Potentials of the Science, Technology, Engineering, Arts and Mathematics (STEAM) education for gender inclusion in science: A systematic literature review

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Abstract: The aim of this article is to present an overview of the current context of research that explores the STEAM education in its intersection with gender. A systematic review was conducted, following the procedures outlined by the PRISMA statement. The 47 articles revealed a growing interest in the topic but highlighted research gaps in some regions. The gender views that prevailed in the works recognize the influence of structural barriers to gender gaps in scientific and technological fields but without deepening discussions on these issues. Disciplinary integration was not always evident, with science and technology predominating in detriment of mathematics, arts, and, to a greater extent, engineering. Art was predominantly conceived as artistic education, introduced in these cases through music, drawing, and painting. Most of the proposals do not include the set of methodologies considered fundamental for the development of the approach but rather focus on one or a few of them, being implemented during classes, as didactic sessions, and having a short duration. The methodologies contributed in different dimensions to bringing girls closer to science, positively impacting their motivation to learn, their acquisition of knowledge, and the development of autonomy and interest in STEAM fields.

Keywords: STEAM education, science education, gender, research systematic review.

Título: Potenciales del enfoque Ciencia, Tecnología, Ingeniería, Artes y Matemáticas (CTIAM) para la inclusión de género en la ciencia: Una revisión sistemática de la literatura

Resumen: El objetivo de este artículo es presentar una panorámica del contexto actual de la investigación que explora el enfoque STEAM en su intersección con el género. Se llevó a cabo una revisión sistemática, siguiendo los procedimientos señalados por la Declaración PRISMA. Los 47 artículos encontrados revelan un creciente interés por el tema, sin embargo, muestran lagunas en la investigación en algunas regiones. Las visiones de género predominantes en los trabajos reconocen la influencia de las barreras estructurales en las lagunas de género en las áreas científicas y tecnológicas, pero sin profundizar las discusiones acerca de estas cuestiones. La integración disciplinar no ha sido siempre prominente, prevaleciendo la ciencia y la tecnología en detrimento de las áreas de matemáticas, artes y, en mayor grado, de la ingeniería. El arte se concibió predominantemente como educación artística, introduciéndose en estos casos a través de la música, el dibujo y la pintura. La mayoría de las propuestas no incluyen el conjunto de metodologías consideradas fundamentales para el desarrollo del enfoque, sino que se centran en una o unas pocas de ellas, siendo implementadas durante las clases, como sesiones didácticas y de corta duración. Las metodologías han contribuído en distintas dimensiones a acercar a las niñas a la ciencia, impactando positivamente en su motivación por aprender, la adquisición de conocimientos, el desarrollo de la autonomía y el interés por las áreas STEAM.

Palabras clave: CTIAM educación, enseñanza de las ciencias, género, revisión sistemática de la investigación.

Introduction

Over the years, gender stereotypes have influenced women's educational choices, contributing to low female representation in science, technology, engineering, and mathematics (STEM). At a global level, women are still underrepresented in these areas, not only as students but also as teachers and researchers, which creates a significant gender gap, limiting the creative and innovative potential of these areas (Román-Graván et al, 2020). This disparity becomes even more evident when we consider gender identities outside of cisnormativity, as well as the intersections with race and social class, which increases the challenges faced by women who seek to enter and excel in areas dominated by men.

The lack of female presence in science and technology is often illustrated by the metaphor of a tube with many holes through which girls slip until they almost completely disappear when they reach the professional stage (Lykkegaard and Ulriksen, 2019). One of the main gaps is a lack of confidence, frequently affected by gender stereotypes, teacher expectations, and a lack of social support, which persists throughout education and career, impacting professional choice and development in STEM fields (Guenaga Gómez and Fernández Álvarez, 2020).

Recently, there has been significant interest in developing academic research that addresses these diversity gaps, so recent research already points to the influences of gender processes on learning opportunities (Arpaci et al, 2023) and career choice (Boyle, 2019; Oliveros, 2019) in STEM fields. However, few studies focus on understanding how different pedagogical proposals can contribute to the inclusion of girls in STEM fields while they are still in school.

The STEAM (Science, Technology, Engineering, Art, and Mathematics) Education stands out in this context. By adding the letter "A" to the STEM acronym, the approach represents a shift in the design and practice of teaching to incorporate the arts into a broader spectrum of disciplines that emphasize creativity and innovation. By integrating the arts in an interdisciplinary way, STEAM provides the opportunity to express creativity and broaden perspectives in areas often considered rigid and logical. By combining elements such as creativity, critical thinking, and a holistic view of STEM fields, STEAM can offer girls a more welcoming and inclusive environment, enabling them to apply their skills in scientific and technological contexts. It enriches their learning experiences and also encourages innovative thinking and creative problem-solving (Wajngurt and Sloan, 2019).

Based on the context presented, we aim to present an overview of the current context of research that explores the STEAM Education in its intersection with gender. To do this, we are guided by the following questions: Q1: What are the trends in publications that address STEAM and Gender? Q2: Which gender views do the authors present? Q3: How were STEAM areas integrated? Q4: What was the conception of Arts adopted for the approach? Q5: What is the contribution of the adopted teaching methodologies to the inclusion of gender in scientific and technological fields?

