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Review article

Factors to consider from education to promote an image of science and technology with a gender perspective

Carolina Martín-Gámez [a,*], Desireé García-Durán [a], Alicia Fernández-Oliveras [b], Verónica Torres-Blanco [a]

[a] Department of Science Education, University of Malaga, Malaga, Spain
[b] Department of Science Education, University of Granada, Granada, Spain

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ABSTRACT

The image of science influences on the decision of girls when opting for studies related to STEM disciplines, since in many cases they are perceived as masculine, due to the image promoted from different areas of society, including the education system. Consequently, women do not feel identified with these disciplines, and prejudices and beliefs are generated that promote the well-known gender gap that exists in these areas. Therefore, this article sets out the considerations to be taken into account from science and technology education to avoid showing an image of science as individual, stereotyped and elitist, among other aspects, and, ultimately, to promote an image of science and technology with a gender perspective. It is necessary to transform curricular content and teacher training following these considerations, so that students perceive a realistic image of science and technology. This will have a positive influence by minimising the Pygmalion effect that occurs in girls and helping to combat social inequality that generates the under-representation of women in scientific-technological fields.

1. Introduction

There is currently great concern about the relatively low number of students in general and girls in particular who are choosing science and technology as areas for their future professional development [1, 2, 3]. In other words, there is evidence of a low representation of women both in higher education and in the study of degrees relating to the STEM subjects (Science, Technology, Engineering and Mathematics). In this regard, a report by UNESCO [4] shows the surprising inequality between genders, revealing how females account for a mere 35% of students on study programs related to STEM and just 28% of researchers in the world. More specifically, in Spain, in 2017, with 53.3% of university qualifications obtained by women, the rate for those graduating with STEM degrees out of the total stood at only 13.1% compared to 30.4% of male graduates [5]. As for the European Union, the data is similar, with no progress since 2015 [6]. In 2018, female doctorates in STEM fields were in Physical Sciences (38.4%), Mathematics and Statistics (32.5%), ICT (20.8%), Engineering and Business Engineering (27%), and Architecture and Construction (37.2%). Another example occurs in the United States, where the data show that even though the proportion of women and men working in occupations other than STEM is almost equal, in the case of STEM professions, this disproportion continues to occur with 24% of women working in areas related to the scientific-technological sectors compared to 76% of men [2]. It is a problem that exists in all countries, although data points out it is higher in developed countries [7]. For example, in Egypt, the data indicates that achievements in STEM areas of women are 7,73% in front of 15,30% in men [8].

This tendency has been the case for over a decade [9, 10, 11, 12]. Thus, already in 2004, the ROSE (Relevance of Science Education) project indicated that adolescents aged 15 were unlikely to choose a STEM profession [13]. It revealed that, in the majority of the industrialised countries where the study was carried out, students preferred subjects other than science, along with a future professional career away from technology. In addition, the project showed that in some countries, there was a large gender bias, that is, girls showed a greater dislike for subjects and future jobs related to science and technology [10, 13]. For example, in countries such as Norway, Denmark, Sweden, Latvia, Russia or Israel, differences of 1 point out of 5 are found when students are asked if they would like to have a job related to technology (20% less predisposition in female students) [14, 15]. Notwithstanding, for most developing countries where the project was implemented, there was a greater preference for science in education and related professions, and a smaller

* Corresponding author.
E-mail address: cmartin@uma.es (C. Martín-Gámez).

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gender difference than in industrialized countries, but still with appreciable gender differences and maximum scores of 3.5 out of 5 in questions about students willing to enrol in scientific or technical studies [14, 15] Spain coincided with the pattern for the industrialised countries, with Spanish students showing little intention of opting for higher STEM studies, especially in the case of women [16]. This situation is surprising, given that students consider science and technology as being fields of great relevance and importance for society [17]. Given this contradiction, there may be specific factors that are having an influence on this biased choice in higher education. Research in differential psychology has shown that, in general, men and women possess similar capabilities for studying science and technology [18, 19]. Thus, the lack of representation of women both in higher education and in the study of degrees in these areas must be due to other factors.

In this sense, Kerkhoven et al. [20] recognize that, amongst other issues relating to this lack of vocational interest that occurs at the beginning of adolescence, are those connected to the stereotypes and gender biases promoted from the different spheres of society, including those from the educational system. For some, it seems to originate in problems relating to identity, upon observing that the image of STEM subjects is loaded with elitist stereotypes and disassociated from the interests of students [21, 22]. Further, a number of authors assert that the view held by girls about what work in these professional fields is like makes it considerably unlikely for them to be inclined towards a future scientific-technological career [11, 23, 24]. There is a belief, for example, that training and working as a scientist or technologist is incompatible with having a family and raising children means they rule out STEM professions, seeing them as irreconcilable with these personal objectives. Other beliefs also create obstacles in this regard, such as thinking that it is impossible to break down barriers in order to achieve goals in professional scientific-technological spheres [11] or mistakenly considering there to be cognitive factors that mean women are less capable of studying STEM subjects [5].

