Heliyon 8 (2022) e10300

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Review article

The gender gap in higher STEM studies: A systematic literature review

Sonia Verdugo-Castro [a,*], Alicia García-Holgado [b], Mª Cruz Sánchez-Gómez [c]

[a] GRIAL Research Group, Department of Didactics, Organization and Research Methods, Research Institute for Educational Sciences, Universidad de Salamanca, Salamanca, Spain

[b] GRIAL Research Group, Computer Science Department, Research Institute for Educational Sciences, Universidad de Salamanca, Salamanca, Spain

[c] GRIAL Research Group, Department of Didactics, Organization and Research Methods, Universidad de Salamanca, Salamanca, Spain

ARTICLE INFO

Keywords:
Gender gap
STEM
Gender
Stereotypes
Diversity
Higher education

ABSTRACT

The development of science, technology, engineering, and mathematics (STEM) requires more qualified professionals in these fields. However, gender segregation in higher education in this sector is creating a gender gap that means that for some disciplines female representation does not even reach 30% of the total. In order to propose measures to address the phenomenon, it is necessary to understand the possible causes of this issue.

A systematic literature review and mapping were carried out for the study, following the PRISMA guidelines and flowchart. The research questions to be answered were (RQ1) What studies exist on the gender gap in relation to the choice of higher education in the STEM field; and (RQ2) How do gender roles and stereotypes influence decision-making related to higher education? The review of peer-reviewed scientific articles, conferences texts, books and book chapters on the European education area was applied. A total of 4571 initial results were obtained and, after the process marked by the PRISMA flowchart, the final results were reduced to 26. The results revealed that gender stereotypes are strong drivers of the gender gap in general, and the Leaky Pipeline and Stereotype Threat in particular. To narrow the gender gap, it is necessary to focus on influences from the family, the educational environment, and the peer group, as well as from the culture itself. Positive self-concept, self-efficacy, self-confidence, and self-perception need to be fostered, so that the individual chooses their studies according to their goals.

1. Introduction

The science, technology, engineering and mathematics (STEM) field is experiencing a shortage of skilled workers (Codiroli Mcmaster, 2017), yet it is experiencing a great deal of technological development (Winterbotham, 2014). In addition, the STEM education sector suffers from under-representation of gender diversity, namely of women (García-Holgado et al., 2019a, 2019b, 2019c; Jacobs et al., 2017). This situation invites reflection on the cause of gender segregation in scientific and technical higher education.

With regard to motivation as a vector for deciding which higher education studies to pursue, studies have been published, such as that of Guo et al. (2018), in which it is pointed out that women prefer to opt for professions related to people, their care and education, while men prefer to opt for the fields of things. However, beyond the simple explanation of what they prefer, it is necessary to detect what modifies and conditions the motivation, and therefore the final decision.

Gender stereotypes in the STEM education sector are related to Stereotype Threat (Corbett and Hill, 2015) and the Leaky Pipeline, which lead to the loss of equal representation in the sector.

Stereotype Threat is a social phenomenon that occurs when the person concerned fears confirmation of the negative stereotyping of the group to which they belong (Cheryan et al., 2017). Given that the STEM sector has been socially ascribed to men (Blackburn, 2017; Nosek et al., 2009), women may fear rejection in the field of study and careers. One of the consequences of Stereotype Threat is when erratic stereotypical thoughts lead the affected persons to doubt their abilities, deteriorating their self-confidence, despite having optimal performance results (Correll, 2001).

This situation of loss of a sense of belonging can erode women's self-efficacy (Hall et al., 2015), and eventually lead to the phenomenon of the Leaky Pipeline (Berryman, 1983).

Understanding the factors involved in the process of deciding which higher education studies to pursue will shed light on how to enable the retention of women (Reiss et al., 2016). Such retention is essential to

* Corresponding author.
E-mail address: soniavercas@usal.es (S. Verdugo-Castro).

https://doi.org/10.1016/j.heliyon.2022.e10300
Received 18 March 2022; Received in revised form 28 May 2022; Accepted 11 August 2022

avoid further loss of human capital, given that female participation rates in STEM studies are worryingly low.

In addition, to combat the gender gap, the different social and cultural factors involved, as well as gender stereotypes, which, as pointed out by authors such as Bian et al. (2017), can be observed from the age of six, must also be taken into account in the frame of reference. However, taking as a reference authors such as Ceci et al. (2014), the need to pay attention to solid environmental influences is reaffirmed. The latter authors (Ceci et al., 2014), in their study, concluded that early sex differences in spatial and mathematical reasoning do not necessarily stem from biological bases, that the gap between the average mathematical ability of females and males is narrowing, and that sex differences show variations over time and across nationalities and ethnicities. Thus, all this points to the need to pay attention to environmental and contextual factors that modulate the impact on the gender gap.

On a biological basis, there is controversy in the literature. While some authors argue that the gender gap is not biologically based (Bian et al., 2017; Blackburn, 2017; Borsotti, 2018; Cantley et al., 2017; Codiroli Mcmaster, 2017), other authors do suggest that differences between men and women in career and lifestyle preferences are to some extent due to biological influences (Stewart-Williams and Halsey, 2021).

Therefore, as Ceci et al. (2014) point out, gender discrimination has historically been a potential reason for the under-representation of women in scientific academic careers. Today, however, attention must also be paid to the barriers girls and women face to full participation in scientific and technical fields (Ceci et al., 2014).

Although segregation does not occur in 100% of the countries in the world, there is a widespread trend of gender segregation in tertiary studies. As an example, about STEM higher education, during 2018, in France, 28,857 men (74.55%) studied tertiary Physics studies, compared to 9,850 women (25.45%). The same was true in Spain with 73.23% male representation, in Greece with 70.51% and in Austria 78.32%. In the disciplines of Mathematics and Statistics, for example, in the UK, 63.05% of the representation was male, as in France with 70.41%. And in Sweden, in Exact Mathematical Sciences 66.06% of the students were male. Also, in 2018, 81.67% of students in ICT studies in the European Union were male. For example, in Spain, 86.92% of students in Software disciplines were male. Moreover, during 2018, 73.53% of students in Engineering, Manufacturing and Construction disciplines in the European Union were male. For example, in Germany, 82.02% of Engineering students were male. And finally, 81.93% of Electronics and Automation students in Turkey were male, as was the case in Architecture with 69.07% of men (European Institute of Gender Equality, 2018).

To explore the factors involved in horizontal gender segregation in the STEM education sector, a review of the existing literature is proposed through a Systematic Literature Review on the gender gap in STEM education in the European Union.

After searching and reading other reviews, it was decided to develop the Systematic Literature Review.

First, Canedo et al. (2019) address the barriers that women face in software development projects. The authors aim to find mechanisms to encourage women's interest in the field of software development projects. In turn, Gottfried et al. (2017) present a literature review on how friends and familiar social groups play a role in the likelihood that high school students do or do not pursue advanced studies in mathematics and science. Also, Wang & Degol (2013) address motivational pathways towards STEM career choices, in relation to gender; they do so using Expectancy Value Theory as a framework. Finally, Yazilitas et al. (2013) focus on micro-level and macro-level patterns linked to the unequal representation of students of both genders in STEM.

After reading the reviews, it was decided to continue with the review process of the present study, given that they did not respond to the research questions posed for the research. Canedo et al. (2019) focus their attention on software development projects; however, they do not address other STEM fields and do not propose to analyse the social, academic, and personal factors involved in segregation. On the other hand, Gottfried et al. (2017) base their study on the influence of friends and family on the decision to study mathematics and science, however, the spheres of technology and engineering are not included, and the perspective is not open to another classification of elements, such as personal and academic. Similarly, Wang & Degol (2013) propose to discover the motivations towards the choice of careers, although they do so from a psychological perspective, and the study is outdated as it was published in 2013. Finally, Yazilitas et al. (2013) also start from a psychological perspective. Nonetheless, in order to answer the research questions of the review presented here, it is necessary to take an educational perspective and not only a psychological one, because socio-educational elements are addressed.

In deciding to continue the process, the PRISMA model was used. The aim of the work was to identify what work has been or is being developed on the subject, and to understand the influence of gender stereotypes on the segregation process. The aim was to answer what are the objectives pursued in the existing studies, what are the methodologies and scientific methods used, whether specific instruments and/or data collection techniques have been used for the study of the gender gap in STEM studies, as well as what are the results obtained in the studies. Also, it aimed to know the relationship between the gender gap in STEM studies and the cultural and social patterns surrounding gender.

This paper is organised in six blocks. The first is the introduction, followed by the planning of the research in the second block (materials and methods), then the results of the mapping in the third block, and the results of the Systematic Literature Review and the discussion in the fourth block. The fifth section contains the conclusions. Finally, the sixth section describes the threats to the validity of the study.

2. Materials and methods

Systematic Literature Review (SLR) allows for the identification, evaluation and interpretation of all available research relevant to a particular research question, thematic area, or phenomenon of interest (Kitchenham, 2004). The systematic literature review process is divided into three phases: planning the review, conducting the review and writing the report (Kitchenham and Charters, 2007). Along with the Systematic Literature Review, a systematic mapping can be carried out, which entails the same phases as outlined above (Petersen et al., 2015).

In the work presented, an SLR and a systematic mapping of the gender gap in higher education in the Science, Technology, Engineering, and Mathematics (STEM) sector have been carried out. In this work, the systematic mapping is presented as a complementary element to the Systematic Literature Review. The procedure followed is the PRISMA flowchart and guidelines (Moher et al., 2009).

The review and mapping process was divided into a set of phases or steps. These phases range from the systematic review of other SLRs related to the gender gap in STEM higher studies–to determine the need to carry out the present study–, to the results obtained after carrying out the review. The phases followed were: (1) systematic review of other SLRs, (2) definition of the research questions for the SLR and mapping, (3) definition of the inclusion and exclusion criteria, (4) definition of the search strategy, (5) definition of the quality criteria, (6) data extraction, (7) results, and (8) data analysis and report writing.

The complete detailed explanation of each step of the systematic literature review presented in this article is contained in supplementary material 1. Each element has been detailed in supplementary material 1, simplifying the information in this document to facilitate the wording of the explanatory steps of the review.

2.1. Identifying the need for a review

Before conducting a systematic review or mapping of the literature it is necessary to examine whether there is a real need for the review. It should be determined whether a systematic review already exists that answers the research questions posed and can support the research.

There is no scientific reason to conduct a systematic review or mapping that has been done before, unless there is a clear bias in the review or it is outdated and new studies have been published since the existing review was completed (Petticrew and Roberts, 2005). To find out whether there are previous reviews or mappings that answer the research questions posed in the study, a search for existing systematic reviews and mappings should be conducted. For this part of the analysis, the following research question is posed: Do SLRs or mappings exist that answer the research questions of this study?

