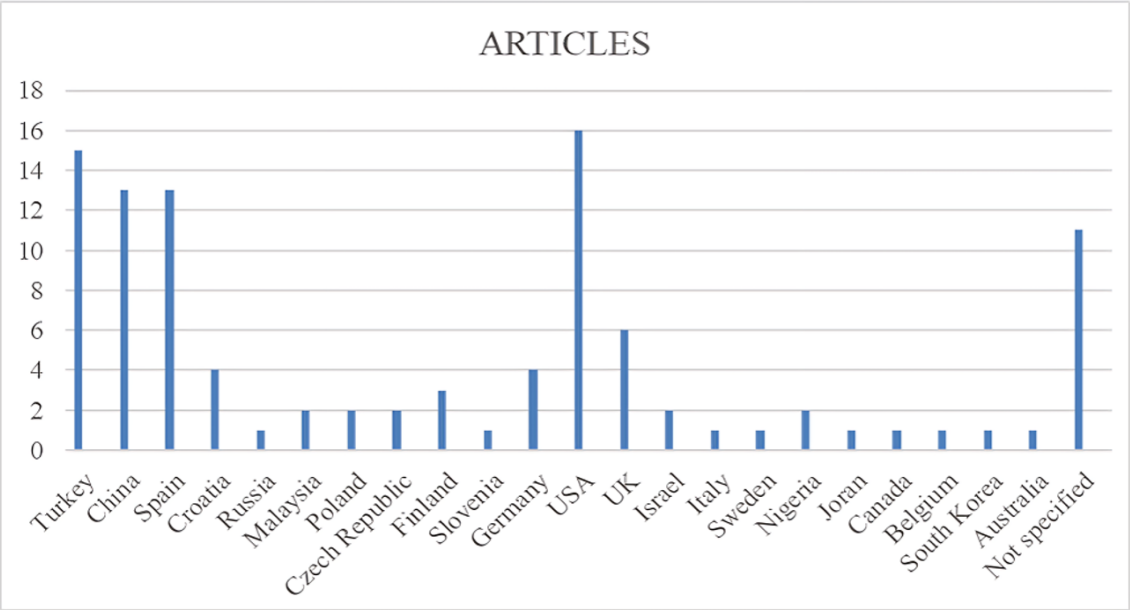

Figure 2. Countries of publications (Source: Authors' own elaboration)

Emerging Topics

Following the general analysis, there was then a study of the "thematic approach", with the purpose of understanding how the authors consider gender perspective in scientific-engineering education through their research.

Six emerging categories were found. The first gather a summary of the studies that attempt to analyze students' identity formation and their perceptions of science and engineering fields of knowledge. The second category shows studies that focus on students' attitudes towards STEM areas, and the third category includes those works that analyze whether or not there are differences in science skills between girls and boys. The fourth category entails studies focusing on academic performance and success. The results related to the effect of emotions associated with learning science and engineering subjects have been gathered in the fifth category, and finally, the sixth category is concerned with analyzing studies dealing with other factors that have a bearing on the failure to choose scientific-engineering subjects and studies.

These six emerging categories are described below in detail.

Identity and Perceptions

Student identity is progressively constructed through their interaction with their surroundings and their experiences (Schiefer et al., 2021). This means that, in turn, a determined perception or image regarding STEM areas is constructed. The compatibility of both self-identity and perceptions in STEM areas is going to be a determining factor in the development of the preferences of students and, in short, in their predilection or not for scientific-engineering subjects. Therefore, the bigger the stereotypes they possess, the more influence these will have in the choice and continuation with STEM area studies, independently of school achievements (Blažev et al., 2017).