This situation raises different problems, amongst which is the current low participation in science and technology of younger generations, in general, and young women, in particular [25]. Other facets of identity may also be influenced, such as migrant status, religion, ethnicity, or social class [21], so the issue has the intersectional significance that characterizes inequalities [26]. Indeed, reflections on feminist scholars and frameworks that critically explore issues of race, class, gender, and sexual orientation lead to consider contemporary events and trends affecting higher education, which include persistent gendered and racialized inequities in science, technology, engineering, and mathematics fields [27]. Given the complexity of the subject and the prevalence of the gender factor, this study focuses on addressing the lower connection of women in general to these fields compared to that of men.

For example, in 2011, in the United States, the average of working women with STEM degrees was half that of men, with them having less of a presence in engineering and more in biological sciences [28]. The low representation of women in STEM subjects may also result in economic and social consequences. Experts highlight the fact that to prosper over time, the economies of countries are not just reliant on a scientifically literate population but also need a large workforce of professionals from science, technology, engineering and mathematics, as demonstrated by the health crisis brought about by COVID-19 [29,30]. Moreover, given that STEM careers are often more well-paid, this would open the doors to a greater equilibrium between genders from a socio-economic perspective [31]. In addition, regarding to the comprehensive education of people, it is important to draw attention to the fact that it is not just what STEM subjects can contribute to collective development, but also to personal development [32]. That is, there must be a consideration of the discrimination suffered by women at a level of personal realisation that the denial of their presence in scientific-technological and mathematical areas supposes. In short, ignoring the under-representation of women in STEM fields does not only have serious economic consequences, it perpetuates gender inequality and social injustice.

A reflection on why women's involvement in STEM is decreasing, despite support and new opportunities, could point to traditional perspectives of political tendencies raised in some countries (e.g., the "new far right" in Europe [33]). That would mean that women would have to fall back on traditionally more feminine roles (e. g., the rhetoric of Kinder, Küche, Kirche -children, kitchen, church-, with a long tradition in Germany [34]), far from those engaged in STEM fields [35].

This all underlines the importance of involving under-represented segments of the population in STEM fields, as is the case for women, wherein education must carry out a fundamental role. As Jones, Howe & Rua [36] affirm, it involves enabling STEM disciplines to be shown in an appropriate way for both girls and boys. For this to take place it is necessary to work from science and technology education, as well as providing female references, giving a realistic image of science and technology for students not only to contemplate these areas as something important, but also as something they want to form part of. Thus, the aim of this study is to show what factors to consider in order for an image of science and technology with a gender perspective to be promoted from education.

To do so, it has conducted a procedure from a qualitative approach, through a deductive process carried out from the theoretical analysis. Through interconnected tasks of reduction, data arrangement, transformation, and extraction and verification of the collected information, a set of factors was developed.

For this, techniques such as classification and categorization, models, and typologies were used. Once the information was organized, explanatory matrices and graphs were constructed to establish connections between the data and make interpretations about them [37]. Subsequently, data collection and review processes were carried out to identify regularities, build a frame of reference and develop data typologies. The result was the definition of the following combination of factors to be considered from education to promote an image of science and technology with a gender perspective.

2. Image of science and gender perspective

A decisive element for girls when opting for studies linked to STEM disciplines is the image they have of who, what and how you work in them [11, 12, 24, 31, 38, 39, 40, 41, 42]. In other words, science and technology education should not only consider the understanding "of" science, rather comprehension "about" it [17, 43, 44]. It is about tackling aspects more related to nature of science (NOS) than what science is, what its objectives are and how knowledge of it is built.

This approach is reinforced by studies that reveal the existence in the population of certain beliefs that hinder understanding of NOS, including ideas about science based on gender stereotypes [39, 45]. Scientific-technological contents are understood as masculine, due to the image promoted from different sections of society, such as the media, the educational system and the family sphere, amongst others [20, 38]. Hence, prejudices arise based on the main idea that science and technology are not appropriate for women. This creates negative consequences in attitudes towards STEM studies on the part of students in general and girls in particular [11, 12, 24], due to them not feeling identified with these subjects.