Finally, 107 documents were identified in Scopus with this equation of terms, 36 of them related to reviews and mappings. After reviewing the 36 documents, only 2 met the indicated criteria. On the other hand, in Web of Science, 49 documents were identified with the search string stated. Of the 49 documents, 9 were associated with a literature review or mapping, and, after examining the documents, only 2 met the criteria. Of the four final articles, one of them followed the SLR methodology, one of them partially followed the SLR methodology and the other two did not follow the SLR methodology.

From the review of the four final papers, it was concluded that none of them answered the research questions that were posed for this study. This is because they focus on other elements related to the gender gap (Canedo et al., 2019; Gottfried et al., 2017), in addition to the fact that two of them are outdated, as they are publications from 2013 (Wang and Degol, 2013; Yazilitas et al., 2013). Nine years have passed since 2013, which means almost a decade left unaddressed in these reviews.

Detailed information on this section of the systematic literature review and on the inclusion and exclusion criteria, search strategy, search strings, and criteria for quality assessment can be found in supplementary material 1.

2.2. Research questions

Once the actual need to carry out the SLR of the present study was determined, the process began. The first phase was to review the research questions and the mapping questions. First, two research questions (RQ) were defined:

- RQ1: What studies exist on the gender gap in relation to the choice of higher education in the STEM field?
- RQ2: How do gender roles and stereotypes influence decision-making related to higher education?

Secondly, eight mapping questions (MQ) have been defined:

- MQ1: Which databases publish studies in relation to the gender gap in the STEM education sector?
- MQ2: Which keywords are applied in the studies?
- MQ3: How are the studies distributed per year?
- MQ4: What kind of methodologies and methods do the studies apply?
- MQ5: In which countries do the studies take place?
- MQ6: With which population are the studies conducted?
- MQ7: What instruments or data collection techniques have been validated?
- MQ8: What kind of data collection instruments or techniques are used?

Based on the research questions defined, the PICOC method proposed by Petticrew and Roberts (2005) was used to define the scope of the review:

- Population: Gender gap in the STEM sector.
- Intervention: Studies conducted, and proposals related to the gender gap in the STEM education sector
- Comparison: No comparison.
- Outcomes: Results of studies conducted in relation to the gender gap in the STEM education sector.
- Context: Students integrated in the European educational field, especially in the STEM sector, with a special focus on EQF levels 5, 6, 7, and 8 (European Qualifications Framework for Lifelong Learning).

Universal human factors condition the gender gap in STEM higher education. Since as known from the scientifically accepted SCCT model of Lent et al. (1994), motivations and outcome expectations condition the decision on which higher education studies to pursue. However, the gender gap is not only influenced by intrinsic factors but also by extrinsic elements. Cultural patterns marked by stereotypes and gender roles present themselves differently, depending on the local culture (Bourdieu, 1980a, 1980b, 1984). Since the gender gap is a sociological phenomenon that responds to socio-cultural rules, the gender gap index does not occur equally in all world geographical regions (García-Holgado et al., 2019c; World Economic Forum, 2021).

In this sense, it is of scientific interest to analyse the gender gap in developed geographical areas which implement measures to alleviate segregation where the gap is manifest. For this purpose, global gender gap reports have been consulted to determine the gender gap index situation in the different world regions.

According to the World Economic Forum (2021), each country is in a particular situation concerning closing the gender gap. According to the World Economic Forum (2021), the geographical areas of Eastern Europe and Western Europe are in a worse situation in terms of closing the gender gap than areas of North America such as Canada and the United States. In the global ranking of gender gap indices, updated to 2021, Canada ranks 24th out of 156, and the United States ranks 30th out of 156. In 2021 Canada closed 77% of the gender gap and the United States 76%. Meanwhile, other Eastern and Western European countries are in less favourable positions. In 2021 Hungary was ranked 99 out of 156, with 69% of the gender gap closed; Greece was ranked 98 out of 156, with 69% of the gender gap closed; Romania was ranked 88 out of 156, with 70% of the gender gap closed; Malta was ranked 84 (70%); the Czech Republic ranked 78th (71%); the Slovak Republic ranked 77th (71%); Poland ranked 75th (71%); Italy ranked 63rd (72%); Luxembourg ranked 55th (73%); Estonia ranked 46th (73%); Croatia ranked 45th (73%); Slovenia ranked 41st (74%), and Bulgaria ranked 38th (75%).

Also addressing gender segregation in the vertical sense, according to the World Economic Forum (2021), the low presence of women in top positions demonstrates the persistence of a "Glass Ceiling" even in some of the most advanced economies. While in the United States women occupy the 42% of senior and management positions, in other countries such as Sweden they occupy the 40%, in the United Kingdom the 36.8%, in France the 34.6%, in Germany the 29%, in Italy and the Netherlands the 27%.

On the other hand, as far as the gender pay gap is concerned, developed countries still have a gap to close, e.g., France has 39% of the gap to close, Denmark has 38% of the gap to close, while the United States has 35% of the gap to close.

Therefore, given the results of the reports, it has been decided to analyse the scientific production on the gender gap in higher STEM studies in the European Union. Although it is a geographical area that is on the way to reducing the gender gap, there are still high rates to be closed.

2.3. Data mining

Regarding the data extraction, the metadata of the publications obtained from the search was downloaded from the databases in CSV format. The raw datasets are available in Zenodo (Verdugo-Castro et al., 2021). The phases of defining the protocol, searching and extracting the initial data from the databases were carried out by all the authors of this publication. The search results are current as of 10 November 2021. Subsequent filtering of the successive phases was done by peer review among the authors. The data mining process is an iterative and incremental process. The process was done through different phases

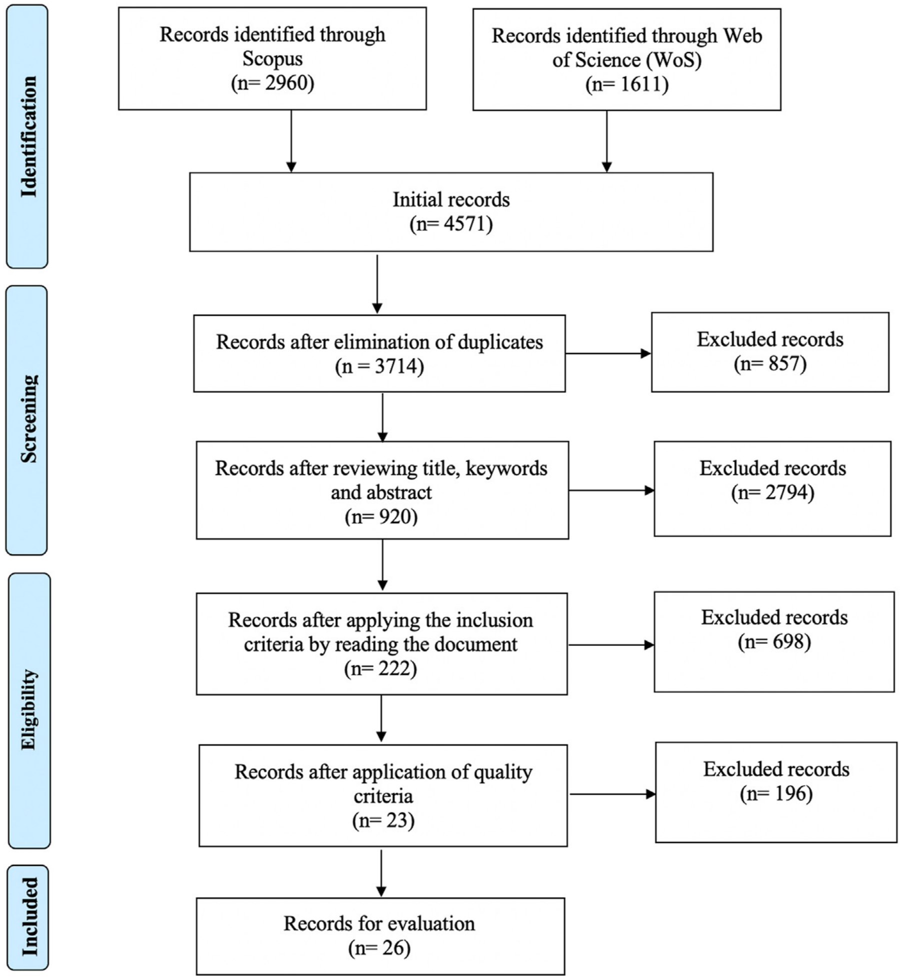

Figure 1. PRISMA flowchart of the Systematic Literature Review. Source: Created by the authors.

(Figure 1). The process is described through the PRISMA flowchart (Moher et al., 2009).

First, the results were identified, following the application of search strings in the two selected databases. The results of the databases were downloaded in CSV format. Then, all results were organised in a spreadsheet in Google Sheets. The spreadsheet was configured to automatically detect duplicate titles to facilitate their search and removal. After removing the duplicate items, the data extraction stages began with the application of different filters (http://bit.ly/3a4gRM5).

- First stage: On a second sheet of Google Sheets, three items were analysed to see if the publication was related to the study objective and the research questions. This phase allowed us to define the candidates for reading. These three elements were the title, the abstract and the keywords (http://bit.ly/39lO0DX).
- Second stage: The documents resulting from the previous phase were then dumped onto a third sheet. On this third sheet of Google Sheets, the inclusion and exclusion criteria were applied. To proceed to the next stage, each publication had to meet all the inclusion criteria (http://bit.ly/39lO0DX).

During the first phase, 2794 items were removed, and during the second phase, 698 items were removed. A total of 3492 items were eliminated between the first and second phases. The reasons for discarding these publications were:

- o The publication's subject matter did not have a clear relationship to the gender gap in the STEM education sector.
- o The study addressed the gender gap in STEM fields at the employment or business level but, not in the educational field.
- o The study addressed gender segregation in education, but from the perspective of female teachers, not female students.
- o The study addressed educational elements not related to the gender gap. For example, academic performance and grades.
- o The research was not carried out in European Union countries or regions.
- o The publication was not open access or available through University of Salamanca databases subscriptions.

- Third stage: The third stage of the process focused on the eligibility of publications. The publications selected in the previous stage were read again. This time they were read with the aim of answering the quality questions (http://bit.ly/36fnBpi). In total, there were 10 questions, each of which was answered with one of the following options: yes (1), no (0), partial (0.5). Each answer corresponded to a score, so that the sum of the answers gave each paper a score between 0 and 10. Those papers with a score equal to or higher than 6 were selected for the final stage.