Of the works analyzed, on the one hand studies have been found that focus their research on identifying the identity and perceptions or beliefs of students regarding people who work in science and engineering. Thus, there are studies that apply the draw-a-scientist test (Newton & Newton, 1998; Potęga et al., 2021), where the representations of people who work in science created by students reveal a stereotyped vision of the "mad scientist" with glasses, white coat and beard in a laboratory, with this perception being shown to a greater extent in the drawings of boys than girls in primary education. These same results can also be appreciated in the mental image they have of people who work in engineering (Park & Lee, 2014; So et al., 2022). For his part, Buldu (2006) concludes how perceptions vary according to age, as the youngest students do not include stereotypes in their drawings, and also show a more social image of these individuals. Along this same line, the work by Korkmaz and Secken (2015) shows how drawings made by seventh and eighth grade primary education students (12-14 years old) show people from the field of chemistry who express positive emotions and try and "save the world", despite there being difference in the image perceived buy each gender. According to the results of Cheng and Huang (2016); however, in the representation of people working in IT careers, made by fifth and sixth year Primary Education students (11-12 years old) there are no perceptions of stereotypes according to gender, despite there being signs of a more negative attitude towards these professional paths, and there is a preference for other professions socially attributed to their gender. In the face of these

perceptions, studies such as that by Christidou et al. (2016) propose modernizing the image and work of people in science, making it clear that elitist qualities are not necessary in order to dedicate oneself to these areas of knowledge.

Furthermore, investigations are found that address identity and perceptions or beliefs focusing their analysis on change following the use of different methodologies and resources. In this regard, there are studies that show that the employment of more active methodologies, such as inquiry, and the use of technologies, permits the improvement of beliefs and motivation of girls towards the sciences (Arabit et al., 2021; Cai et al., 2022; García & Martín, 2019; Schiefer et al., 2021; Veloo et al., 2013; Zviel-Girshin et al., 2020). A number of different authors also conclude that in the use of real practices related to the different STEM careers before secondary education, specifically experiences of working with science professionals to solve diverse everyday problems in our society, it has a positive impact regarding the transformation of the interests of girls towards these areas (Ayuso et al., 2019; Chen et al., 2022; D'Inverno et al., 2016). An example of this is the experience shown by Capobianco et al. (2015) who found how learning experiences based on engineering design were very beneficial for both genders, having a greater effect on girls.

Another of the methodologies highlighted by the research is that of game-based learning (GBL) from early ages (Arztmann, 2022), and specifically how the use of well selected video games can improve the capacity for reaction, analysis and decision making in students. Greenfield (1997), and Novotný and Maněnová (2019) in particular argue how there are computer games that strengthen these qualities and that on many occasions there is little acceptance of them by the female gender, and their usage is even restricted to the male gender as a result of the imposition of specific gender biases by a section of society. More focused on educational resources we find works that use the Scratch application to initiate students in programming. The results of these show that, although the learning for both genders was extremely satisfactory (Funke & Geldreich, 2017; Zdawczyk & Varma, 2022), the use of this application does not help to reduce stereotypes or the concerns of girls as regards science, nor does it create a sense of their belonging towards the area of IT (Zdawczyk & Varma, 2022). In this regard, Carroll and Faruque (2021) point to the fact that it is not just the addressing of programming in a practical and creative way that is needed, but also the fostering of spaces of reflection and debate in order to encourage a neutral computational culture regarding gender. Continuing along this line of proposals related to engineering and technological aspects, there is a suggestion for organizing peer tutorials aimed at eliminating gender stereotypes (Prendes-Espinosa et al., 2020). Other investigations from different authors (Dele-Ajayi et al., 2020; Edres, 2022; Kerkhoven et al., 2016) indicate how the visual content present in online resources and textbooks shows a stereotyped image in scientific-engineering fields that is manifested in illustrations with a greater representation of men. He (2002) coincides in pointing to the absence of female examples in these materials, furthermore, adding the lack of these in practical experiences that create positive emotions in students, as well as transforming their perceptions and stereotypes (Gömleksiz, 2012).

The next group of studies related to identity and perceptions or beliefs revolves around analyzing how they change following the inclusion of certain approaches and contents in the teaching of scientific-engineering subjects. Thus, Boeve-de Pauw et al. (2020), in their educational proposal, shows students the importance of science in society and the relationship between STEM content and practical experiences. The results reveal how this approach enabled girls to transform the stereotyped vision of engineering and technology only being for boys, seeing in it a possible future professional path. In this same vein of changing perceptions towards individuals who work in science is the design of the intervention by Shimwell et al. (2021), in which each week students are shown a person who works in a sphere related to science, using a vocabulary against stereotypes for the activity. In this way they achieve long lasting effects in the improvement of the conception of individuals who work professionally in STEM fields. Likewise, González-Pérez et al. (2020) conclude that the incorporation of examples and role models in the teaching of scientific-engineering subjects is another aspect that generates a positive effect on the image transmitted of sciences, facilitating the breaking with existing stereotypes and increasing enjoyment, achievements obtained, expectations and the importance afforded to these subjects.