For all of the foregoing, there is a need to work from STEM education on aspects that are aimed at promoting a realistic image of those who participate in the construction of science and technology, and how and why they do it, connecting with the interests of boys and girls. Also, this helps to break gender stereotypes and avoid inadvertent reinforcement of outdated stereotypes and norms [46]. In this sense, such aspects are outlined below as factors that are going to permit the promotion of an image of science and technology with a gender perspective.

2.1. Importance in society

Something that should be addressed with students is the importance, usefulness and need of science and technology in society as key elements that have an influence on our environment, which has been evident in the COVID-19 sanitary crisis. That is, the education system should show them the existing interaction between science, technology and society [47], making them see that whatever is addressed in scientific-technological matters has a repercussive effect on their environment and lives [31].

This approach, in the case of girls, is even more necessary for a fundamental reason related to the professional preferences shown by them. Studies such as those carried out by Su, Rounds & Armstrong [42] revealed that women are more attracted to professions with a greater social orientation, which have a strong influence on the care of others [31]. In other words, girls show a greater preference towards professional futures that permit them to have a more beneficial impact on society [24]. It is because of this that addressing the social usefulness of STEM subjects will contribute to students having a better perception of thereof [48]. In other words, drawing attention to aspects especially valued by society, such as "the well-being of humanity (for example, research for curing disease), usefulness for daily life and personal interest in science and technology topics" [17] (p. 29), will promote the choosing of STEM subjects amongst girls.

2.2. Collaborative image of science

One of the most widespread images to come out of the scientific and technological knowledge building process is the individualism and isolation of those who develop it [49]. Christidou, Bonoti & Kontopoulou [39], in their study on the perceived image by students of people dedicated to science and technology, found that a significant number of participants considered that this type of job, as well as being done by men, was on the whole carried out on an individual basis That is, students, including girls, do not appear to hold the view that work in STEM areas requires a combined effort from various people, and much less so, that it implies the collaboration of different genders.

It is important to consider this factor, given that studies point to a preference on the part of women for jobs where there is interaction and social contact [50]. There is a need, from the educational system, and more specifically from STEM subjects, to break from the individualist vision of science and technology, and for there to be promotion of an image that shows that the actions and achievements related to them are the result of a collaborative effort by men and women trying to reach a common goal [21]. For this to happen, there is a need for the promotion of an image of equality from these areas through two channels. Firstly, learning to do science and technology in this way via the teaching-learning methodology employed in the classroom, which should be based on the combined work of students of different genders to achieve a common objective; secondly, via the different educational resources uses, which should show a collaborative image in the building of scientific and technological knowledge.

2.3. Image of science outside academia

The teaching and learning of science should contribute to the building of cognitive structures in students, which should be connected to familiar contexts in order to facilitate their understanding [51]. However, in general, the science and technology taught in educational centres are far removed from reality and, further, bear little relation to that developed in professions in the STEM sphere [52, 53]. For Occelli & Valeiras [54] there are highly impactful educational resources that use uncontextualised scientific and technological terminology, without providing explanations of events, and leaving students to extract the relationship between concepts that are explicit in such resources and reality. In this regard, Bamberger [11] argues that students are unfamiliar with the concepts used by scientists and technologists, and they are unrelated to what they study in their subjects. This means that these materials are not very interesting or attractive to students [9], and there is no encouragement to construct frameworks for allowing students to create and place knowledge, taking into account the zone of proximal development proposed by Vygotski. Therefore, promoting an image of science and technology that goes beyond the merely academic would avoid the rejection and discouraging perception of the subjects held by students [55].

This approach, as well as being justified from a general point of view, acquires more emphasis from the gender perspective. Failing to offer girls the opportunity to find connections between science and technology and the lives of people and their environment could mean they find it difficult to observe their value and relevance for improving society. This may influence their vocational orientation, negatively affecting their chance to opt for degrees related to STEM subjects [21].

This is why it is important for the teaching of these subjects to encourage girls to continuously make connections between scientific-technological knowledge and their daily lives, thus understanding the importance and value of this knowledge, not in an abstract sense, but from their meaningfulness or usefulness for society [31]. Equally, these connections must be related to situations that correspond to the most recent events possible, in this way producing a real and current perception of their usefulness for society [47].

2.4. Image of science beyond the empirical

In the majority of cases the educational system promotes a vision of science and technology as purely empirical disciplines. This appears to create a lack of interest on the part of pre-adolescents, in general, and girls, in particular, in scientific-technological subjects [21]. That is to say, one possible reason for the lack of predilection for STEM studies is their empiricist vision, according to which science and technology are only linked to experimental activity and, on occasions, to dangerous situations perceived as specific to the male gender. Moreover, teaching-learning in these disciplines is frequently focused on the final product obtained, ignoring fundamental processes of scientific methodology that go beyond the purely empirical [54].