At the quality stage, 196 items were discarded if they did not reach the minimum cut-off score of 6. While all publications were related to the gender gap in the STEM education sector in an EU country or region, the reasons for exclusion were as follows:

- o The objectives of the publication were not clearly aligned with the gender gap in STEM. In some cases, the approach to segregation was collateral and superficial.

- o Some research did not propose methodological approaches of interest at qualitative, quantitative or mixed levels.
- o Other research did not propose intervention proposals (four of the ten quality questions are linked to socio-educational proposals).
- o Some studies do not take into account the limitations encountered throughout the research.
- o The publication does not answer at least one of the two SLR research questions.

Finally, 26 items made it to the final phase. Each selected paper was analysed in detail to obtain the answers to the research and mapping questions.

3. Results of the systematic mapping

The results to the systematic mapping questions are presented below.

3.1. MQ1: which databases publish studies in relation to the gender gap in the STEM education sector?

About three quarters of the publications are indexed in Scopus, compared to 23% of those indexed in Web of Science.

3.2. MQ2: which keywords are applied in the studies?

As presented in Table 1, the most frequently used keywords are gender, STEM, and stereotypes.

3.3. MQ3: how are the studies distributed by year?

As shown in Figure 2, the years with the highest number of publications are 2018 and 2017.

3.4. MQ4: what kind of methodologies and methods do the studies use?

It can be seen from Figure 3 that there is a preponderance of studies based on quantitative paradigms, although qualitative designs and mixed approaches are emerging. Complete information on this question can be found in Table 1 of Supplementary Material 2 linked to this article.

Table 1. Results to the MQ2.

Gender	7
STEM	7
Stereotypes	3
Computer Science Education, Diversity, Engineering education research, Gender Diversity, Gender gap	2
21C Learning, Attractiveness of education, Badged Open Courses, Best practices, Blended learning, Career advice and guidance, Choice of college major, Cognitive-activation, Collaboration, Collaborative learning, Communities, Companies, Competitiveness, Computational thinking, Computer science mentoring, Computing, Cooperation, Digital badging, Educational capital, Educational robots, Employability, Engineering, Enjoyment, Enrollment, Environmental education, Equality, Exploratory Case Study, Extracurricular STEM program, Female, Female STEM students, Future career perspective, Future educational plans, Gender balance, Gender differences, Gender equity, Gender stereotypes, Gender study, Gendered innovation, Gifted education, Gifted girls, Gifted magnet school, Girls4STEM, Hands-on experience, High school curriculum, High-achiever-track secondary school, Human-robot interaction, ICT, Impacts, Inclusion, Inquiry-based learning, Learning, Learning capital, Mathematics education, Mental Models, Mentoring, Motivation for learning, Network analysis, Online gifted education, Profiling tool, Program evaluation, Programming, Questionnaire theory of planned behavior, Reform evaluation, Research methods, Residential programme, Rich Picture Analysis, Robot evaluation, Science and Technology Education, Science capital, Science education, Science exhibition, Science interest, Scientific understanding, Scratch, Self-concept, Self-Efficacy, Self-perception, Software Development Education, STEM outreach, Student diversity, Student' questioning, Support, University education, Women in STEM, Women returners, Young people	1

3.5. MQ5: in which countries are the studies carried out?

As presented in Figure 4 and 9 studies were carried out in Germany; 5 in Spain, 3 in the UK and Ireland, 2 in areas such as Italy, Portugal, Denmark, Belgium and Finland, and only one study in other regions, such as Slovenia, Norway, Scotland, Latvia, Estonia and the Czech Republic.

3.6. MQ6: with which population are the studies conducted?

As shown in Figure 5, the samples with which the studies have been carried out are primarily university students and secondary school students. Studies have also been carried out with primary school students and secondary school and university students. Finally, in one study, there have been samples of primary, secondary, and university education; and in another study, the sample has been female graduates.

Complete information on this question can be found in Table 2 of Supplementary Material 2 linked to this article.

3.7. MQ7: what data collection instruments or techniques have been validated? And MQ8: what kind of data collection instruments or techniques are proposed?

Table 2 provides information on what kind of techniques or instruments have been used to collect the data and which of them have been validated.

4. Results of the systematic literature review and discussion

The qualitative analysis of the resulting papers in the systematic literature review has been organised into two main blocks (4.1. and 4.2.). Since there are two research questions to be answered for SLR, the first research question is answered in the first block (4.1. IQ1: What studies exist on the gender gap in relation to the choice of higher education in the STEM field?), and the second block answers the second research question (4.2. IQ2: How do gender roles and stereotypes influence decision-making related to higher education?).

In turn, a grouping strategy has been followed to classify the results thematically and facilitate their understanding. After reading all of them, the main themes studied in the papers were identified as categories, and the results of the papers were organised based on these categories. Finally, eight main themes have been identified, four to answer the first research question and four to answer the second SLR research question.

In the first block, in which the first SLR research question is answered, the main themes are Socio-educational projects and proposals (4.1.1.), study of gender differences (4.1.2.), initiatives in secondary and university education (4.1.3.) and Active methodologies and intervention initiatives (4.1.4.). On the other hand, in the second block, in which the second research question of the SLR is answered, the main topics are Social Cognitive Career Theory (SCCT) and early intervention (4.2.1.), educational institutions and the learning process (4.2.2.), perceptions of male-dominated domains (4.2.3.) and social structures and contextual influences (4.2.4.).

The first research question addresses what studies exist on the gender gap in relation to the choice of higher education in the STEM field. In this sense, it is possible to identify studies on gender differences, socio-educational proposals, and initiatives that can be organised by educational levels, in this case, secondary and university, and also by typology, active methodologies, and intervention initiatives.

On the other hand, the second question addresses how gender roles and stereotypes influence decision-making related to higher education. In this line, the SCCT model (Lent et al., 1994) explains the relationship between social stereotypes and the decision taken. However, the question can also be answered regarding the influence of education as an institution, social and contextual influences, and the perception of socially androcentric spaces.

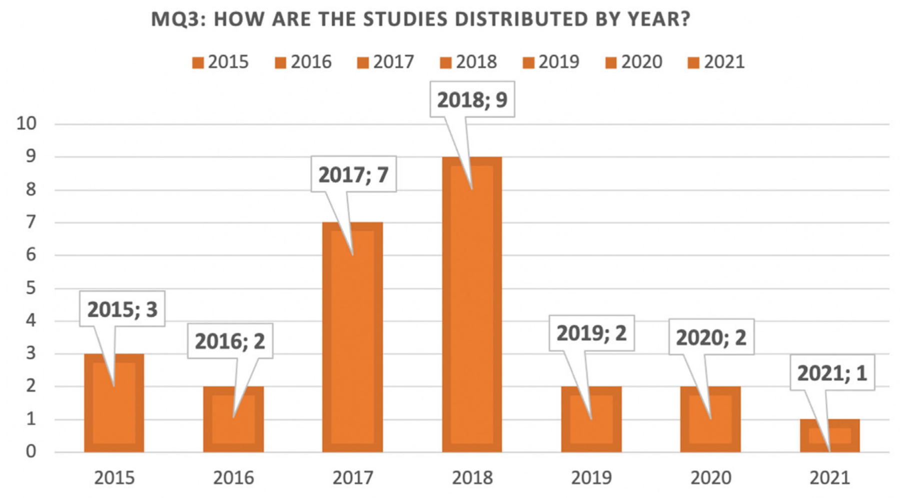

Figure 2. Results to the MQ3.

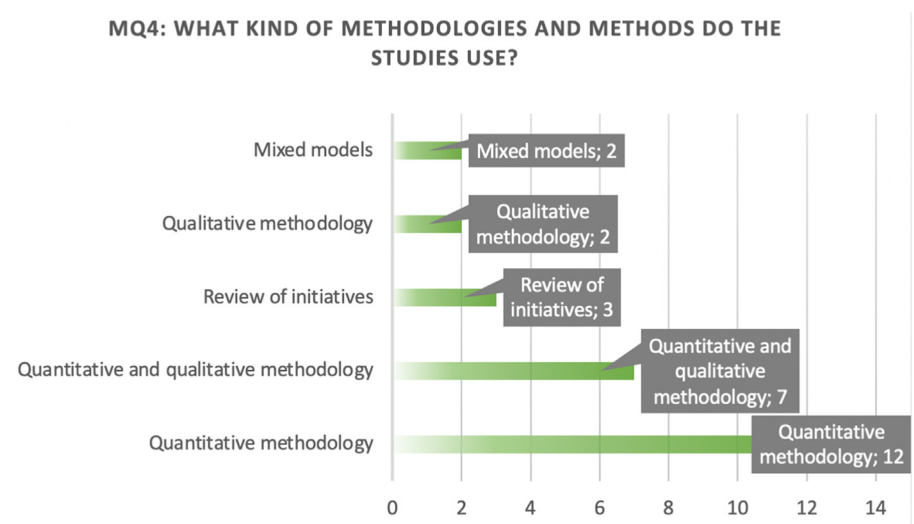

Figure 3. Results to the MQ4.

Figure 6 visually presents the main ideas of the results for the two research questions.

4.1. IQ1: what studies exist on the gender gap in relation to the choice of higher education in the STEM field?

4.1.1. Socio-educational projects and proposals

The IRIS project, Interests and Recruitment in Science, arises to study the factors that determine young people's choices (Henriksen et al., 2015). The aim is to gain a better understanding of how young people evaluate STEM as an option for their educational choices, as achievement in science and technology is only one of many factors that influence their choices.

In terms of specific intervention groups, Heybach and Pickup (2017) allude to a socio-educational approach in the UK. A group called STEMettes (STEMettes, 2021) is working to combat what they consider to be a culture in which girls do not imagine women doing "science stuff" while they are mothers.

In the framework of project design for the improvement of diversity and gender inclusion, there are different technology companies that follow a gender perspective trend, such as LinkedIn, Salesforce, Intel, Google, Microsoft and IBM. In this line, Peixoto et al. (2018) propose an initiative based on robotics, as an inclusive tool, to combat the gender gap.

Also, the Girls4STEM project led by the School of Engineering of the University of Valencia (ETSE-UV) in Spain aims to increase and retain the number of female students, applying its intervention with students aged 6 to 18, their families and teachers (López-Iñesta et al., 2020).

Another project worth mentioning is 'Increasing Gender Diversity in STEM' (Ballatore et al., 2020). The aim is to investigate the gender difference in the self-perception of female students about their career choice. In order to find out the self-perception, a web application for students called ANNA tool was designed and used.

Finally, the project Science and Technology as Feminine, promoted by the Spanish Association of Science and Technology Parks (APTE), aims to raise awareness of the under-representation of women in STEM fields and promote girls' inclusion in scientific and technical careers (Davila Dos Santos et al., 2021).