In this sense, other authors defend in their proposals the need to show a broad image of the sciences, which is adapted to the different interests of students, centers on the social belonging of women and serves to break with erroneous and traditional perceptions that conceive science and engineering as being the exclusive preserve of the male gender (Carlone et al., 2014; So et al., 2022; Tellhed et al., 2017; Uluçinar, 2012). Therefore, STEM teaching should adopt an approach that contributes towards the favoring of an image of the sciences compatible with the development of the identity of students, as well as maintaining their interest, participation, positive aspirations, and concept of self. This last aspect is, furthermore, key, given that Vinni-Laakso et al. (2019) hold that individuals who possess a high self-concept of having optimum skills for sciences have a greater facility when learning these subjects. Hence if, as seen in the study by these authors, at the beginning of schoolgirls have a high level of this self-concept and are motivated to engage in science learning,

it is necessary to investigate what happens afterwards to bring these levels down (Capobianco et al., 2015). Some authors explain this progressive disinterest in their studies (Greenfield, 1997; Hunt et al., 2021; Mihladiz et al., 2011), explaining that among the reasons is the acceptance and internalization of stereotypes, given they create a weaker concept of self in the case of girls; and the influence of teachers when explaining these STEM subjects (Ayuso et al., 2021).

Attitudes towards science

Attitudes towards STEM subjects considering the gender variable is a topic that has also been widely researched. We refer to studies on feelings, perceptions, beliefs, preferences and values held towards any scientific object, school science, the impact of science on society and people who work in science themselves (Uluçinar, 2012). These have focused on three aspects: discovering whether differences exist between girls and boys and some reasons that could be an influence on these differences; analyzing whether the use of specific resources or methodologies have a bearing on the interests and attitudes of girls towards these subjects; and studying whether working on specific contents and with a determined approach in the classroom improves these attitudes in girls.

In relation to the first of these, we find the work by Wang and Berlin (2010), which presents an instrument and its validation to measure students' attitudes towards science, assessing the level of enjoyment in learning science, confidence in the ability to do so, and the importance given to science in society. The remaining studies analyzed and related to discovering whether differences exist between boys and girls as regards attitudes towards scientific-engineering subjects, show that no consensus exists in the results obtained. On the one hand, there are works that show the existence of a gender gap in attitudes towards science (Brosnan, 1998; Emanovský & Gonda, 2020; Fagbohun et al., 2018; Hong & Lin, 2011; Marbà-Tallada & Márquez, 2010; Martínez-Moreno et al., 2021; O'Rourke & Prendergast, 2021; Román-González et al., 2018; Sullivan & Bers, 2019; Toma et al., 2019; Uluçinar, 2012; Wieselmann et al., 2021); others that in contrast fail to find differences in this regard (Eren et al., 2015; Kaplan & Topsakal, 2013; Mladenović et al., 2020; Wang & Berlin, 2010); and others that, however, find better attitudes towards science classes in the case of girls (Akpınar et al., 2009). On the other hand, various studies also show how to the extent that girls progress through the educational stages there is a progressive decrease in these attitudes (Akpınar et al., 2009; Toma et al., 2019; Zhou et al., 2021). Among the reasons justifying this, Greenfield (1997) and Hong and Lin (2011) point to the perceived stereotyped image of STEM areas, which is also used by boys in messages in which they relate sciences with masculine concepts. In this sense, Costa et al. (2020) confirm this fact, as they highlight the influence of classmates' opinions on girls' attitudes towards science. In fact, the study by Ng and Chu (2021) shows that female students lose interest in STEM subjects because they feel they lack support in them from male classmates, with this being one of the most important motivational constructs for implication in the learning of scientific-engineering subjects (Ng & Chu, 2021).