Theoretical foundation

STEAM education

The acronym STEAM (Science, Technology, Engineering, Arts, Mathematics) emerged as an extension of STEM (Science, Technology, Engineering and Mathematics), introduced more than three decades ago in the United States, as part of efforts to promote a skilled workforce in the areas of Science, Technology, Engineering and Mathematics. Throughout this development process, the idea of combining different disciplines converged, resulting in an integration approach that goes beyond the original meaning of STEM (Ortiz-Revilla et al, 2021) and marks the beginning of a line of educational research and practice that, more recently, has been incorporated into the arts, rising the acronym STEAM. This expansion is a significant advance over its predecessor, arguing that focusing on STEM without the "Arts" necessarily excludes important areas that contextualize science (Ortiz-Revilla et al, 2021). The increasing expansion and popularization of the approach have led to various pedagogical models derived from different understandings of the STEAM acronym. In addition to the definition of the acronym, the concept of STEAM is characterized in several ways that differ in terms of the conception of integration, the definition of the letter "A" in the acronym, and the implementation strategies of the proposals.

In STEAM, disciplinary integration involves different approaches, including multidisciplinarity, interdisciplinarity, and transdisciplinarity. In multidisciplinarity, several disciplines contribute separate knowledge to solve a problem without integration between them. In interdisciplinarity, there is an attempt to integrate the contributions of several disciplines, but they are often separately approached before being combined. In transdisciplinarity, the focus is on the problem itself, and the disciplines are used integrated to address the problem holistically. In STEAM education, understanding these approaches is critical to promoting an education that develops problem-solving skills and an interconnected understanding of concepts (Quigley and Herro, 2016).

According to Perignat and Katz-Buonincontro (2019), in research on the STEAM Education, the idealization of arts encompasses Arts Education, Arts as Arts as any discipline related to the areas of languages or humanities, and Arts as a synonym for project-based learning, problem-based learning, technology or creation-based learning. Sanz-Camarero et al (2023) argue that incorporating arts and humanities into the STEAM Education promotes interdisciplinary collaboration and offers students a complete view of problems and their solutions, favoring the development of creativity, critical thinking, digital skills, and positive attitudes towards science and math. Despite this, the authors observe a tendency in some discussions to underestimate the development of artistic skills compared to scientific skills. However, they emphasize that it is essential to recognize the importance of the arts in comprehensive training to face contemporary challenges (Sanz-Camarero et al., 2023).

Arts integration is suggested as a way to make subjects more attractive to a variety of students that encompasses less represented educational groups, including minorities and those who do not have an affinity with science, technology, engineering, and mathematics subjects, in the design of pedagogical practices (Alexopoulos et al., 2021). According to current trends, integrating the arts into other areas is a strategy with the potential to increase girls' interest and engagement in science, technology, engineering, and mathematics classes. One of the justifications is that STEAM opens the way for new forms of being and learning beyond the current gender norms related to scientific and technological domains and the arts. This idea aligns with the thought that this integration transcends disciplines and generates something new with the capacity to train innovative thinkers for the future (Areljung and Günther-Hanssen, 2022).

Science, tecnology and gender

The concept of gender has evolved significantly over time, marked by a paradigm shift in understanding social identities. Initially, it emerged as an analytical category, seeking to emphasize historical, social, and political aspects of human experiences as opposed to the biological and essentialist approach to sex. This conception emerged in the context of the feminist movement, which highlighted the importance of considering the complexities of gender identities and underlying power relations. Throughout theoretical development, the concept of gender expanded beyond the traditional dichotomy between female and male, questioning fixed binaries and opening space for a more fluid and diverse understanding of gender identities. This evolution has enabled its application in various areas of knowledge, contributing to a broader analysis of social dynamics and power relations (Matos, 2008).

There is a broad debate surrounding the precise ways in which gender, on the one hand, and science and technology, on the other, intersect. Hearn and Husu (2011) discuss the importance of considering gender in science and technology, highlighting how they reflect existing structures in society and contribute to the construction and, at times, subversion of dominant gender relations. The authors point out that the underrepresentation of women in scientific and technological fields reflects social inequalities and influences how knowledge is produced and valued within them. Furthermore, they highlight how scientific and technological organizations are intrinsically marked by gender divisions, both in terms of distribution of work and authority, and how representations of gender in the history of science often underestimate or ignore the contributions of women. They further argue that gender perspectives influence theories, methodologies, and language, which can have significant consequences on how knowledge is produced and understood. From this perspective, they propose five conceptions that underlie both political interventions and theories around gender and science: gender based on sex; masculinity/femininity and sexual roles; categoricalism, structure, and plural structures; post-structuralist, discursive, and deconstructive approaches; the material-discursive.

These categories address different aspects of the social construction of gender. Sex-based gender refers to the traditional association between behavioral and social characteristics and biological sex. Masculinity/femininity and sexual roles explore social expectations regarding the behaviors of men and women. Categoricalism, structure, and plural structures examine how social norms and institutions organize gender in society. Post-structuralist, discursive, and deconstructive approaches question fixed notions of gender, highlighting its fluidity and social construction. Finally, material-discursive combines elements of materialism and post-structuralism to analyze how social and discursive practices shape and are shaped by material contexts, recognizing the interconnection between social structures and discursive constructions of gender (Hearn and Husu, 2011).