4.1.2. Study of gender differences

From the study by Kang et al. (2019) it was found that during the transition period from primary to secondary school there were gender differences in relation to interest in and preferences for science subjects, and in relation to future career prospects. Preferences were mostly in

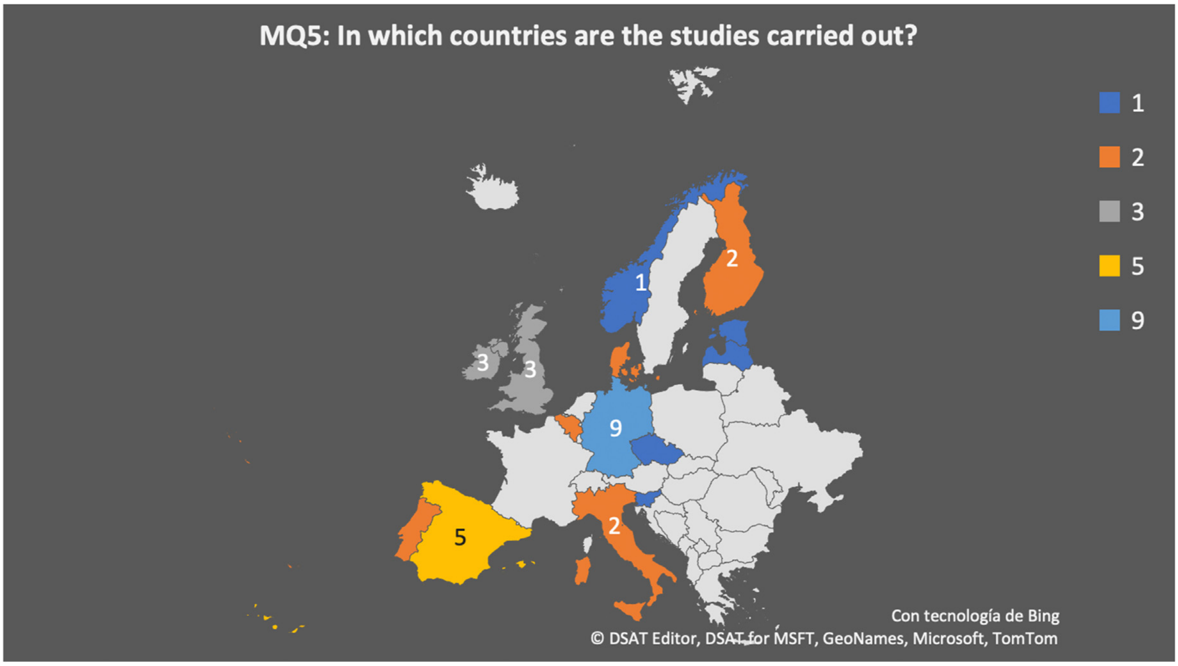

Figure 4. Results to the MQ5.

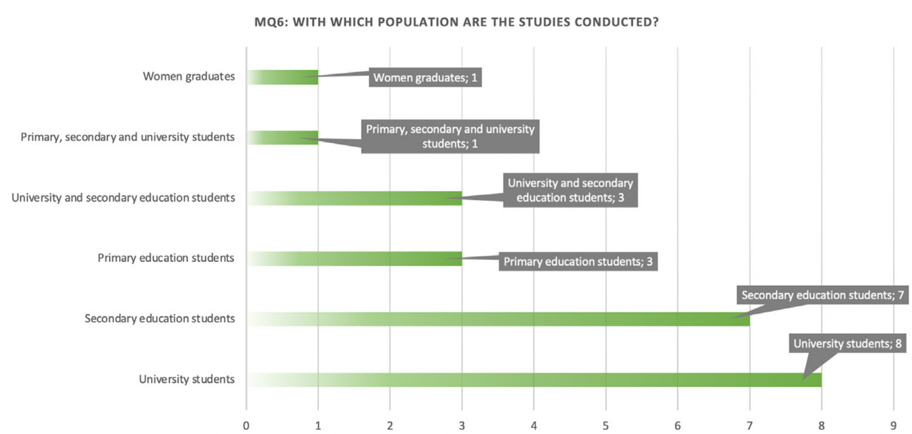

Figure 5. Results to the MQ6.

biology for girls and physics and chemistry for boys. Furthermore, it was concluded that teachers are agents of change involved in the educational process, so it is necessary for them to take care of the material they use and the way they communicate with students. Perhaps by conveying to girls the fact that science careers can respect people's personal time, they might retain their interest in science.

Also, an element to pay attention to is self-efficacy and, for this, Brauner et al. (2018) work from mental models. The study was carried out in Germany and a socio-educational approach was proposed, in which the subjects were participants in robotics courses to increase vocational interests and interest in computer science. From the results it can be concluded that the participants drew predominantly male STEM people in rather isolated situations. The people drawn are perceived to look *nerdy*, although they are also perceived as quite attractive and intelligent. Even so, the mood of the people in the pictures was perceived as slightly negative. It was concluded that girls reported significantly lower levels of technical self-efficacy and lower interest in computer science than boys. However, it is of deep concern that this effect emerges so early and can be measured empirically at the age of 11 or 12 years. The study by Brauner et al. (2018) shows that gender differences with respect to mental models, self-efficacy and interest have already developed by the age of 12.

Furthermore, in the line of socio-educational applications, the research by Wulff et al. (2018) is based on the performance of the Physics Olympiad in Germany in 2015. The aim was to generate motivation in young men and women in the field of physics. To this end, the aim was to develop physical identity for both men and women. After the Olympiad, the return rate for the following year for female participants was 60% (62% for males), while the return rate for non-participating females was 28% (39% for males).

Finally, the study by Reich-Stiebert and Eyssel (2017) tested the effect of gender-typicality of academic learning tasks on HRI (Human-Robot Interaction) and showed that the gender of the robot had no influence on the participants' objective learning performance. That is, participants' learning was neither positively nor negatively affected by learning with a "male" or "female" robot. This fact could be exploited to reduce gender-related performance disparities and contribute to equal opportunities for male and female students in higher education.

Table 2. Results for the MQ7 and MQ8.

	MQ7: What data collection instruments or techniques have been validated?	MQ8: What kind of data collection instruments or techniques are proposed?
Cincera et al. (2017)	-	SEI questionnaire, adapted from the NoS instrument.
Kang et al. (2019)	The validated instrument was formed from PRiSE and PISA, from the MultiCO project.	
Olmedo-Torre et al. (2018)	The validated survey "Survey for engineering students and graduates" was applied with quantitative and qualitative data collection.	
Ertl et al. (2017)	A quantitative instrument on female students' self-concept was validated. A semi-structured interview is also used.	
Padwick et al. (2016)	The Aspires Questionnaire is used. A short questionnaire, a ranking activity based on Diamond 9 on attributes: Most Like Me/Most Like a Scientist and a ranking activity on STEM jobs.	
Salmi et al. (2016)	An instrument for measuring attitudes towards science is validated, considering school performance, knowledge and motivation. The following scales, mostly Likert-type, are used: Deci-Ryan motivation, Situation motivation test, Science attitudes, Future educational plans, Raven test, Knowledge test and School achievement.	
Reich-Stiebert and Eyssel (2017)	-	Instruments have been applied to assess intrinsic motivation, robot agency, robot quality, and "Usability Scale" and "Technology Commitment Scale" have also been used.
Sullivan et al. (2015)	An adaptation of a Papastergiou questionnaire is used for the measurement of perceptions and self-efficacy in relation to Computer Science. It assesses female students' understanding, confidence and motivation to study computer science, their perception of computer science and IT, their perceived self-efficacy in computer science, their performance in mathematics and their perception of the appropriateness of computer science.	
Borsotti (2018)	-	Semi-structured interviews and anonymous surveys.
Cantley et al. (2017)	Validated Aiken scale for measuring interest in mathematics.	
Finzel et al. (2018)	-	A questionnaire that allows to analyse the effects of tutoring on the basis of the proposals of the Theory of Planned Behaviour (TPB). Intention, attitude, subjective norms and perceived behavioural control have been analysed.
Brauner et al. (2018)	-	Data collection technique using drawings and a socio-demographic questionnaire.
Herman et al. (2019)	-	Survey with closed and open questions, feedback from webinars and workshops and an open interview.
Stoeger et al. (2017)	Questionnaire of Educational and Learning Capital (QELC)	
Stoeger et al. (2017)	-	Frequency analysis.
Martinho et al. (2015)	-	Interviews.
Wulff et al. (2018)	An instrument on Identity constructs is developed, where an internal consistency analysis is applied to the following scales: (1) Interest: Content interest physics and Situational interest (post). (2) Recognition: Recognition in Physics Olympiad and Recognition in physics class. (3) Competence: Competence belief in Physics Olympiad.	
Henriksen et al. (2015)	The validated IRIS Q questionnaire is used, as well as focus groups and personal interviews.	
López-Iñesta et al. (2020)	The approach is quantitative, and a questionnaire is used. The GENCE questionnaire is validated.	
Ballatore et al. (2020)	-	The approach is quantitative, and a questionnaire is used.
Davila Dos Santos et al. (2021)	-	The study adopts a qualitative, applied, exploratory and descriptive approach. The quantitative approach was also used. Interviews and questionnaires are used for this purpose.

4.1.3. Initiatives in secondary and university education

One innovation introduced by the education system is presented in the study by Görlitz and Gravert (2018). It analyses the potential of redesigning the secondary school curriculum in Germany to achieve increased enrolments in higher STEM degrees. The results suggest a positive and robust increase in the likelihood of choosing STEM as a university major for males, although there is no effect for females. One cause could be the acquired roles of men and women.

Another proposal in Germany is that of Finzel et al. (2018), who aim to motivate secondary school female students to consider Computer Science as a possible option. The latest measure has been the introduction of the *make IT* mentoring programme in 2014. The programme was designed to provide female students with information about Computer Science and to include measures that consider self-concept and gender stereotypes correlated with a negative image of women in Computer Science. Within *make IT*, participants should be supported to achieve a more realistic self-assessment and positive feedback of their own abilities.

In addition, Ertl et al. (2017) work on self-concept. From their research they conclude that students who reported a higher number of favourite STEM subjects at school have a higher self-concept, while higher levels of school support and teacher stereotyping indicate a lower and less positive self-concept in STEM. Regarding the impact of stereotypes, STEM female students mentioned that they were pursuing an atypical career path and that their social environment was surprised by this type of career choice.