It is necessary, therefore, to revert to the approach in the sense indicated for two fundamental reasons. The first is it appears that girls find it complicated to dedicate themselves to these supposedly less safe fields of work due to the notions they have been educated in, which have made them think that these spaces are not appropriate for women [4]. This means that choosing STEM degrees supposes a multitude of barriers for them, being distanced from such cultural norms [22]. The second reason is related to their interests and preferences, which cover the development of procedures more associated with communication and reflection [24]. Therefore, affording visibility to the more reflexive and communicative part of the processes employed in the building of scientific-technological knowledge may combat the lack of interest of women in STEM related fields [21].

In other words, it is necessary to address the teaching and learning of science and technology by combining reliable empirical procedures with others where, additionally, students can put into play skills related to reflection, communication and the contrasting of ideas [31]. It involves following a constructivist approach via which thinking skills necessary for working in the fields of science and technology are developed.

2.5. Non-elitist image of science

The belief that it is necessary to possess specific skills for STEM-related fields is another element that explains the insufficient representation of women therein [24]. Recent studies indicate there is a greater probability of people thinking that fields dominated by men require an innate intelligence than those with a greater proportion of women [40, 41]. Along the same line, Bian, Leslie & Cimpian [56] put forward that at a social level a greater intellectual capacity is attributed to men than women and that women even assume that they lack the same brilliance, despite getting good results in scientific-technological subjects [41]. In other words, there is an extended notion that in order to dedicate oneself to science and technology people must be gifted with innate abilities, and thus they are fields that are only in reach of a few, in particular, men [21]. Therefore, women may be avoiding STEM degrees because they mistakenly believe that not only are innate qualities required for success, but also that it is less likely that they possess such qualities.

However, elitism is not the key to success in scientific-technological areas; rather, other attitudes make achieving it possible, such as effort, dedication and interest. Thus, if the value of these attitudes in students is strengthened from scientific-technological education, this will help to break the gender gap. In addition, this will improve equality and equity in the sense of developing the maximum potential of each student [4]. For this to happen, it is necessary to create expectations of achievement that are favourable in all students, trusting their qualities, in a way that they all see any goal within STEM subjects as reachable [24]. This will eradicate the idea that only some, above all men, will in reality become scientists and technologists, being considered "people of science" [21].

2.6. Stereotypical image of science

When a group is stereotyped, a whole series of characteristics is applied to it which are deemed valid for all of its members, thus cancelling out individual characteristics [57]. Students attribute qualities to people who opt for STEM subjects depending on their experiences in these areas. According to these stereotypes, those who work in science are men with very specific physical features (beard and/or moustache, glasses and white coat) [22, 39, 53], untidy clothes and look, and an appearance of intelligence, seriousness and responsibility [11]. This is reinforced by the biased and segregating image fostered from textbooks [11], which encourages boys to attribute science to their own gender, which girls do not [16, 21, 36, 39, 58].

These gender stereotypes represent an element that is influential in girls when contemplating the possibility of choosing STEM professions [22, 24, 38]. It is thus necessary to break with these beliefs imposed from society, to create in students an appropriate scientific identity [21], in accordance with an image of science and technology contrary to any stereotype or barrier, understanding that people who work in these areas of knowledge do not have determined characteristics.

2.7. Factors to promote an image of science and technology with a gender perspective

To clarify all the ideas and reflections shown above, Table 1 is presented, which tries to collect each of the factors that must be considered to address the teaching of science and technology aligned with female preferences.

Table 1. Factors to promote an image of science and technology with a gender perspective.

Factors	Educational Implications
Importance in society	Show the usefulness of science and technology as a key element that affects our society in many areas (for example, research for curing disease).
Collaborative image of science	- Learn to do science and technology through a methodology based on the combined work of students of different genders to achieve a common objective.
	- Use different educational resources, which should show a collaborative image in the building of scientific and technological knowledge.
Image of science outside academia	The teaching of STEM subjects where the establishment of connections between scientific-technological knowledge and their daily lives is favoured (situations that correspond to the most recent events possible).
Image of science beyond the empirical	Developing teaching and learning of science and technology by combining empirical procedures with others where, additionally, students can put into play skills related to reflection, communication, and the contrasting of ideas.
Non-elitist image of science	Encourage the creation of favourable achievement expectations in all students, trusting their qualities, so that everyone sees any goal within STEM subjects as attainable.
Stereotypical image of science	Fostering reflections with students about real scientific identity, contrary to any stereotype or barrier, to understand that people who work in these areas of knowledge do not have determined characteristics.