Archer et al. (2012) discuss how post-structuralist feminist theory can be applied to understand children's identifications with science and how they reconcile their scientific aspirations with performances of gender identity. From this perspective, gender is not innate or natural but rather a performance repeatedly performed through verbal and bodily acts. In turn, identities are not fixed or given but rather constructed and contested through discursive and social practices shaped by broader social structures such as gender, class, and race. The authors discuss how gender norms are socially instituted and maintained and how specific gender performances are considered intelligible while others are rendered unintelligible by the dominant culture, implying social pressures that children face to conform to gender norms and how these pressures can influence their aspirations and identities in science. The study reveals that, although most children like science, the majority already perceive scientific careers as not being for them. In this way, social perceptions associating science with traits such as "intelligence" and masculinity pressure girls to reconcile their interest in science with conformity to popular notions of femininity (Archer et al., 2012).

Methodological path

A systematic review of the literature was conducted to develop this study. A systematic review is a type of research that follows strict protocols to organize and analyze a large volume of documents. Its goal is to determine what works and what doesn’t in a specific context, ensuring reproducibility and transparency. It provides detailed information on the databases consulted, search strategies, selection and analysis criteria, as well as acknowledging its own limitations and those of the studies reviewed (Galvão and Ricarte, 2020). To ensure accuracy and transparency in identifying articles, we followed the procedures outlined in the PRISMA statement (Page et al., 2022) (Figure 1).

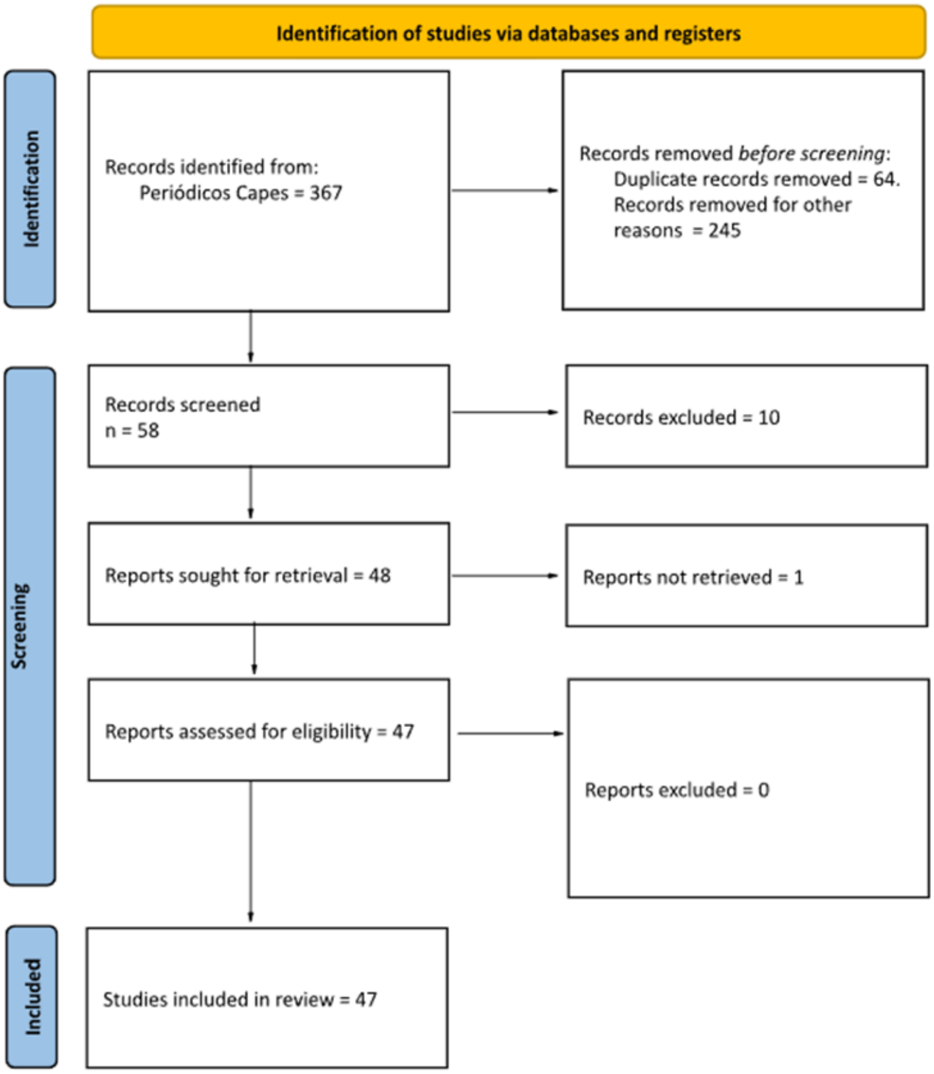

Figure 1 - PRISMA flowchart for presenting the study selection process. Adapted from Page *et al*., 2022.

The research process was conducted in November 2023. In the first stage, we searched the Capes Periodicals Portal database, using descriptors STEAM education AND gender, STEAM education AND girls, STEAM education AND woman, and STEAM education AND women. The Capes Periodicals Portal database is a Brazilian platform that provides access to restricted scientific databases through institutional agreements with universities and research institutes. It offers a wide range of resources, including national and international journals across various fields of knowledge (Galvão and Ricarte, 2020). This is the reason we chose to work with this platform. We then applied filters to obtain only peer-reviewed scientific articles to ensure the quality and validity of the selected studies. Since STEAM education is a recent approach, we chose not to restrict the search to a specific time limit.

Articles that were impossible to obtain their full texts, those that were not in Portuguese, English, or Spanish, as well as duplicates, and those considered false results, as they did not explore the STEAM Education in its intersection with gender issues, were excluded. The latter only mention the search terms and do not effectively represent our object of study. Therefore, 47 articles were selected for critical analysis.