4.1.4. Active methodologies and intervention initiatives

Continuing with the proposals, mentoring is proposed as a measure to reduce the gender gap in STEM. Stoeger, Hopp, et al. (2017) conducted their study in Germany and aimed to compare the effectiveness of individual versus group online mentoring in STEM. This was done within the framework of *CyberMentor*, an online mentoring programme in STEM for gifted girls designed to increase participation rates of talented girls in STEM. In terms of results, the proportion of communication about STEM topics was higher in group mentoring than in individual mentoring. Girls in group mentoring showed a higher amount of STEM-related networking compared to girls in individual mentoring. Finally, group mentoring mentees reported an increase in elective intentions in STEM, while individual mentoring mentees reported no significant differences.

In addition, to work on interest and attitudes towards mathematics, Cantley et al. (2017) work from Collaborative Cognitive Activation Strategies, and from the Izak9 resource. Following the study there was a small increase in girls' enjoyment of mathematics in both the Republic of Ireland and Northern Ireland. However, boys' enjoyment increased marginally in the Republic of Ireland and decreased marginally in Northern Ireland.

In terms of attitudes, Borsotti (2018) empirically investigates the main socio-cultural barriers to female participation in the software development degree programme at the IT University of Copenhagen in Denmark (ITU). The results reveal that almost all respondents attributed the gender gap to a greater extent to the existence of stereotypes.

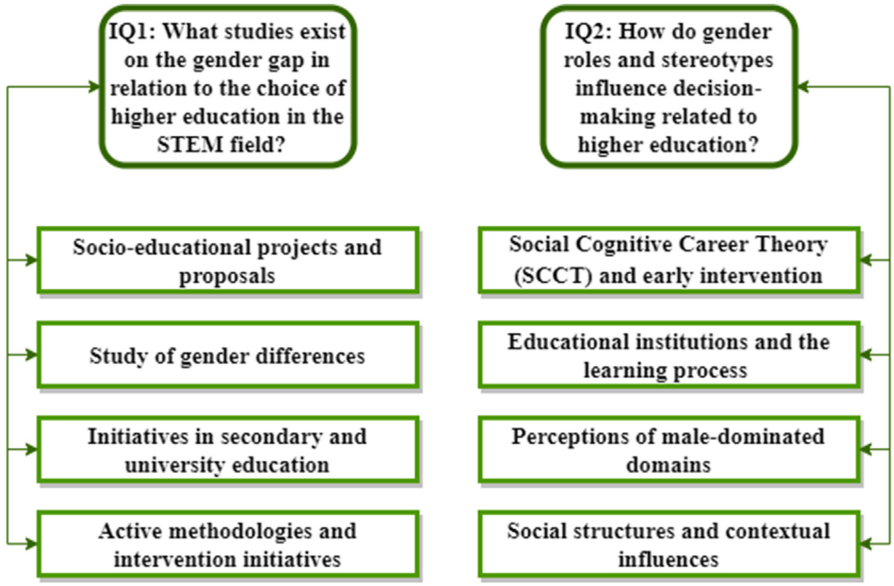

Figure 6. Main ideas of the results for the two research questions.

On outreach interventions, Sullivan et al. (2015) aim to help secondary school girls develop an optimal view of the role of computers in society and to learn some of the key computer skills, including computer programming. It examines CodePlus, a programming club based on the Bridge 21 model, which was established in three all-girls schools. Students worked together on activities including computational thinking, computers in society and programming using Scratch. The results obtained in the Sullivan et al. (2015) study are: (1) there was no gender difference in expected and actual mathematics grades, (2) boys played computer games for much longer than girls, (3) girls spent more time using computers for homework, while boys spent more time using computers to look up general non-school related information, (4) boys demonstrated significantly higher levels of self-efficacy than girls, (5) boys were also more likely to study computer science at university than girls and were more confident about being accepted into a computer science degree. The comparisons demonstrate clear differences in how girls view themselves in terms of computer science ability.

On the other hand, Salmi et al. (2016) found that after visiting science, technology and engineering exhibitions with students, girls were in a better position to decide about their future because they experienced more autonomy than boys. This study also revealed that girls had higher attitudes towards science than boys. However, for the engineering factor, boys' attitudes were significantly more positive than girls'. Motivations are also explored in the study by Olmedo-Torre et al. (2018). In this case, they study the differences between the motivations of female STEM students, forming two groups: (1) Computing, Communications, and Electrical and Electronic Engineering studies (CCEEE women), and (2) other STEM studies (non-CCEEE women). The female respondents considered social stereotypes (31.47%) and immediate environment (14.5%) as the main reasons for the low enrolment of women in STEM studies. Surprisingly, the third reason (11.03%) is that women do not like engineering. In addition, CCEEE women were less likely than non-CCEEE women to consider themselves more able than men in physics, chemistry, mathematics, computer science and graphic expression.

Also, Botella et al. (2019) aim to increase the number of female students by providing them with support, in order to prevent them from giving up in the early stages. The work programme of the School of Engineering of the University of Valencia (ETSE-UV) is organised around four main actions: (1) providing institutional encouragement and support, (2) increasing the professional support network, (3) promoting and supporting leadership and (4) increasing the visibility of female role models. Two other elements to study are identity as a scientist and scientific capital. The study by Padwick et al. (2016) is developed for this purpose within Think Physics (Northumbria University, Newcastle) (Think Physics, 2016). Through collaboration with industry, agencies and schools, Think Physics (Think Physics, 2016) addresses the gender imbalance and under-representation of lower socio-economic groups in the physics, engineering, and computing sectors.

Furthermore, continuing with the analysis of capital, Stoeger et al. (2017) study whether the level of educational capital and the learning capital of students are related to STEM Magnet schools. The findings show that more and more girls are choosing STEM magnet school options as part of their studies. Interestingly, however, this general trend is not followed when choosing higher STEM studies. Cincera et al. (2017) also address scientific understanding, applying a programme to enhance the acquisition of scientific skills. However, there was no significant change in either the girls' or the boys' group.

Meanwhile, the study conducted in Portugal by Martinho et al. (2015) seeks to identify gender differences with respect to cooperation and competitiveness. The results reveal that women are more cooperative than men and men are more competitive than women. Thus, one of the socially assigned gender roles is manifested.

However, the gender gap also concerns communities and industries. González-González et al. (2018) present good practices from communities and industries. Laboratorial, which has a "Talent Fest", stands out. There is also Microsoft, which offers mentoring to young women, for the development of their digital skills. Finally, there is also the Women at Google initiative, which aims to increase the presence of women in the company and encourage them to feel more empowered.

Also, Herman et al. (2019) aim to promote the re-entry into the STEM labour market of women who abandoned their careers, through a blended learning programme. The Badged Open Course (BOC) was developed in 2016 to support women returning to STEM careers after a long period of time.

Finally, as is known from the updated indices published in the latest report of the World Economic Forum (2021), the different countries included in the rankings still have a percentage of the gender gap to close. However, given the results obtained in the systematic review of the literature, it is striking that in those countries where initiatives have been implemented to alleviate the gender gap, the gender gap continues to persist. This finding is consistent with the conclusions obtained in the study by Stoet and Geary (2018). The authors concluded in their research that, paradoxically, countries with lower gender equality indexes had relatively more female graduates in STEM disciplines than those with higher gender equality indexes. As noted by the same authors (Stoet and Geary, 2018), this finding is noteworthy since, following other authors such as Williams and Ceci (2015), countries with higher gender equality indexes are those that offer girls and women more educational and empowerment opportunities and generally promote women's participation in STEM fields. In line with Stoet and Geary's (2018) argument, it is not only social and cultural factors that play a role, but also the individual choices and attitudes that students make, which may be influenced by other factors such as socioeconomic status. In this sense, and in agreement with other authors (Stoet and Geary, 2018; M.-T. Wang and Degol, 2013), students should base their educational decisions on their potential, regardless of the educational field to which the decision is directed.

4.2. IQ2: how do gender roles and stereotypes influence decision-making related to higher education?

4.2.1. Social Cognitive Career Theory (SCCT) and early intervention

According to Heybach and Pickup (2017) in order to suppress gender roles and stereotypes that foster the gender gap it is necessary to move away from androcentrism, and the stereotypical belief that the rational mind is male and the passive nature is female. This would move away from the binary logic, in which occupations have either a female or male profile. The STEM workforce should be empowered, preventing gender roles and stereotypes from increasing the Leaky Pipeline (Heybach and Pickup, 2017). To retain girls and women, the Stereotype Threat must be lessened. Girls and women grow up thinking that they should be dedicated to caring for the family, and scientific thinking is also thought to be masculine in nature. To eradicate these erratic beliefs Heybach and Pickup (2017) propose female role models as a possible solution, in order to increase interest.

For their part, Peixoto et al. (2018) indicate that efforts to retain women and girls in STEM focus on secondary education and/or university. However, it is more relevant to work from an early age. From an early age, it is already evident that boys identify more with the concept of science than girls. Stereotypical perceptions of what STEM is lead boys to feel that scientists can be similar to them at higher rates than girls.

Kang et al. (2019) also point to boys' and girls' interests as a key element, as career aspirations may begin around the age of 11 or 12. Academic and extracurricular experiences and science education are conditioning elements. In addition, the Social Cognitive Career Theory (SCCT) points out that attention should be paid to the expectations of results, since they are a major source of interest.

Other authors who also argue the importance of addressing the gender gap from an early age are (Brauner et al., 2018). They point out that self-efficacy plays an important role in decision-making. This in turn relates to the locus of control of Causal Attribution Theory. Considering that gender, ethnicity, and other distinguishing characteristics may also interfere with decision-making, one must again turn to SCCT. This theory points out that different elements need to be addressed in order to reduce segregation: self-efficacy, outcome expectations, personal goals, career interests, career path choices, performance, and perceived achievements.

However, it is not only a question of interests, self-efficacy, and outcome expectations. According to Cantley et al. (2017) attention should also be paid to attitudes. When the transition from primary to secondary school takes place, students' attitudes towards mathematics become more negative. Attitudes are influenced by interest and enjoyment. For this reason, Cantley et al. (2017) propose to work from Cognitive Activation Teaching Strategies, since they are related to the intrinsic motivation of the person.

4.2.2. Educational institutions and the learning process

Padwick et al. (2016) point out that an important and involved element is science capital. Children with higher science capital are more likely to choose higher STEM studies than those with lower science capital.

Also, Stoeger, Greindl, et al. (2017), who report on STEM magnet schools and non-STEM magnet schools, assume that gender stereotypes can be observed at the age of six. This fact implies that STEM magnet schools could play an important role in increasing participation in STEM studies.

In this line, Salmi et al. (2016) emphasise the difficulty of changing attitudes after primary education, since they are formed at an early age. Salmi et al. (2016) focus on cognitive, motivational, and learning aspects, because motivation and attitudes precede intention. Therefore, if positive attitudes towards the STEM sector can be generated at an early age and motivational elements are introduced, a behavioural approach to science and engineering can be generated.

