STEM FEMALE LEADERS – THE WAY FORWARD TO REDUCE THE GENDER GAP IN STEM FIELDS

Bilgin, A. S.[1], Molina Ascanio, M.[1], Milanovic, I.[1], Kirsch, M.[2], Beernaert, Y.[2], Scicluna Bugeja, D.[3], Noriega, M.[4], Farrugia, J.[5], Evagorou, M.[6], Molina, P.[7], Kapoor, K.[8], Malmberg, B.[9], Trullàs, M.[9], Pedralli, M.[10], Neuberg, C.[11], Koliakou, I.[12], Magid-Podolsky, S.[13], Herrero, B.[14], Christou, E.[15], Niewint-Gori, J.[16], Fabry, E.[17], Quarta, B.[1], Miotti, B.[16], Muscat, M.[3], Vargas, R.[4], Gras-Velázquez, A[1].

(1) European Schoolnet, (2) Educonsult, (3) Directorate for Quality and Standards in Education (Maltese MoE), (4) INTEF - Spanish Ministry of Education and Vocational Training, (5) University of Malta, (6) Department of Education, University of Nicosia, (7) Tecnalia, (8) Elias Robot, (9) Notebloc, (10) Pearson Italia (Sanoma Learning)[1], (11) Leeds Trinity University, (12) Anatolia College Thessaloniki, (13) Tzamarot Ayalon, (14) Huawei / European Leadership Academy, (15) Cyprus University of Technology, (16) INDIRE (National Institute for Documentation, Innovation and Educational Research, IT MoE), (17) European Centre for Women and Technology.

Abstract

As early as two years old, children are exposed to gender role stereotypes and biased ideas about the science and mathematics performance of girls and boys. Consequently, girls tend to have low confidence in their STEM skills and low interest in STEM, although their STEM abilities are on par with boys. There are many initiatives to raise girls' interest in STEM and encourage young women to persevere in a STEM career, but the gender gap in STEM is a complex challenge that requires interventions that consider the age of pupils, gender stereotypes, the role of stakeholders, the national context, and follow-up assessments. Scientix, the community for science education in Europe, organised an online Science Topics Networking Seminar (STNS) in collaboration with the projects GEM and URBANAGE. At the event, more than 20 experts representing various stakeholders in STEM education came together to discuss the challenges and progress of STEM initiatives to reduce the gender gap in STEM fields. This observatory paper outlines the key discussion points raised during the seminar. The main points to consider in the success of initiatives are: (1) a greater involvement of parents and boys in programmes for girls and young women in STEM; (2) a better collaboration with media, industry, science centres and museums; (3) a further integration of the topics of STEM education and gender stereotypes in initial teacher education and

[1] Since September 15th, 2022, Pearson Italia has become part of Sanoma Learning, the Education company present in 12 European countries.

The work presented in this document has received funding from the European Union's H2020 research and innovation programme – project Scientix 4 (Grant agreement N. 101000063), coordinated by European Schoolnet (EUN). The content of the document is the sole responsibility of the organizer, and it does not represent the opinion of the European Commission (EC), and the EC is not responsible for any use that might be made of information contained.

professional development; (4) the involvement of non-STEM and ECEC (early childhood education and care) schoolteachers; (5) the use of role models appropriate for the girls' age and context; (6) better monitoring of the initiatives' impact; and (7) a better connection between social sciences and STEM.

Keywords: gender stereotypes, gender bias, maths anxiety, STEM education, teacher professional development, entrepreneurship

Introduction

Although girls and boys show similar performances in science and mathematics (OECD, 2020), and girls even achieve higher digital literacy scores (Fraillon et al., 2020; Siddiq & Scherer, 2019), women are less present in STEM. There are many factors maintaining the gender gap in STEM fields, such as gender stereotypes, male-dominated cultures, low self-efficacy in STEM and maths anxiety (Ayuso et al., 2020; Rodríguez et al., 2020; Wang et al. 2021). The support of educators, peers and family has a significant influence on the choice of a STEM career (Nugent et al., 2015). It is therefore important for education systems to intervene to rekindle or maintain girls' and young women's aspirations for a STEM career. Encouraging girls to pursue an education and career in the STEM field is important not only to remedy the lack of graduates in the STEM job market, but also to diversify and enrich perspectives to ensure that researchers, entrepreneurs, and leaders in STEM tackle the complex problems facing the world from diverse viewpoints. Reaching gender parity in STEM also serves two of UNESCO's Sustainable Development Goals[2]: ensuring inclusive and equitable quality education and achieving gender equality. Similarly, the United Nations sees gender equality 'not only as a fundamental human right, but a necessary foundation for a peaceful, prosperous and sustainable world.'[3]. Furthermore, the pandemic has amplified inequalities for girls when it comes to STEM education, thus increasing the need to take decisive action. Climate change and the COVID-19 pandemic are exacerbating the gender gap and other inequalities – and disproportionately affecting women and girls in all countries. As the world responds to these crises, there is a need for STEM knowledge and skills.