After the search, a complete reading of the articles was conducted to characterize the publication, referring to the author, magazine, and country, and the research, referring to the nature (theoretical or empirical), teaching level, and objectives. Also, we extracted data related to the gender views presented by the authors, the conception of Arts in the STEAM Education, the forms of disciplinary integration, and the teaching methodologies used.

Results and discussion

This research resulted in a dataset of 47 articles that deal with the STEAM Education and its intersection with gender, showing rapid growth in the last decade. Chart 1 presents the characterization of the articles, with information about authorship, year of publication and main objectives (Appendix 1).

Next, we return to our guiding questions to present and discuss the results.

What are the trends in publications that address STEAM and gender?

From the data presented, it is possible to conduct a temporal analysis and examine the evolution of academic research over the years. The results confirm that we are dealing with a current topic, with publications investigating the potential of the STEAM Education for gender inclusion appearing only since 2013. This research has shown constant growth over the years, reaching the highest number of publications in 2021. The recent emergence of research on gender inclusion in STEAM, although research using this approach began in 2006 (Aguilera and Ortiz-Revilla, 2021; Hasti et al., 2022), can be attributed to the growing recognition of gender inequality in science, technology, engineering, and mathematics.

Identifying just one study in Brazil reinforces that studies on the STEAM Education and its relationship with gender inclusion are still in the early stages in the country. This finding follows results from other research, which indicate that the topic has gained more prominence in recent years. These studies demonstrate that, although the STEAM Education has existed for almost two decades in some countries, the topic has recently been introduced at events such as fairs and congresses in Brazil (Pugliese, 2020). This fact reflects a reality that is still timidly included as an object of investigation in research but which is robust in other dimensions of society.

Regarding geographic distribution, there were articles from 22 different countries. Among these countries, the United States and Spain stood out with 11 and 9 publications, respectively. The location analysis was carried out based on the institution of the authors, which means that each research can cover more than one institution in different regions of the country. The emerging and relatively new nature of the STEAM Education can justify the research gaps in some regions, especially those that conduct some gender analysis. Furthermore, it is worth considering that different regions face different challenges in relation to gender equality and inclusion in STEAM fields due to different cultural, social, political, and economic factors. These specificities can influence how the topic is approached and prioritized in different parts of the world. However, it is essential to recognize the importance of expanding research and initiatives in these less-studied regions. By addressing existing gaps, it is possible to build a broad knowledge base, considering specific realities and challenges of each context.

Most of the interventions analyzed were conducted directly with students, mainly in Elementary Schools (28), with a small amount of research and actions aimed at teachers (4). The number of research focused on Early Childhood Education (4) was also low, with only three articles aimed at students and one at teachers. Voicu and Matei (2021) state that the STEAM Education is little used in primary and preschool education, mainly due to teachers' lack of knowledge about the approach, even though they agree on its value for child development and as a good practice for science teaching.

It is also possible to observe that most of the objectives are focused on the efficiency of the approach (32), with the others concentrated on career motivation (5) and teacher practice (2). Attention to gender issues is evident in the objectives of 19 articles, in addition to two others that indicated a focus on working with diverse students. In other articles, these issues are presented only in the methodology or results. The focus from the initial phases of the research, indicating intentionality in exploring the potential of the STEAM Education for gender inclusion, contributes not only to the presentation of a more targeted and specific analysis of the research results but also to an understanding of the challenges faced by girls in these areas and to identify strategies to overcome these barriers and promote more significant equality of opportunities.

Which gender views do the authors present?

The analysis of gender views was based on four categories proposed in this study, as an adaptation of Hearn and Husu (2011), which address different aspects of the social construction of gender in science: binary - focuses on the boy/girl, man/woman, feminine/masculine duality, to analyze differences related to STEAM fields; biological - associates behavioral and social characteristics with biological differences between the sexes; structural - recognizes the influence of social factors on gender gaps in science, but does not analyze them in depth; post-structural - problematizes the complexities involving gender and science, considering the underlying power relations (Chart 2).

Historically, science and technology have often been considered gender-neutral, as if they were separate from social and cultural issues. However, this perspective has been increasingly questioned as it is recognized that scientific and technological activities are shaped by social factors, including gender. This fact is shown in the articles analyzed because most demonstrated the underrepresentation of women in scientific and technological fields. However, not all their discussions consider social, cultural, and institutional barriers that contribute to these gaps.

Understanding how gender identities impact the production and dissemination of scientific and technological knowledge is essential to identifying and addressing gender inequalities and barriers in these areas.