In relation to the influence of resources and methodologies on the attitudes of girls, the studies show the positive effects of some of them. For example, the works by Ershova et al. (2021), Sullivan and Bers (2019), and Zhou et al. (2019), which show how the use of digital platforms such as Yandex, which permits an evaluative and educational feedback (Ershova et al., 2021), the development of an introductory Python programming course (Nanavati et al., 2020) and the implementation of resources related to robotics (Sullivan & Bers, 2019), improve the confidence of girls and, therefore, favor their attitudes towards scientific-engineering subjects. In addition, the use of methodologies such as project-based learning (Daher, 2022; Emanovský & Gonda, 2020), and problem-based learning (PBL) (Toma et al., 2019) (ABP) may favor a greater interest in the development of STEM activities. In this regard, authors including Wieselmann et al. (2020) recommend these activities be planned so that their development involve the assumption of roles that avoid only boys adopting control functions and only girls adopting support functions. Along the same line, Zhong et al. (2022) coincide in highlighting the importance of roles in the development of activities carried out in groups and furthermore add the need for groups to be mixed. These approaches, according to Torres-Torres et al. (2020), will permit dynamics to be brought to the classroom that educate from equity and the empowerment of women, and contribute to a greater participation and motivation on the part of girls, along with the learning progress of both genders.

Lastly, in relation to the contents to be tackled in the classroom, Yilmaz et al. (2004) confirm that teaching proposals focusing on environmental and sustainable development issues encourage a more favorable attitude among girls. According to these authors, this is due to the altruistic, cooperative and caring education they receive, which contrasts with that of boys, who are characterized by being more independent and competitive (Erbas et al., 2012). Carrier et al. (2014) also present very positive results regarding the attitudes and interests of girls when they work with environmental problems and in the open air. Moreover, Wünschmann et al. (2017) obtain similar results when they propose an extracurricular outing to a zoo in their design, with the aim of bringing content to reality and in this manner reduce tension and pressure on girls, favoring their learning of and motivation toward the topic. Likewise, regarding content of a more engineering and technological nature, Zhong et al. (2022) indicate how

the implementation of teaching focused on content connected to robotics may reduce lack of interest in girls and promote their learning of these subjects. For their part, Master et al. (2017) sustain the need for students during their compulsory education to be permitted to go through positive programming experiences, given that these promote a greater interest and self-efficacy as regards engineering subjects. For this to occur, it is recommended that these contents be addressed making use of a programming language based on blocks or a combination thereof with text-based programming (Mladenović et al., 2020), in a practical and creative way, also favoring spaces of reflection and debate (Carroll & Faruque, 2021).

Scientific skills

Scientific skills, understood as abilities used during the development or study of science and engineering, is another of the topics that stands out in the bibliography analyzed, which focuses on investigating whether or not there are differences between girls and boys in this regard.

In this sense, a number of the studies consulted coincide in there being certain differences in some science related skills between girls and boys, and others where such differences are not detected. Specifically, in the primary education stage, Wang and Tseng (2015) identify that boys show better scientific skills (e.g., observing, classifying, inferring and predicting), whereas girls have better attitudes as regards learning and communication. For their part, Julià and Antolì (2018), and Taylor and Hutton (2013) obtained higher results in boys in terms of spatial skills, the latter authors proposing the use of origami or paper engineering for reducing these differences. Lulek (2020) also observed how girls more successfully carried out the experiment put to them following the instructions given but however showed more difficulties than boys in using appropriate terms and drawing precise conclusions. In contrast to all of these studies we find for example the works by Kožuh et al., (2018), and Ong et al. (2015) who show that in basic and problem solving skills no differences are appreciated between them, and even the studies by Aydinli et al. (2011), and Dökme and Aydinli (2009), and which showed how girls had better scientific skills. On the other hand, studies such as that by Wang and Tseng (2015) concluded that the thinking of boys tended to be more holistic, and that of girls, more analytical in nature.

Academic performance and success

Performance and success at school is another key aspect that, following the review, has been looked at from three approaches: to study the existing differences according to age and gender; to discover its connection to and influence on the development of attitudes towards science on the part of girls; and to analyze whether the employment of certain methodologies and resources have a bearing on said performance.