In terms of motivation, according to Görlitz and Gravert (2018) those who choose to take mathematics and science classes in secondary education are more likely to specialise in these areas at university.

In addition, scientific identity and agency play a role in decision-making. In accordance with Wulff et al. (2018) agency and scientific identity, tinged with social roles, are a possible source of underrepresentation. Elements such as stereotypes, lack of interest, motivation or sense of belonging may explain the underrepresentation of young women in domains such as Physics.

4.2.3. Perceptions of male-dominated domains

In the sense of identity, as Borsotti (2018) points out computer science has been socially constructed as a masculinised domain, resulting in stereotypical perceptions and beliefs, low self-efficacy on the part of women and girls, and biased assessment in STEM subjects.

To address this, according to Sullivan et al. (2015) exposure to computer science, at home or at school, and encouragement from family and peers are the main factors influencing girls' decisions to pursue higher education in computer science. Other factors include self-perception, self-confidence, self-efficacy, scientific understanding, parenting strategy, stereotypes, and biases that girls and women must combat, and the barriers girls face when working in male-dominated environments.

In this regard, Ertl et al. (2017) also consider that negative perceptions, stereotypical beliefs and Stereotype Threat reinforce dysfunctional attribution patterns, which ultimately lead to a lower proportion of women, especially in the areas of technology and engineering. The authors also focus on self-concept as a key element to avoid the gender gap, based on Expectancy-Value Theory.

4.2.4. Social structures and contextual influences

Olmedo-Torre et al. (2018) insist on the relevance of the perception of the immediate environment. It is important to involve families and teachers in the search for a solution. According to Botella et al. (2019) gender roles and patterns and stereotypes installed in the family and in society about relevant careers for both men and women have an impact on the future education of boys and girls, and on their career choices. There are proposals to address these obstacles, such as the promotion of female role models in STEM fields, academic counselling, teacher mentoring, internship opportunities and career and skills development.

Furthermore, picking up on the idea of mentoring, according to Finzel et al. (2018) the probability of choosing higher studies in computer science is lower for women than for men. However, the low proportion is not due to a lack of competence of female students, as they are not less qualified. Instead, the presence of gender stereotypes and the absence of female role models are possible reasons for the low representation of women in computer science. Therefore, mentoring programmes are proposed to encourage the development of higher education in STEM.

In terms of real-world initiatives, Reich-Stiebert and Eyssel (2017) propose an intervention with robots. They aim to investigate whether "female" gendered robots could effectively support learning in STEM disciplines, and whether "male" gendered robots could support learning in linguistic and literary studies. After conducting the study, it can be concluded that the female agent tends to be more effective regardless of the gender of the participants.

Moreover, Henriksen et al. (2015) indicate that the challenge for future research is to further explore the social structures, discourses, curricular components, etc., that impede women's participation in the fields of science, where they have so far had only a small representation.

In addition to all of the above, the educational factor leads to the employment factor. According to González-González et al. (2018), the problem of educational segregation extends to professional life. Finally, Cincera et al. (2017) point out that an optimal response to segregation is to encourage interactive learning through multimedia applications, in order to attract students' attention to science.

5. Conclusions

5.1. Methodologies and methods and population groups

According to the literature, the methodologies and methods that can be applied in gender gap studies in the STEM education sector may differ. Mixed models (Herman et al., 2019; Padwick et al., 2016) and multi-method approaches (Borsotti, 2018; Brauner et al., 2018; Ertl et al., 2017b; Finzel et al., 2018; Henriksen et al., 2015; Olmedo-Torre et al., 2018) can be used. Quantitative studies (Cantley et al., 2017; Cincera et al., 2017; Görlitz and Gravert, 2018; Kang et al., 2019; Reich-Stiebert and Eyssel, 2017; Salmi et al., 2016; Stoeger et al., 2017; Stoeger et al., 2017; Sullivan et al., 2015; Wulff et al., 2018), or qualitative studies (Botella et al., 2019; Martinho et al., 2015) can also be applied. On the other hand, another type of study is based on the review of initiatives (González-González et al., 2018; Heybach and Pickup, 2017; Peixoto et al., 2018).

However, what is most interesting is to know which population groups are of scientific interest in investigating this topic of study. The literature reveals that it is of interest to investigate from early ages to the working stages (González-González et al., 2018; Herman et al., 2019) through primary education (Padwick et al., 2016; Salmi et al., 2016; Sullivan et al., 2015), secondary (Brauner et al., 2018; Cincera et al., 2017; Kang et al., 2019; Wulff et al., 2018) and university (Ertl et al., 2017b; Henriksen et al., 2015; Martinho et al., 2015; Olmedo-Torre et al., 2018; Reich-Stiebert and Eyssel, 2017; Stoeger et al., 2017). Moreover, as revealed in the literature, it is not only interesting to focus on one age group. Research can be conducted with students and women who are at different stages of their educational trajectory (Botella et al., 2019; Cantley et al., 2017; Finzel et al., 2018; Görlitz and Gravert, 2018; Stoeger et al., 2017), such as students in primary, secondary and university education simultaneously.

5.2. Measurement and assessment resources

It is helpful to know what resources can be used to carry out studies in which the gender gap in the STEM education sector is studied and measured. Among the resources are gender gap measurement and assessment tools. After consulting the literature, it is noted that some instruments are aimed at detecting scientific identity, such as the Aspires Questionnaire (Padwick et al., 2016). There are also instruments for measuring attitudes towards science, such as: Deci-Ryan motivation, Situation motivation test, Science attitudes, Future educational plans, Raven test, Knowledge test and School achievement (Salmi et al., 2016).

On the other hand, Sullivan et al. (2015) have used an adaptation of the Papastergiou questionnaire to measure perceptions and self-efficacy concerning Computer Science. Along the lines of motivation, the Aiken Scale (Cantley et al., 2017) is helpful and validated for measuring interest in mathematics. In addition, Wulff et al. (2018), who conducted a Physics Olympiad, used: Content interest physics and Situational interest, for the measurement of interest. In the context of the IRIS project, Henriksen et al. (2015) used the validated IRIS Q questionnaire.

However, not all possible resources are quantitative instruments. Focus groups (Henriksen et al., 2015) and qualitative interviews (Borsotti, 2018; Martinho et al., 2015) can also be applied to approach knowledge through discourses. Another qualitative strategy is analysing through drawings (Brauner et al., 2018).

Cincera et al. (2017) used the SEI Questionnaire to close the reflection on data collection resources adapted from the NoS instrument. Kang et al. (2019) validated an instrument based on PRiSE and PISA within the MultiCO project. Olmedo-Torre et al. (2018) applied the validated survey "Survey for engineering students and graduates", collecting quantitative and qualitative data. Finally, Stoeger et al. (2017) applied the Questionnaire of Educational and Learning Capital (QELC) to analyse educational and learning capital.

5.3. Possible initiatives

On the other hand, another of the original contributions of this work is the systematisation of possible initiatives to implement aimed at closing the gender gap in the STEM education sector. In this sense, Peixoto et al. (2018) propose an initiative based on robotics as an inclusive and motivational measure to encourage interest from the school stage. Along the same lines, Sullivan et al. (2015) carried out outreach interventions through programming in secondary education.

In terms of proposals that worked positively in the studies, to boost interest and motivation in physics from secondary education, Wulff et al. (2018) applied a Physics Olympiad with boys and girls. Continuing also in the context of secondary education, a proposal that has generated positive effects is the redesign of the curriculum to promote STEM disciplines (Görlitz and Gravert, 2018). Also, to motivate female secondary school students to consider Computer Science as a possible field of study, Finzel et al. (2018) conducted a mentoring programme called make IT. In the same line, Stoeger et al. (2017) conducted a mentoring-based study within the context of the CyberMentor programme.

Using different methodologies, Cantley et al. (2017) promoted the enjoyment of mathematics through Collaborative Cognitive Activation Strategies.

In the university environment, the School of Engineering of the University of Valencia (ETSE-UV) promotes actions to increase the number of female students (Botella et al., 2019). The actions are institutional support, increasing the support network, promoting leadership, and promoting female role models.

Finally, initiatives should not only be promoted in schools and universities. As advocated by González-González et al. (2018), communities and businesses should also promote good practices. Finally, along the same lines, Herman et al. (2019) promote the re-entry of STEM women into the labour market through a Blended Learning programme.

In this way, it is concluded that it is worth investing resources and efforts in proposals based on scope interventions. According to the professional or training stage, applying one type of initiative or another will be more appropriate, as has been seen among those discussed above.

5.4. Impact of stereotypes

Measures and interventions could combat the effects of segregation, including the "Leaky Pipeline" phenomenon and the Stereotype Threat. These stereotypes are perpetuated over time. One of the socially acquired roles is that of family care for women, as demonstrated by Weisgram and Diekman (2015).

However, it is inappropriate to think that intervention measures should focus exclusively on women and girls. The gender gap is a system-wide problem. Education, business and society, and family and social actors are indispensable elements to be mentioned (Craig et al., 2019; Fisher and Margolis, 2003; Lehman et al., 2017; Sax et al., 2017). However, it remains striking that initiatives heavily target women and girls.

The scientific vocation is considerably affected by stereotypes. These stereotypes must be fought to deconstruct them. Investing efforts to close the gender gap should not be a matter of quotas or public image. As presented in a study by the Harvard Business Review (Hewlett et al., 2013), organisations that have a more diverse and inclusive workforce tend to be more innovative and experience greater market growth than companies that do not adopt such a philosophy.

However, action should not be delayed until secondary or university education. Authors such as Kang et al. (2019) –and accordance with Nurmi (2005)– confirm that career aspirations begin at the age of 11–12 years. Therefore, it is necessary to act from an early age, as supported by Brauner et al. (2010), Miller et al. (2018) and Wang (2013).

In this sense, girls generally prefer more family and contact-oriented occupations than boys, as Konrad et al. (2000) point out. Thus, women have continuously shown less interest in science and STEM occupations, especially in engineering (Ceci and Williams, 2010; Diekman et al., 2010).

In addition to personal goals, outcome expectations and interests, other constructs such as self-concept, motivation, attitudes, performance, and self-efficacy should be addressed. By enhancing scientific and confident identity and self-confidence in the discipline, positive self-knowledge can be enhanced. Moreover, if people have gains in agency (Bandura, 1977), they will feel more prepared to engage in what they really want to do.