Gender View	Articles	Evidence
Binary	1; 2; 6; 21; 22; 25; 26; 29; 31;32; 43; 45; 46	"From the findings of this study, the male beginners seemed to have more confidence in developing algorithms and debugging programs than the female beginners. [...] This finding is worth reexamining with a large sample of different ages. The reason for this difference is also worth studying in the future" (Tsai et al., 2019, p.12).
Biological	7; 14	"Because of their physiological and cognitive characteristics, men are considered to have special advantages in the fields of computers, mathematics, and engineering" (Sun et al., 2023, p. 14519).
Structural	3; 4; 7; 8; 9; 10; 11; 12; 13, 15; 16; 17; 18; 19; 20; 23; 24; 27; 28; 30; 33; 34; 35; 36; 37; 38; 39; 41; 42; 44; 47	"This is also related to China's cultural characteristics. In primary school, girls are often expected to have a submissive and well-behaved personality, and boys are encouraged to be brave and responsible" (Liao et al., 2022, p. 614). "Yet, despite several national initiatives to diversify participation in science, technology, engineering, and mathematics (STEM) fields, the underlying culture of computing education remains relatively stagnant, with a curriculum that continues to emphasize areas historically aligned more closely with male interests than women's, such as robotics, computer programming, and physics" (Pepler, 2013, p. 38).
Post-structural	5, 40	" She is among many other Black girls and youth who, despite systemic barriers of racism, classism, sexism, likeability, and nepotism, she still prevails. Students like Star cannot and do not fit within certain spaces because their brilliance exudes the very essence of who they are and who they strive to be. However, they continue to create unique and complex spaces for themselves when individuals and systems of power attempt to discourage, dehumanize, and decenter their voices and abilities " (Lewis Ellison and Qiu, 2023, p. 466). "The stories of these girls – separated by time, place, age, and social histories but bound by sensibilities grown in their Immigrant families and learning contexts – contest U.S. hegemony as the primary rationale for STEM learning; challenge individual gain at the expense of another; problematize what counts as science while insisting on its creative convergence with joy; and honor their ingenuity and humanity" (Sengupta-Irving and Vossoughi, 2019, p.479).

Chart 2 - Gender Views presented in articles

This understanding allows us to recognize how gender stereotypes influence women's participation in specific areas, how gender policies affect research and development, and how gender norms shape scientific and technological narratives. By not considering the complexities of gender identities and social, cultural, and structural influences, studies can lead to a distorted assessment of the strategies adopted, exclusively attributing the results to the proposed intervention.

Even recognizing gender stereotypes identified both in the family and at school and despite considering gender identities in the data collection phase, Fernandez-Morante et al. (2022) chose not to include the analysis of non-binary participants and those who preferred not to disclose their gender due to low representation of these groups in the sample. Differently, Aurava and Meriläinen (2022), even though the Official Statistics of Finland does not recognize more than two genders, in her study, asked which genders the participants identified with and considered all identities in the analyses.

Although contrasting in many ways, the categories established in this study overlap and intersect in some research. Sun et al. (2023) strongly bring the biological view of gender, as seen in Chart 2, but highlight the influence of interests, attitudes, and school environment, as well as teachers' stereotypes on the development of Computational Thinking. Similarly, Ma et al. (2022) initially adopted an essentialist view of gender, suggesting that girls are more motivated to please adults than boys. However, it also recognizes that social factors, such as Chinese culture, influence students' behavior in the classroom.

The two articles that presented a more in-depth discussion about the social factors that permeate gender issues in science were written by women representing minority ethnic-racial groups. The importance of this representation is well-demarcated by Lewis Ellison and Quiu (2021) when they highlight the importance of listening carefully to the stories and lived experiences of black girls. Recognizing that the main focus of the project in which they were involved was the development of a digital application for parents and daughters, they emphasize that the narratives shared by a black girl were marginalized in relation to the project scope. However, the authors argue that these stories and their interactions with the student were fundamental to understanding her STEAM activities and intersectional scientific identities. Highlighting their perspective as women of color, they emphasize that it is easy to lose sight of these narratives when researchers and practitioners focus solely on scientific goals, especially when working with historically underrepresented youth.

Methodological proposals

Only empirical studies that conducted or analyzed an existing intervention were used to analyze the methodological proposals. Therefore, 13 works were excluded from these analyses, including 5 theoretical articles; 4 articles that applied questionnaires to identify interests in STEAM careers, student creativity and teachers' perceptions and practices; 3 articles that aimed to develop assessment instruments related to computational thinking, attitudes, and self-efficacy in programming; and 1 article that aimed to provide an overview regarding the implementation of the STEAM Education through document analysis and interviews.

How were STEAM areas integrated?

Table 1 presents data on the prevalence of the five STEAM areas in research.

Science	Technology	Engineering	Arts	Mathematics
26	27	13	24	21

Table 1 - Prevalence of STEAM areas

These data reveal that although the five STEAM areas are represented in the articles, there is a prevalence of Science and Technology in detriment of Mathematics, Arts, and, to a greater extent, Engineering. Several studies presented proposals for interdisciplinary or transdisciplinary work. However, this integration was not always evident in the methodology, with elements of a discipline often being added without establishing how the concepts and methods of the area contributed to explaining the phenomenon or solving the problem. It is essential to highlight that the analyses were conducted based on the information provided in the articles, and, in several cases, it was very limited.

Technology was mainly implemented through programming and robotics. In some cases, it was used solely to explore scientific concepts, as in the example of using Excel to make spreadsheets and graphs. Likewise, mathematical knowledge was mobilized through modeling, spatial relations, and geometry; however, the area was also mentioned as a resource in several cases, evidenced only in calculations during the development of the proposal. Engineering design was identified in only four studies, while in the others, it was worked on through the development of prototypes without following structured steps.

What was the conception of Arts adopted for the approach?

Although the presence of Arts is a differentiator of the STEAM Education, it was not highlighted in several articles. In the studies in which it was present, art was understood as artistic education (16 studies), creativity (5 studies), and humanities (5 studies). The most used strategies included drawings, music, sculptures, collages, three-dimensional models, posters, paintings, comics, photomontages, and theater.

The inclusion of the arts was advocated as a crucial factor in helping children connect with diverse forms of learning. Its techniques allowed the exploration and creation of models for natural phenomena, giving materiality to educational experiences (Cabello et al., 2021). The results also showed a positive relationship between arts inclusion and the desire to pursue a career in science, technology, engineering, and mathematics fields (Wajngurt and Sloan, 2019). Finally, the importance of the arts is highlighted in stimulating connection with students' life experiences, especially those with non-academic interests (Naukkarinen and Jouhkimo, 2021).