Considering the first of the approaches, the studies indicate the homogeneity that exists regarding performance and success at school between girls and boys in the first years of primary education (Curran & Kellogg, 2016). Specifically, Chapman et al. (2020) confirm this question and add that the situation begins to change in secondary education, where poorer performance in girls is observed and, furthermore, there is a drop in their participation in STEM summer camps. The same is not the case for the investigation carried out by Matteucci and Mignani (2021), which indicates that from the primary education stage the boys in their sample already show better performance than girls, although this decreases in both genders through the academic years. Authors such as Quinn and Cooc (2015) conclude that this gap is wider in sciences than mathematics at 13-14 years of age, and others including Sproesser et al. (2022) consider that in order to compensate the slight gender discrepancies that exist at these ages teachers should become aware of possible unconscious gender stereotypes.

In respect of the studies that focus on whether or not there is a connection between the performance and attitudes of girls towards science, neither does there seem to be consensus. On the one hand, there are works that point to there being no relationship between the achievements obtained and attitudes towards science, considering the gender variable (Marbà-Tallada & Solsona-Pairó, 2012; Sadi & Çakıroğlu, 2015). Some of them go further and put forward how styles of thought (holistic, analytical, and integrating) of boys and girls do not create a difference in school performance as regards science subjects (Wang & Tseng, 2015). On the other hand, there are other studies that contribute another completely opposing vision, alluding to the fact that good results in science may have a bearing on the development of positive attitudes in students in general, and girls in particular (Akpınar et al., 2009).

Finally, those investigations that study whether the school performance of girls in scientific-engineering subjects is influenced or not by the use of determined methodologies and resources show that such a connection does appear to exist. Thus, for example, in the study by Burušić et al. (2021) a better performance was observed in girls when engaging in more engineering and technological activities, such as the use of applications or social networks. For his part Kay (2018) also demonstrated how the introduction of visual applications achieved improvements in learning performance in the case of both boys and girls. Likewise, following the constructivist theory, the employment of visual resources from primary education improves the understanding of scientific concepts (Tas et al., 2011). Similar results were obtained when employing tasks that

include gamification structured according to degree of complexity, such as the use of the Blocky Games application, which permits the teaching of programming via games (Sáiz-Manzanares et al., 2020). In the same vein, Ng and Chu (2021) found differences in academic performance when they exposed girls to activities contextualized in aviation and concluded on the need for encouragement and motivation from the teaching of scientific-engineering areas for the learning of such topics. Furthermore, and more in relation to evaluation test types, Armagan and Koksal (2010) showed how, when implementing a test on ecology, they obtained better results in girls when they asked open questions than they did with those of the multiple-choice type. Moreover, it was also demonstrated that the introduction of interactive elements in evaluation tests favored a better score in girls (Jeng & Liu, 2016).

Emotions

The affective experience is one of the processes that generates attitudes towards science, which is why it is important to provide experiences in which associated emotions contribute towards establishing a favorable affective connection with scientific-engineering subjects (He, 2002).

The studies analyzed show how emotions experienced when taking part in science activities have an influence on students in the area and vice versa; that is, the emotions experienced and attitudes towards science "feedback". This is illustrated combining the conclusions drawn by Kang et al. (2019), who indicate that positive emotions such as enjoyment trigger interest in students, with the results found by Toma and Meneses (2019), who find that students with a high interest state a greater interest in science classes.

Regarding interest towards STEM fields, Babarović (2021) suggests that gender differences do not exist if these areas encompass diversity beyond solely scientific and engineering subjects. Specifically, Kang et al. (2019), and Toma and Meneses (2019), show that a high interest in biology learning can be appreciated in girls, whereas for physics the reverse is the case, with the result being the opposite as regards boys. In terms of mathematics, in the primary education stage girls are highly motivated during the learning process, which tends to change over time (Oppermann et al., 2021), it being appreciated how a lower number of girls experience positive emotions such as enjoyment during the process (Ayuso et al., 2021). In general, attention should be drawn to the studies carried out by Conde et al. (2019), O'Rourke and Prendergast (2021), and Sadi and Çakıroğlu (2015), where it is observed how girls show greater confidence and optimism in science and mathematics subjects during primary education, although it is in adolescence when they show less interest towards STEM subjects. There are authors, however, who indicate that girls may develop a greater interest in STEM professions if these are presented to them linked to the creation of good relationships with others (So et al., 2022).

Other studies that look at the topic of emotions set out how anxiety towards science subjects is not related to student gender, although this anxiety occurs when there are bad experiences at school, there is a lack of role models and stereotypes are shown that obstruct achievements in these areas (Uluçinar, 2012).