5.5. Other segregation types

Finally, while the work presented in this paper focuses on horizontal segregation in women's entry and persistence in STEM fields, horizontal segregation is not the only form of segregation that exists. It is also essential to recognise the existence and impact of vertical segregation (Corbett and Hill, 2015). The latter type prevents or hinders promotion within the field, resulting in the Glass Ceiling phenomenon. Vertical segregation manifests mainly in the labour sector once women are immersed in the labour market. This phenomenon occurs because of the obstacles and barriers women face that make it difficult to progress at the same rate as their male counterparts (Cotter et al., 2001; de Welde and Laursen, 2011; Zeng, 2011). When the Glass Ceiling occurs in the academic and scientific space, it is accompanied by the Scissors Effect (Wood, 2009).

Perceived barriers include the lack of female role models and references, gender bias, hostile work environment, lack of natural work-family balance, unequal growth opportunities based on gender, and the gender pay gap (Botella et al., 2019; ISACA, 2017).

As can be seen, the two types of segregation, vertical and horizontal, share a common trigger: perceived barriers in the environment and context. For this reason, it is essential to work on these barriers to reduce them until they are eradicated.

6. Threats to the validity of the study

The systematic review and mapping presented in this paper, just like any other research method, may suffer from threats to its validity, as well as some limitations. Two categories of threats are identified: construct validity and validity of conclusions.

To preserve the validity of the construct, a series of measures were applied to maintain the objectivity of the results. These measures were: to review previous SLRs to confirm the need to carry out the presented study, and to follow systematised and documented phases marked by inclusion, exclusion, and quality criteria, with the ultimate aim of mitigating possible biases. On the other hand, although a search protocol has been defined, this does not guarantee that all publications related to the subject are included. In order to weigh up this threat, searches have been carried out in the two main research databases, namely Web of Science and Scopus.

In addition, for the validity of the conclusions, the data extraction process has been described step by step and documented by means of different spreadsheets which are available from the links: http://bit.ly/3a4gRM5, http://bit.ly/39lO0DX and http://bit.ly/36fnBpi.

The main limitation encountered in the research was the initial management of the large volume of results obtained from the equation of terms. The initial starting point was 4571 results, which meant that the start of the process took longer than desired.

Finally, as a future prospect, it is proposed to make systematic updates of the literature presented, with the aim of identifying new proposals for intervention, as well as methodological approaches to the factors influencing the gender gap.

Declarations

Author contribution statement

All authors listed have significantly contributed to the development and the writing of this article.

Funding statement

This work was supported by the Spanish Ministerio de Ciencia, Innovación y Universidades under a FPU fellowship (FPU017/01252). This work has been possible with the support of the Erasmus+ Programme of the European Union in its Key Action 2 "Capacity-building in Higher Education". Project W-STEM "Building the future of Latin America: engaging women into STEM" (Reference number 598923-EPP-1-2018-1-ES-EPPKA2-CBHE-JP). The content of this publication does not reflect the official opinion of the European Union. Responsibility for the information and views expressed in the publication lies entirely with the authors.

Data availability statement

Data associated with this study has been deposited at Verdugo-Castro, S., García-Holgado, A., & Sánchez-Gómez, M. C (2021). Code repository that supports the research presented in the paper 'The gender gap in higher.

STEM studies: A Systematic Literature Review' (v1.0) [Data set]. Zenodo. https://zenodo.org/record/5775211.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

Supplementary content related to this article has been published online at https://doi.org/10.1016/j.heliyon.2022.e10300.

Acknowledgements

This research work has been carried out within the PhD Programme of the University of Salamanca in the field of Education in the Knowledge Society (http://knowledgesociety.usal.es), and this research was supported by the Spanish Ministry of Science, Innovation and Universities with a grant for the training of University Teachers (FPU017/01252). Also, the authors would like to thank Elena P. Hernández Rivero (Language Centre-USAL) for translation support.

References

Ballatore, M.G., De Borger, J., Misiewicz, J., Tabacco, A., 2020. ANNA tool: a way to connect future and past students in STEM. IEEE Revista Iberoamericana De Tecnologias Del Aprendizaje-IEEE Rita 15 (4), 344–351.

Bandura, A., 1977. Self-efficacy: toward a unifying theory of behavioral change. Psychol. Rev. 84 (2), 191–215.

Berryman, S.E., 1983. Who Will Do Science? Minority and Female Attainment of Science and Mathematics Degrees: Trends and Causes. Rockefeller Foundation.

Bian, L., Leslie, S.-J., Cimpian, A., 2017. Gender stereotypes about intellectual ability emerge early and influence children's interests. Science 355 (6323), 389–391.

Blackburn, H., 2017. The status of women in STEM in higher education: a review of the literature 2007–2017. Sci. Technol. Libr. 36 (3), 235–273.

Borsotti, V., 2018. Barriers to gender diversity in software development education: actionable insights from a Danish case study. In: 40th ACM/IEEE International Conference on Software Engineering: Software Engineering Education and Training. ICSE-SEET 2018, Gothenburg; Sweden, pp. 146–152, 30 May 2018 through 1 June 2018.

Botella, C., Rueda, S., López-Iñesta, E., Marzal, P., 2019. Gender diversity in STEM disciplines: a multiple factor problem. Entropy 21 (1).

Bourdieu, P., 1980a. Le capital social. Actes de La Recherche En Sciences Sociales 31, 2–3.

Bourdieu, P., 1980b. L'identité et la représentation. Actes de La Recherche En Sciences Sociales 35 (1), 63–72.

Bourdieu, P., 1984. La représentation de la position sociale. Actes de La Recherche En Sciences Sociales 52 (1), 14–15.

Brauner, P., Leonhardt, T., Ziefle, M., Schroeder, U., 2010. The effect of tangible artifacts, gender and subjective technical competence on teaching programming to seventh graders. In: Hromkovič, J., Královič, R., Vahrenhold, J. (Eds.), Teaching Fundamentals Concepts of Informatics. Springer, pp. 61–71.

Brauner, P., Ziefle, M., Schroeder, U., Leonhardt, T., Bergner, N., Ziegler, B., 2018. Gender influences on school students' mental models of computer science A quantitative rich picture analysis with sixth graders. Proceedings of the 4th Conference on Gender & IT 113–122 *(GENDERIT '18)*.

Canedo, E.D., Tives, H.A., Marioti, M.B., Fagundes, F., de Cerqueira, J.A.S., 2019. Barriers faced by women in software development projects. Information 10 (10).

Cantley, I., Prendergast, M., Schlindwein, F., 2017. Collaborative cognitive-activation strategies as an emancipatory force in promoting girls' interest in and enjoyment of mathematics: a cross-national case study. Int. J. Educ. Res. 81, 38–51.

Ceci, S.J., Williams, W.M., 2010. The Mathematics of Sex: How Biology and Society Conspire to Limit Talented Women and Girls. Oxford University Press, pp. xv–270.

Ceci, S.J., Ginther, D.K., Kahn, S., Williams, W.M., 2014. Women in academic science: a changing landscape. Psychol. Sci. Public Interest: J. American Psychol. Soci. 15 (3), 75–141.

Cheryan, S., Ziegler, S.A., Montoya, A.K., Jiang, L., 2017. Why are some STEM fields more gender balanced than others? Psychol. Bulletin 143 (1), 1–35.

Cincera, J., Medek, M., Cincera, P., Lupac, M., Ticha, I., 2017. What science is about—development of the scientific understanding of secondary school students. Res. Sci. Tech. Edu. 35 (2), 183–194.

Codiroli Mcmaster, N., 2017. Who studies STEM subjects at A level and degree in England? An investigation into the intersections between students' family background, gender and ethnicity in determining choice. British Edu. Res. J. 43 (3), 528–553.

Corbett, C., Hill, C., 2015. Solving the Equation: the Variables for Women's success in Engineering and Computing. AAUW.

Correll, S.J., 2001. Gender and the career choice process: the role of biased self-assessments. American J. Sociol. 106 (6), 1691–1730.

Cotter, D.A., Hermsen, J.M., Ovadia, S., Vanneman, R., 2001. The glass ceiling effect. Social Forces 80 (2), 655–681.

Craig, S.S., Auerbach, M., Cheek, J.A., Babl, F.E., Oakley, E., Nguyen, L., Rao, A., Dalton, S., Lyttle, M.D., Mintegi, S., Nagler, J., Mistry, R.D., Dixon, A., Rino, P., Kohn-Loncarica, G., Dalziel, S.R., 2019. Preferred learning modalities and practice for critical skills: a global survey of paediatric emergency medicine clinicians. Emergency Medi. J. 36 (5), 273–280.

Davila Dos Santos, E., Albahari, A., Diaz, S., De Freitas, E.C., 2021. 'Science and Technology as Feminine': raising awareness about and reducing the gender gap in STEM careers. J. Gender Stud. 31 (4), 505–518.

de Welde, K., Laursen, S.L., 2011. The glass obstacle course: informal and formal barriers for women ph.D. Students in STEM fields. Int. J. Gender, Sci. Tech. 3 (3), 571–595.

Diekman, A.B., Brown, E.R., Johnston, A.M., Clark, E.K., 2010. Seeking congruity between goals and roles: a new look at why women opt out of science, technology, engineering, and mathematics careers. Psychol. Sci. 21 (8), 1051–1057.

Ertl, B., Luttenberger, S., Paechter, M., 2017. The impact of gender stereotypes on the self-concept of female students in STEM subjects with an under-representation of females. Frontiers Psychol. 8 (703).

European Institute of Gender Equality, 2018. Overview | Gender Statistics Database. EIGE. https://eige.europa.eu/gender-statistics/dgs.

Finzel, B., Deininger, H., Schmid, U., 2018. From Beliefs to Intention: Mentoring as an Approach to Motivate Female High School Students to Enrol in Computer Science Studies. In: 4th Conference on Gender and IT, GenderIT 2018. Heilbronn University, Heilbronn; Germany, pp. 251–260, 14 May 2018 through 15 May 2018.

Fisher, A., Margolis, J., 2003. Unlocking the clubhouse: women in computing. In: Psychol. Women Q, 26. MIT Press.

García-Holgado, A., Díaz, A.C., García-Peñalvo, F.J., 2019a. Engaging women into STEM in Latin America: W-STEM project. Proceedings of the Seventh International Conference on Technological Ecosystems for Enhancing Multiculturality 232–239.

García-Holgado, A., Vázquez-Ingelmo, A., Verdugo-Castro, S., González, C., Gómez, M.C.S., Garcia-Peñalvo, F.J., 2019b. Actions to promote diversity in engineering studies: a case study in a computer science degree. IEEE Global Engineering Education Conference (EDUCON) 793–800.