What is the contribution of the adopted teaching methodologies to the inclusion of gender in scientific and technological fields?

Firstly, it is essential to characterize the work in terms of implementation strategies (courses, events, curricular educational programs, extracurricular educational programs, and didactic sessions), in terms of duration (punctual, short, medium, and long), in terms of the content covered, the resources used and the purposes of the proposals. Proposals were considered timely if completed in less than a week; short if they lasted from 1 to 4 weeks; averages if they occurred over 1 to 6 months; and long ones extended for more than six months. Table 2 presents the duration of proposals by implementation strategies.

	Courses	Events	Curricular programs	Extracurricular programs	Didactic sessions
Timely	0	0	0	0	2
Short	0	4	2	3	4
Average	1	0	0	0	5
Long	1	0	4	0	3
Not informed	0	0	1	2	0

Table 2 - Implementation Strategies

The courses were aimed at teachers in initial training and high school students. The events focused on programming and application development, game design and music creation, and design thinking workshops. Curricular programs were considered those implemented as educational policy, whether at a national or more restricted level, such as in states and municipalities. Extracurricular programs involved summer courses and camps. Finally, the didactic sessions included strategies implemented as part of school classes.

Although there is no consensus on how the STEAM Education should be implemented, most authors defend the importance of proposals that mobilize knowledge from these areas in an integrated way, focusing on problem-solving skills and collaborative teamwork, through the use of student-centered active methodologies such as inquiry-based teaching and engineering design (Jolly, 2014; Herro et al, 2017; Boakes, 2020; Ortiz-Revilla et al., 2021; Quigley and Herro, 2016). Table 3 presents the methodologies used in the studies, the main strategies adopted, as well as the resources utilized. Methodologies refer to the overarching pedagogical approaches that structure teaching and learning. Strategies are the specific practices or instructional techniques employed within a methodology. Resources correspond to the tools, technologies, materials, or environments that enable the application of the strategies. In this context, methodologies provide the general framework, strategies specify the actions carried out within this framework, and resources enable the execution of those actions.

Problem-based learning was used in only four articles, which addressed strategies for developing sustainable businesses, lighting spaces, and rescuing alien species. Despite the representation was relatively insignificant compared to the total number of articles, this methodology allowed us to consider the girls' interests, relating abstract concepts to real-life situations. As evidence of these contributions, there was more significant student engagement, improvement in the development of scientific, mathematical, and technological skills, as well as attitudes towards science, with emphasis on the increased interest of girls in STEAM fields (Ortiz-Revilla et al., 2021).

Methodology	Number of studies	Main Strategies	Main Resources
Problem-Based Learning	4	Experimentation	Augmented Reality (Alien Rescue)
			Carbon emission data
		Entrepreneurship	Out-of-school education (Partnerships with companies)
Inquiry-Based Teaching	4	Experimentation	Out-of-school education (Science centre exhibition)
			Augmented Reality
			Mechanical properties of materials
			Cell culture
Engineering Design	3	Testing and Simulations	Out-of-school education (Science centre Exhibition)
			Aircraft prototype
			Lighting Prototype
Design thinking/Maker	3	Programming	E-textiles
			Adafruit's Gemma
			SparkFun's
			LilyPad
No Specific Methodology	22	Two- and three-dimensional visualisation tasks	Augmented Reality (HP reveal)
			Virtual Reality (Minecraft, Quest 2 Headset)
		Unplugged Activities	Bebras
		Programming	E-textiles
			Earsketch
			Scratch
		Robotics	Kibo Robot
			Mouse Robot Colby
		Modeling	Paint 3D
		Experimentation	Spectroscopy
			Chromatography
			Out-of-school education (Science centre Exhibition and Museums)

Table 3 - Methodologies main strategies adopted and resources used in the studies

Engineering design emphasizes real problem-solving and the practical application of learned concepts (Ortiz-Revilla et al., 2021). It also provides universal, flexible, and adaptable activities to the learning needs of each student, allowing students to experiment with their skills and competencies in an impartial way. This methodology promoted students' learning motivation, self-efficacy, and the acquisition of interdisciplinary knowledge with gender equality (Jia et al., 2021). Inquiry-based teaching emerges as an alternative for fostering the development of competencies in all their complexity. In the studies analyzed, this methodology contributed to increased interest among girls and improved their competency development (Ortiz-Revilla et al., 2021).

Collaborative work favored social interaction and was highlighted in strategies that involved non-formal learning spaces. Students who participated in these visits increased motivation, interest, autonomy, and performance in assessments (Arpaci et al, 2023, Sun et al., 2023). The collaboration had the most impact on the girls, both in the learning process and in their personal development (Arpaci et al, 2023).

Technology played a central role in several articles, with emphasis on the use of augmented reality resources, programming, and educational robotics. In augmented reality, the HP Reveal application stands out, which transforms abstract concepts into concrete three-dimensional experiences, combining visual, sound, and audiovisual elements to make activities more enjoyable. These applications have positively impacted students' motivation to learn science. In educational robotics, software such as Arduino and kits such as Mouse Robot Colby were used, and they contributed to promoting more autonomy among students when handling equipment. It was also possible to see the benefits for the students, who demonstrated positive perceptions regarding educational robotics before and after participating in experiences with these resources (Román-Graván et al, 2020).