3. Conclusions and implications for educational practice

The majority of girls, unlike boys, do not have experiences in their environment related to science and technology, to which the gender gap is significant in this regard [21, 23]. Stereotypes and negative expectations "are particularly critical for students who are vulnerable due to lack of prior experiences or low levels of self-confidence, both common attributes of girls in relation to science" [59] (p. 397). Prejudices based on the principal idea that science and technology are unsuitable for women create negative consequences in attitudes towards STEM studies by students in general, and girls in particular [11, 12, 24], who neither feel identified with these fields of knowledge, nor prepared to become professionals within them.

In view of this, schools must offer equal opportunities to afford all students the same possibilities of choosing to continue with scientific studies [36]. Placing emphasis on how education contributes towards changing or reproducing social, class and gender inequalities [60], science and technology education must play a fundamental role when involving women in STEM fields. Education in these areas, as part of the comprehensive education of individuals, must be one more channel of empowerment and should be linked to the integration of feminist methodologies and epistemologies in the shared building of knowledge [61]. Furthermore, and in line with these authors, spaces should be offered in these areas for working on critical reflection on the reproduction of gender power relationships inside and outside the classroom, contributing to training active subjects of social change as regards gender inequality. In this regard, it is of utmost importance to influence teacher training, taking into account the persistence of sexist beliefs that can still be found in future teachers, who would be willing to transmit this ideology in the face of the diverse legislative proposals that pursue equality [62].

For this to take place, it is necessary to transform curricular content teacher training following the considerations put forward in this article, with the objective of promoting an image of science and technology with a gender perspective. This will have a beneficial effect on teaching and learning approaches relating to science-technology disciplines in compulsory education, minimising the Pygmalion effect on girls. In other words, from scientific and technological education, it is necessary to work on the expectations and beliefs of the students, as this manuscript points out so that there are no obstacles that can directly influence their decisions. It involves addressing aspects relating to the nature of science which contribute to the creation of a realistic image of those who participate in scientific-technological knowledge building, and of how and why they do it.

The idea is to promote an image of science and technology connected to the lives of people and their surroundings, of great relevance for social change, which reflects combined building of knowledge through teamwork and that, in addition, presents reflection, the contrasting of ideas and communication as fundamental pillars for the creation of such knowledge. Moreover, STEM disciplines should be worked with showing that people dedicated to these knowledge fields do not have determined characteristics, and do not require innate capacities. Therefore, practitioners need to be cognisant of breaking down gender stereotypes, "as well as the need for extra attention to be paid in shifting some of the more deeply and culturally entrenched stereotypes and norms" ([46] p. 13).

To do this, it would be necessary to use a global teaching approach that integrates all these ideas. Currently, the studies show that all these educational implications are being carried out in the classroom in isolation. For example, Mclean, Nation, and Spina [63] investigated the impact of collaborative engineering design on the development of engineering identities and found that collaborative engineering design programs helped reduced the gender gap; and Hill, Overton, and Thompson [64] who investigated whether engaging students in reflection would increase their ability to recognize and articulate their skill development. So, our proposal involves adopting a methodology that encourages the design of STEM programs focused on socio-scientific issues close to the lives of students that promote the collaborative work, reflection, and the contrast of ideas; and that allow the creation of favourable expectations of achievement in students though their attributes and the elimination of beliefs based on stereotypes or barriers.

In this manner there will be a positive influence, counteracting the gender gap produced in STEM fields, and along with this, there will be a contribution to ending discrimination against women on the personal and socio-economic planes. That is, on the one hand, there will be an improvement in the situation of the female gender in terms of personal realization and self-esteem, the latter being one of the objectives for empowering women [65]; and, on the other hand, it will help to improve social justice, given the promotion of the presence of women in crucial scenarios for progress and decision making, as the crisis derived from the COVID-19 pandemic has made clear [6]. In this sense, the current pandemic has shown an unprecedented need to educate future scientists, men, and women, not only in evidence-based reasoning and critical thinking but also in action-oriented and socially responsible citizenship [29].

After this reflection based on an in-depth bibliographic review and for future research, it would be interesting to investigate the motivations and reasons that influence the female choosing for scientific-technological professions and compare these results with the theoretical factors identified in this work. Also, other factors may be considered, since notions of identity are multifaceted and complex, being shaped in relation to intersecting axes, such as gender, ethnicity, and social class, which can generate powerful notions of what is/not appropriate or normal for "people like me" and, in turn, can profoundly shape individuals' educational choices and trajectories [21].

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Author contribution statement

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Additional information

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