STEM choices

The choosing of scientific-engineering studies and professions in general, and for girls in particular, is another of the topics on which the bibliography consulted focuses, given the existence of a lack of a clear vocation in order to aspire to being science and engineering professionals (Marbà-Tallada & Márquez, 2010). Thus, it can be appreciated that the works that address this question concentrate on two aspects. On the one hand, attempting to spell out the reasons that may be having an influence on the choice of studies and professions related to STEM fields; and on the other hand, on analyzing whether the undertaking of certain educational actions and proposals encourage girls to choose studies and professions in scientific-engineering areas.

Regarding the first aspects, studies such as that of Alfred et al. (2019) show that the traditional constructions that exist in society of what people who work in STEM spheres are like have an influence from primary education and reinforce the gender gap. According to these authors, these conceptions make women feel inferior in terms of skills, interests and aspirations as regards these subjects. In this sense, authors such as Wang and Degol (2017) conclude that specific competencies students believe they possess, such as mathematical and/or language skills, do have a bearing on their decisions. Therefore, it is illustrated how girls with both scientific and language skills tend to opt for studies more related to the latter. This does not appear to occur in the case of boys. Different studies show how girls tend to choose careers related to care or health, whereas boys opt for professions related to sports, scientific-engineering areas and defense (Marbà-Tallada & Márquez, 2010; Schiefer et al., 2021; Scholes & McDonald, 2022). Authors including Kang et al. (2019), and Shamai (1996) indicate that these occupational preferences laden with stereotypes can start to be seen in the sixth year of primary education (11-12 years of age). During these ages, girls begin to show a lack of motivation and loss of interest, despite studies indicating that 7-year-old girls are still motivated by science (Vinni-Laakso et al., 2019) and that even between the ages of 9-11, they respond positively when presented with the possibility of choosing engineering studies (Edmonds et al., 2022).

Furthermore, in relation to the works that analyze educational programs and proposals for encouraging girls to opt for STEM studies, it is observed that in general extremely positive results are obtained in this regard. Thus, Hunt et al. (2021) analyzed the implementation of a program in which secondary education girls were developing a study within an institution. Afterwards, in class, they participated in seminars in which they searched for and read related scientific literature, exchanged advances in their work and made oral presentations of their results. The process finally ended with the drawing up of a written document in the format of a scientific research article. The results of the analysis of the program revealed that the girls who participated had more probabilities of choosing a professional future related to STEM fields given that they improved their scientific skills and their individual concepts of self (Hunt et al., 2021). Similar data are obtained with the design of a chemistry summer camp comprising practical experiments, trips and interactions with female role models (Levine et al., 2015). Furthermore, we find the proposals put forward by Costa et al. (2020), and Ng and Chu (2021) who designed activities focused on aeronautics considering key aspects such as experiences lived through, support received, self-efficacy and expectations of results. Their proposals took into consideration aspects such as the visibility of female role models in the field of study, the inclusion of practical experiences, the applicability in society and the development of confidence amongst the participants, attempting at all times to show an image of the area of study free of obstacles and stereotypes.

DISCUSSION

The aim of the study was to develop a series of methodological guidelines to better align teaching in scientific and engineering fields with the interests of students in general and girls in particular. In this sense, the results obtained suggest that the promotion of students' literacy, the development of their identity in these disciplines and the transformation of their interests can be achieved by encouraging their participation in real practices where they must apply their knowledge to solve problems in society (Ayuso et al., 2019; Boeve-de Pauw et al., 2020; Chen et al., 2022; D'Inverno et al., 2016; Ribarić & Novoselić, 2025). These ideas align with Carroll and Faruque's (2021) proposal aimed at 9-12-year-old students in the Primary Education stage, which introduces programming in a practical and creative way, providing a scenario where they imagine living in a castle and decorating their bedroom. With this same focus on primary education, Santos et al. (2025) integrated design thinking and maker education into the design of a technological prototyping workshop using Scratch and Makey Makey, with the aim of addressing gender disparities and improving students' self-efficacy and motivation. Similar results were shown by Avraamidou (2014) who concluded that to foster changes in the development of science teacher identity and promote students' scientific literacy, it is essential to provide teachers with concrete, everyday experiences that allow them to integrate theoretical and practical learning simultaneously in the teaching process.