In the program, game development events stand out, with special attention to game jams, which, supported by the STEAM Education, including music, drawing, and conversation with professionals, have contributed to changing attitudes towards technology and programming, mainly among girls and non-binary students (Aurava and Meriläinen, 2022). Likewise, the use of the Scratch platform for game programming stimulates cognitive skills by encouraging students to think creatively and critically to solve problems instead of memorizing information, contributing to the development of computational thinking skills without significant differences between genders. Another platform, Ear Sketch, which integrates programming and music, also positively impacted changes in attitudes toward computing, highlighting girls' higher interest in the whole area (Magerko et al, 2016).

The studies that presented specific strategies for gender inclusion encompassed the creation of spaces just for female students and the approach of female professionals in the STEAM fields to promote female role models (Kijima and Sun, 2021; Kijima et al., 2021; Barros et al., 2023), in addition to themes considered feminine (Boyle, 2019; Boakes, 2020) to attract girls to science clubs and scientific areas. These factors presented as motivators of girls' participation in science reveal a worrying trend towards the reaffirmation of gender roles. Some of these researches have suggested that girls do not have an affinity for certain fields or are inherently attracted to crafts or subjects considered feminine (Arpaci et al., 2023; Boyle, 2019) and may consolidate the misconception that girls' preferences and abilities are determined by their gender identity.

Conclusions

This study presented an overview of research that explores the STEAM Education and its intersection with gender. The temporal analysis revealed that academic research on the topic is constantly growing, demonstrating a recognition of gender inequality and an interest in understanding how the STEAM Education impacts this issue. In turn, the geographic analysis highlighted research gaps in some regions, which may be related to the emerging nature of the STEAM Education, as well as the different challenges faced in each region in relation to gender equality.

The more significant focus of the proposals on Elementary Education highlights the need for more research at other levels of education and teachers, aiming to expand knowledge, training, and support in the context of gender inclusion in STEAM subjects. Furthermore, the fact that 19 articles presented gender issues as their objective showed intentionality in exploring the potential of the STEAM Education for gender inclusion from the initial stages.

The predominant gender views in the articles recognize the influence of structural barriers to gender gaps in scientific and technological fields but without deepening discussions on these issues. It is necessary to consider these factors to avoid a distorted assessment of the strategies adopted, in which the results are not attributed exclusively to the proposed intervention. The two articles that problematize the complexities involving gender and science were written by women representing minority ethnic-racial groups, reinforcing the importance of diversity in the authorship of research, especially when working with historically underrepresented groups. This fact also highlights the impacts of the underrepresentation of women on how knowledge is produced in scientific and technological fields, reflecting not only social inequalities but also affecting the valuation of knowledge within these areas, as pointed out by Hearn and Husu (2011).

Concerning the integration of disciplines, there was a prevalence of Science and Technology to the detriment of other areas, especially an underrepresentation of Engineering. Disciplinary integration, as proposed by Quigley and Herro (2016), was not always evident in the methodology, and often, there were combinations between some of them without establishing how the concepts and methods of the area contributed to explaining the phenomenon or solving the problem.

The conception of Art varied between Art Education, creativity, and humanities, and, consistent with the ideas of Sanz-Camarero et al. (2023), its presence was defended as crucial for the exploration and representation of phenomena, to stimulate interest in careers in STEAM fields, and to stimulate connection with students' life experiences, especially those with non-academic interests. The artistic dimension was introduced mainly through music, theater, drawing, and painting.

Most proposals were implemented during classes, as didactic sessions, and were short in duration, not exceeding five weeks. The methodologies contributed in different dimensions to bringing girls closer to science.

Problem-based learning allows students to relate abstract concepts to real situations, favoring engagement, the development of scientific, mathematical, and technological skills, and the attitude towards science, with emphasis on the increased interest of girls in STEAM fields. Collaborative learning and social interaction brought benefits to both the learning process and the student's personal development.

Technology has played a central role in several research by enabling students to think creatively and critically to solve problems rather than memorizing information. This methodology positively impacted the motivation to learn science and the development of autonomy and computational thinking skills, highlighting the change in the attitude of girls and non-binary students, who demonstrated positive perceptions regarding computing, robotics, and programming after participating in experiences with these resources. Engineering design enabled the practical application of the concepts learned, promoting motivation for learning, self-efficacy, and the acquisition of interdisciplinary knowledge, with equality between genders.

The factors presented in scientific research as motivators of girls' participation in science reveal a worrying trend towards the reaffirmation of gender roles. Several of these studies, when suggesting that girls do not have an affinity for specific areas or are inherently attracted to manual work or themes considered feminine, can consolidate the mistaken idea that gender identity determines the preferences and abilities of girls.

Finally, from this research, it is possible to signal paths for future investigations that expand research in less studied regions, considering specific realities and challenges of each context. Furthermore, considering that student behaviors can be reinforced or reduced depending on the teachers' stance, it is essential to conduct more research from this perspective to expand knowledge, training, and support for teachers to use the STEAM Education to reduce gender gaps in science teaching.