García-Holgado, A., Verdugo-Castro, S., Sánchez-Gómez, M.C., García-Peñalvo, F.J., 2019c. Trends in studies developed in Europe focused on the gender gap in STEM. Proceedings of the XX International Conference on Human Computer Interaction 47, 1–47, 8.

González-González, C.S., García-Holgado, A., De Los Ángeles Martínez-Estévez, M., Gil, M., Martin-Fernández, A., Marcos, A., Aranda, C., Gershon, T.S., 2018. Gender and Engineering: Developing Actions to Encourage Women in Tech, pp. 2082–2087.

Görlitz, K., Gravert, C., 2018. The effects of a high school curriculum reform on university enrollment and the choice of college major. Education Economics 26 (3), 321–336.

Gottfried, M., Owens, A., Williams, D., Kim, H.Y., Musto, M., 2017. Friends and Family: A Literature Review on How High School Social Groups Influence Advanced Math and Science Coursetaking, 25. Education Policy Analysis Archives.

Guo, J., Eccles, J.S., Sortheix, F.M., Salmela-Aro, K., 2018. Gendered pathways toward STEM careers: the incremental roles of work value profiles above academic task values. Frontiers Psychol. 9.

Hall, W.M., Schmader, T., Croft, E., 2015. Engineering exchanges: daily social identity threat predicts burnout among female engineers. Social Psychol. Personality Sci. 6 (5), 528–534.

Henriksen, E.K., Dillon, J., Ryder, J., 2015. Understanding Student Participation and Choice in Science and Technology Education. Springer Netherlands, p. 412.

Herman, C., Gracia, R., Macniven, L., Clark, B., Doyle, G., 2019. Using a blended learning approach to support women returning to STEM. Open Learning 34 (1), 40–60.

Hewlett, S.A., Marshall, M., Sherbin, L., 2013. How Diversity Can Drive Innovation. Harvard Business Review. https://hbr.org/2013/12/how-diversity-can-drive-innovation.

Heybach, J., Pickup, A., 2017. Whose STEM? Disrupting the gender crisis within STEM. Edu. Stud.-Aesa 53 (6), 614–627.

ISACA, 2017. ISACA'S 2017 Women In Technology Survey, "The Future Tech Workforce: Breaking Gender Barriers". http://www.isaca.org/info/2017-women-in-technology-survey/index.html?.

Jacobs, J.A., Ahmad, S., Sax, L.J., 2017. Planning a career in engineering: parental effects on sons and daughters. Social Sci. 6 (2).

Kang, J., Hense, J., Scheersoi, A., Keinonen, T., 2019. Gender study on the relationships between science interest and future career perspectives. Int. J. Sci. Edu. 41 (1), 80–101.

Kitchenham, B., 2004. Procedures for Performing Systematic Reviews. Keele University.

Kitchenham, B., Charters, S., 2007. Guidelines for Performing Systematic Literature Reviews in Software Engineering. Version 2.3.

Konrad, A.M., Ritchie, J.E., Lieb, P., Corrigall, E., 2000. Sex differences and similarities in job attribute preferences: a meta-analysis. Psychol. Bulletin 126 (4), 593–641.

Lehman, K.J., Sax, L.J., Zimmerman, H.B., 2017. Women planning to major in computer science: who are they and what makes them unique? Computer Sci. Edu. 26 (4), 277–298.

Lent, R.W., Brown, S.D., Hackett, G., 1994. Toward a unifying social cognitive theory of career and academic interest, choice, and performance. J. Vocational Behav. 45 (1), 79–122.

López-Iñesta, E., Botella, C., Rueda, S., Forte, A., Marzal, P., 2020. Towards breaking the gender gap in science, technology, engineering and mathematics. IEEE Revista Iberoamericana De Tecnologias Del Aprendizaje-IEEE Rita 15 (3), 233–241.

Martinho, M., Albergaria-Almeida, P., Dias, J.T., 2015. Cooperation and competitiveness in higher education science: does gender matter? In: Uzunboylu, H. (Ed.), Proceedings of 6th World Conference on Educational Sciences, 191. Elsevier Science Bv, pp. 554–558.

Miller, D.I., Nolla, K.M., Eagly, A.H., Uttal, D.H., 2018. The development of children's gender-science stereotypes: a meta-analysis of 5 decades of U.S. Draw-A-Scientist studies. Child Develop. 89 (6), 1943–1955.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., Group, T.P., 2009. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLOS Medicine 6 (7), e1000097.

Nosek, B.A., Smyth, F.L., Sriram, N., Lindner, N.M., Devos, T., Ayala, A., Bar-Anan, Y., Bergh, R., Cai, H., Gonsalkorale, K., Kesebir, S., Maliszewski, N., Park, J., Schnabel, K., Shiomura, K., Tulbure, B.T., Wiers, R.W., Akrami, N., Ekehammar, B., et al., 2009. National differences in gender–science stereotypes predict national sex differences in science and math achievement. PNAS 106 (26), 5.

Nurmi, J.-E., 2005. Thinking about and acting upon the future: development of future orientation across the life span. In: Understanding Behavior in the Context of Time: Theory, Research, and Application. Lawrence Erlbaum Associates Publishers, pp. 31–57.

Olmedo-Torre, N., Sanchez Carracedo, F., Salan Ballesteros, M.N., Lopez, D., Perez-Poch, A., Lopez-Beltran, M., 2018. Do female motives for enrolling vary according to STEM profile? IEEE Trans. Edu. 61 (4), 289–297.

Padwick, A., Dele-Ajayi, O., Davenport, C., Strachan, R., 2016. Innovative methods for evaluating the science capital of young children. 46th Annual Frontiers in Education Conference, FIE 2016-November, 1–5.

Peixoto, A., Strachan, R., de los Ángeles Martínez, M., González-González, C.S., Plaza, P., Blázquez, M., Castro, M., 2018. Diversity and inclusion in engineering education: looking through the gender question. In: IEEE Global Engineering Education Conference (EDUCON). IEEE, pp. 2077–2081.

Petersen, K., Vakkalanka, S., Kuzniarz, L., 2015. Guidelines for conducting systematic mapping studies in software engineering: an update. Infor. Software Tech. 64, 1–18.

Petticrew, M., Roberts, H., 2005. Systematic Reviews in the Social Sciences: A Practical Guide. Blackwell Publishing.

Reich-Stiebert, N., Eyssel, F., 2017. (Ir)relevance of Gender?: on the Influence of Gender Stereotypes on Learning with a Robot. ACM/IEEE International Conference on Human-Robot Interaction, pp. 166–176. *Part F127194*.

Reiss, K., Sälzer, C., Schiepe-Tiska, A., Klieme, E., Köller, O., 2016. PISA 2015. Eine Studie zwischen Kontinuität und Innovation.

Salmi, H., Thuneberg, H., Vainikainen, M.-P., 2016. How do engineering attitudes vary by gender and motivation? Attractiveness of outreach science exhibitions in four countries. European J. Eng. Edu. 41 (6), 638–659.

Sax, L.J., Lehman, K.J., Jacobs, J.A., Kanny, M.A., Lim, G., Monje-Paulson, L., Zimmerman, H.B., 2017. Anatomy of an enduring gender gap: the evolution of women's participation in computer science. J. Higher Edu. 88 (2), 258–293.

STEMettes, 2021. We're showing the next generation that girls do Science, Technology, Engineering & Maths (STEM) too at our free, fun, food-filled experiences. Stemettes ®. https://stemettes.org/.

Stewart-Williams, S., Halsey, L.G., 2021. Men, women and STEM: why the differences and what should be done? European J. Personality 35 (1), 3–39.

Stoeger, H., Greindl, T., Kuhlmann, J., Balestrini, D.P., 2017a. The learning and educational capital of male and female students in STEM magnet schools and in extracurricular STEM programs: a study in high-achiever-track secondary schools in Germany. J. Edu. Gifted 40 (4), 394–416.

Stoeger, H., Hopp, M., Ziegler, A., 2017b. Online mentoring as an extracurricular measure to encourage talented girls in STEM (science, technology, engineering, and mathematics): an empirical study of one-on-one versus group mentoring. Gifted Child Quarterly 61 (3), 239–249.

Stoet, G., Geary, D.C., 2018. The gender-equality paradox in science, technology, engineering, and mathematics education. Psychol. Sci. 29 (4), 581–593.

Sullivan, K., Byrne, J.R., Bresnihan, N., O'Sullivan, K., Tangney, B., 2015. CodePlus—designing an after school computing programme for girls. In: IEEE Frontiers in Education Conference, FIE.

Think Physics, 2016. Think Physics. http://www.thinkphysics.org.

Verdugo-Castro, S., García-Holgado, A., Sánchez-Gómez, M.C., 2021. Code Repository that Supports the Research Presented in the Paper 'The Gender gap in Higher STEM Studies: A Systematic Literature Review' (v1.0 *[Data set]*. Zenodo. https://zenodo.org/record/5775211.

Wang, X., 2013. Why students choose STEM majors: motivation, high school learning, and postsecondary context of support. American Edu. Res. J. 50 (5), 1081–1121.

Wang, M.-T., Degol, J., 2013. Motivational pathways to STEM career choices: using expectancy-value perspective to understand individual and gender differences in STEM fields. Develop. Review 33 (4), 304–340.

Weisgram, E., Diekman, A., 2015. Family friendly STEM: perspectives on recruiting and retaining women in STEM fields. Int. J. Gender, Sci. Tech. 8 (1), 38–45.

Williams, W.M., Ceci, S.J., 2015. National hiring experiments reveal 2:1 faculty preference for women on STEM tenure track. Proceedings of the National Academy of Sciences of the United States of America 112 (17), 5360–5365.

Winterbotham, M., 2014. The UK Commission's Employer Skills Survey 2013: UK Results. London, UK Commission, 200.

Wood, J.T., 2009. Gendered Lives: Communication, Gender, and Culture, eighth ed. Wadsworth https://dokumen.pub/gendered-lives-communication-gender-amp-culture-twelfth-edition-9781305280274.html.

World Economic Forum, 2021. The Global Gender Gap Report 2021. Insight Report. World Economic Forum. https://www.weforum.org/reports/global-gender-gap-report-2021/.

Wulff, P., Hazari, Z., Petersen, S., Neumann, K., 2018. Engaging young women in physics: an intervention to support young women's physics identity development. Physical Review Physics Edu. Res. 14 (2).

Yazilitas, D., Svensson, J., de Vries, G., Saharso, S., 2013. Gendered study choice: a literature review. A review of theory and research into the unequal representation of male and female students in mathematics, science, and technology. Edu. Res. Evaluation 19 (6), 525–545.

Zeng, Z., 2011. The myth of the glass ceiling: evidence from a stock-flow analysis of authority attainment. Social Science Research 40 (1), 312–325.