On the other hand, the results of this work also suggest that the implementation of activities based on the promotion of engineering practices in primary education has great potential to enhance the interest, participation and self-concept of students of both genders (Capobianco et al., 2015; Hewitt & Forcino, 2025). This approach offers a number of dimensions and core ideas that help to implement it, considering both the necessary processes and the resulting products that students produce during its development (Simarro & Couso, 2022). In this context, the results also point out that the inclusion of spaces for reflection and discussion during the development of this approach is fundamental to increasing diversity and addressing the gender gap in STEM fields (Carroll & Faruque, 2021).

Furthermore, the study also shows that it is highly relevant to highlight the crucial role of role models and role models, as they can be highly influential in women's preferences and aspirations towards scientific and engineering fields (González-Pérez et al., 2020). For example, Avraamidou's (2023) research showed how interactions with people in scientific fields contributed to students identifying with them and imagining themselves as future professionals in these fields. In this way, students' personal identities can be reconciled with their images of these professionals (Couso et al., 2022).

Furthermore, the review shows how it is necessary for science and engineering education to offer a realistic image of these areas devoid of obstacles and stereotypes (Costa et al., 2020; Hunt et al., 2021; Levine et al., 2015; Ng & Chu, 2021). That is, compulsory education should provide experiences that enhance students' science skills and self-concept so that they consider choosing STEM careers as a viable option in the future (Torres-Torres et al., 2024). These findings are consistent with the conclusions of Drymiotou et al. (2024), who state that the choice of STEM disciplines is influenced by expectations, the ability to understand the content and the opportunity to construct a desirable identity within those disciplines.

Ultimately, it is crucial to provide enriching experiences for students that encourage engineering practices, discussion and reflection, as well as the knowledge of STEM references, in order to remove barriers and stereotypes and enhance the development of their scientific skills (Burušić et al., 2021; Kay, 2018; Ng and Chu, 2021; Sáiz-Manzanares et al., 2020; Tas et al., 2011). All of this will be crucial for maintaining students' interest in these subjects and for their choice of future studies (Kang et al., 2019; Toma and Meneses, 2019).

CONCLUSIONS

The intention of this systematic review has been to analyze scientific literature on the consideration of aspects of gender in scientific-engineering education in compulsory stages, especially primary education, with the purpose of taking a closer look at the characteristics presented in the selected scientific production and the main topics in the studies included. Moreover, we present the implications of the findings of these studies for both professional practice and the development of future lines of research.

In particular, this work sheds light on the need to promote educational proposals that consider many of the aspects shown and thus have a design with theoretical support. Most of the works found in this regard do not have a theoretical framework that serves as a basis for supporting their design. Despite this, it has been possible to observe positive results in many of the studies, allowing the determination of a series of methodological orientations when teaching these subjects considering the gender perspective, such as the importance of contributing female role models, developing practical experiences that provoke favorable emotions, promoting reflection, showing content in relation to reality and putting forward a broad vision of the different career opportunities that can be developed in the STEM sector. However, the importance of this review resides in underlining the need to act from early ages such as those corresponding to the primary education stage, to thus encourage interest towards science in all students, and help to retain girls in disciplines of a more scientific and engineering nature.

Regarding the barriers to progress in gender equality in these areas, it can be concluded that it is necessary to internalize a positive image and one that reduces the impact of stereotypes. To do so, it is proposed that constant feedback be employed, along with tutorials between equals and the use of vocabulary and images that go against stereotypes, which help to adequately conceive people who work in science and engineering. Furthermore, to offer constructivist learning in accordance with female preferences, it is advisable to use active methodologies, such as inquiry-based teaching, PBL and GBL. Likewise, appropriate experiences in programming and robotics contribute towards increasing interest on the part of girls and favoring their perception of self in these areas of knowledge. Moreover, it will improve the attitudes of all students and girls in particular, promoting the development of a favorable affective connection to these areas.

Limitations

This study is limited to the systematic review of the main international data source WoS for pragmatic reasons and to articles published until September 2022. Likewise, there is a bias in access, excluding articles not available online or written in a language different than English and Spanish, and those outside our funding sources.

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APPENDIX

Table A1. Studies included in the meta analysis

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Table A1 (Continued). Studies included in the meta analysis

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