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	Authors (year)	Objective
1	Alkhabra et al. (2023)	Advocate for augmented reality-based e-content to improve learning retention and reinforce critical thinking. Study the interaction between AR and gender.
2	Arpaci et al. (2023)	Explore the effectiveness of a space-themed STEAM-based learning module in teaching science.
3	Barros et al. (2023)	Reflect on a conceptual and practical alternative for education in digital technological times that serves women.
4	Durán et al. (2023)	Design musical activities disconnected from Bebras challenges and evaluate their effectiveness concerning CP in students.
5	Lewis Ellison and Qiu (2023)	To understand the agency experiences of a Black adolescent girl's digital literacy and STEAM practices.
6	Salmi et al. (2023)	Assess cognitive learning outcomes after participation in our inquiry-based out-of-school environment.
7	Sun et al. (2023)	Develop a specialized scale for assessing teachers' CT skills.
8	Sung et al. (2023)	To examine the feasibility of a STEAM program integrated into the national curriculum in a Korean early childhood education setting and explore possible gender differences after treatment.
9	Szabó et al (2023)	Enhance preteens' spatial skills through a STEAM-based educational program.
10	Arias et al. (2021)	Identify influential factors in choosing a STEAM course and the reasons for the gender disparity in these courses.
11	Fernández-Morante et al. (2022)	Study the effect of participation in interdisciplinary projects on students' perception of self-efficacy in basic learning skills and analyze the role of gender in this perception.
12	Hasti et al. (2022)	Gather data on existing practices that will be used in STEAM-Labs.
13	Liao et al. (2022)	Explore differences in learning outcomes and social recognition between different types of students.
14	Ma et al. (2022)	To Examine learning behaviors in a STEAM program and compare performance by gender.
15	Tamargo-Pedregal et al (2022)	Identify the areas of knowledge to which students aspire, focusing on STEAM subjects and contextual aspects of students, such as their career expectations and gender.
16	Skowronek et al. (2022)	Explore the challenges of traditional education in STEM fields, with attention to underrepresented students and minorities in STEM.
17	Yu and Li (2022)	Assess children's practical drawing skills based on the global characteristics of their realistic figure drawing.
18	Alexopoulos et al. (2021)	Monitor changes in students' creativity and motivation before and after participation in a STEAM intervention and investigate gender differences in creativity and scientific motivation.
19	Aurava and Meriläinen (2022)	Describe the expectations and experiences of young digital game jam participants attending Finnish schools.
20	Cabello *et al*. (2021)	Document the design and implementation of a science education program for young children that uses STEAM and gender.
21	Gul et al. (2021)	Develop a valid and reliable scale to measure high school students' attitudes toward programming.
22	Jia et al. (2021)	Introduce a new elementary STEAM course, integrated with Maker's focus on technology and creativity.
23	Kijima et al. (2021)	Explore an educational intervention in Japan designed to change young females' perceptions of STEM topics.
24	Lin et al. (2021)	Explore how Taiwan's economy has advanced from a "function"-based approach to an "emotion"-based approach and how gender issues related to STEM have been addressed.
25	Naukkarinen and Jouhkimo (2021)	Evaluate the implemented educational model by examining students' perceptions of sustainability and studying differences

	Authors (year)	Objective
		between different groups of students.
26	Ortiz-Revilla et al. (2021)	Determine the influence of implementing a STEAM DU approach on students' overall level of competence and determine whether there are gender differences concerning students' development and attitude towards science.
27	Piila et al. (2021)	Find out if a multidisciplinary learning module helped students develop their 21st-century skills.
28	Rivas et al. (2022)	Characterize scientific production related to the use of robotics in STEAM areas in Early Childhood Education.
29	Tan *et al.* (2021).	Exploring the Effectiveness of the Integrated STEAM Approach via Scratch on the Computational Thinking of Male and Female Students on the Concept of Electricity.
30	Voicu and Matei (2021)	Identify views from teachers, education stakeholders, parents, and STEAM professionals on STEAM implementation and the value of STEM+Arts education in increasing young girls' motivation and participation in science education and careers.
31	Boakes (2020)	Develop design thinking with 22 high school girls participating in a summer STEM program.
32	Conradty and Bogner (2020)	Not explicit.
33	Conradty et al. (2020)	Explore ways to spark young people's enthusiasm for science.
34	Guenaga-Gómez and Fernandéz-Álvarez (2020)	Increase girls' interest in STEAM in elementary school and promote science and technology careers.
35	Kijima and Sun (2021)	Highlight the possibilities of using design thinking to encourage young females to become more interested in STEAM fields.
36	Román-Graván et al. (2020)	Attract more women to technical and scientific careers, especially those related to programming.
37	Boyle (2019)	Outline a series of STEAM club activities based on a theme that will appeal to many girls.
38	Liu et al. (2019)	Examine the use of an enriched multimedia system (PBL Science Environment) by vulnerable students.
39	Oliveros (2019)	Understand the factors that define the motivation of women in STEM careers at three public universities.
40	Sengupta and Vossoughi (2019)	Explore how two Black girls experience two STEM learning environments.
41	Wajngurt and Sloan (2019)	To evaluate the impact of a "Chemistry with the Arts" course on the subsequent pursuit of STEM subjects by female students.
42	Conradty and Bogner (2018)	To empirically quantify adolescent creativity.
43	Tsai et al (2018)	To assess computer programming self-efficacy and explore possible gender differences in the dimensions of computer programming self-efficacy.
44	Magerko *et al.* (2016)	Determine whether female and male students experience the same or different changes in internal characteristics resulting from participating in the EarSketch.
45	Park *et al.* (2016)	Investigate how Korean teachers actually practice STEAM education in the classroom.
46	Jeong and Kim (2015)	Examine the impact of hands-on global climate change monitoring projects on developing STEAM content knowledge.
47	Pepler (2013)	Not explicit.