It is necessary to exchange the experiences gained from implementing different policies and interventions, because the gender gap in STEM is a complex issue involving many societal and individual aspects, depending on context, age, and country (Viarengo, 2021). Therefore,

[2] UNESCO's Sustainable Development Goals - https://en.unesco.org/sustainabledevelopmentgoals
[3] The Sustainable Development Goals Report - https://unstats.un.org/sdgs/report/2020/#:~:text=The%20Sustainable%20Development%20Goals%20Report,meet%20the%20Goals%20by%202030

the STNS aimed to explore the key success factors in existing interventions to help increase girls' interest and engagement in STEM. The seminar provided an opportunity to discuss the engagement of girls in STEM in different contexts, as it brought together a diverse group of stakeholders to exchange knowledge and good practices, and lay the groundwork for new partnerships and collaborations. Attendees included representatives from Ministries of Education (MoEs), industry, teachers, policymakers, start-up entrepreneurs, researchers, teacher trainers, and education consultants.

This paper outlines the main outcomes from the STNS entitled 'STEM female leaders: How successful programmes are reducing the gender gap in STEM fields', which was held online on 29 April 2022. The paper combines a literature review based on the research and projects mentioned by the attendees during the discussions in the seminar, as well as observations in their personal and professional lives related to the gender gap in STEM. Therefore, by combining theory, research, and practice, the paper offers a unique account of the European landscape of initiatives, projects, and interventions to better engage girls and young women in the STEM field.

The current state of the gender gap

According to Eurostat statistics from 2018[4], the EU counted virtually twice as many male graduates as female graduates in science, mathematics, computing, engineering, manufacturing, and construction in the age range of 20-29 years. The picture is not brighter on the professional and academic scene. The report 'She Figures 2021' (European Commission, 2021) highlighted that, in Europe, women represent only a quarter of self-employed professionals in STEM, 32% of doctoral graduates in physical sciences and mathematics, and 41% of the total labour force in science and engineering. Women are not underrepresented in life sciences, but their numbers drop towards PhD level, a phenomenon often referred to as the leaky pipeline (Blickenstaff, 2005).

Having more women in leadership positions seems to be beneficial for companies (Schneider & Eckl, 2016). Despite this, there is a similar gender gap when it comes to leadership roles in STEM. According to a World Economic Forum report[5] covering 21 countries and 13 million

[4] Data from Eurostat 2018 - https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Tertiary_education_statistics#Participation_of_men_and_women_in_tertiary_education

[5] "Want more women in leadership roles? Start by fixing the leaky talent pipeline" - https://www.investmentmonitor.ai/insights/women-leadership-leaking-talent-pipeline

employees around the world, only 27% of professionals in managerial positions were women in 2021.

In 2020, over half (51.3%) of the workforce employed in science and technology in the EU were women. However only 27.7% of employees in manufacturing were women[6] and only 21% of scientist and engineers in manufacturing were female[7]. According to the Global Gender Gap report, in the ICT field, only 18% of ICT specialist jobs go to women and only 20% of ICT graduates are women (WEF, 2021).

Although women scientists publish articles at a similar rate to men according to data from over 7 million scientists (Huang, Gates, & Sinatra, 2020), in publications regarding STEM, women tend to be second author 59% of the time and first author 34% of the time. Women authors also seem to be less cited in the literature than men (Beaudry & Larivière, 2016). As a whole, gender stereotypes seem to have been well ingrained into society, and a big challenge ahead is to tackle stereotypes to help attain gender parity in STEM.

Challenges in closing the gender gap in STEM fields

The discussions held during the seminar highlighted several challenges in closing the gender gap in STEM fields. These can be categorised as challenges related to age, stereotypes, cultural differences, economy, and the monitoring and evaluation of STEM programmes. Although some of these challenges are societal and harder to tackle, such as exposure to stereotypes at a very young age, it is nevertheless important to understand them to design and implement programmes that are mindful of the complexity of the issue.

Age

Age is a critical factor for STEM interventions. Although early interventions are important, the age of 12 seems to be a critical point (González-Pérez, de Cabo, & Sáinz, 2020; Sáinz & Eccles, 2012) when girls start losing interest in STEM and confidence in their STEM skills. A Microsoft-commissioned survey[8] found that girls in Europe become interested in STEM subjects around the age of 11 and lose interest mostly by the age of 15. 'The ABC of Gender Equality' report by the OECD revealed that girls have lower confidence than boys in their ability

[6] Data from Eurostat 2021 - https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Human_resources_in_science_and_technology
[7] Data from Eurostat 2019 - https://ec.europa.eu/eurostat/web/products-eurostat-news/-/edn-20210210-1
[8] The exact age when girls lose interest in science and math - https://money.cnn.com/2017/02/28/technology/girls-math-science-engineering/index.html

to complete science and mathematics tasks (OECD, 2015). Confidence in STEM skills is very important to tackle, because it is one of, if not the strongest predictor of interest in science (Cheung, 2018).

This decrease in confidence and interest is possibly due to being exposed to gender stereotypes (Eccles, Jacobs, & Harold, 1990), lack of support and/or pressure from parents (Hoferichter & Raufelder, 2019), classmates who are not doing well or who are not interested in STEM (Raabe Boda, & Stadtfeld 2019; Riegle-Crumb, Farkas, & Muller, 2006) and classmates being biased about girls' abilities in STEM (Bloodhart et al., 2020). Believing that they will succeed in STEM is also an important factor for whether girls will choose to study STEM (González-Pérez, et al., 2020).

Women are more likely than men to drop out from STEM studies (Preston, 2004), especially IT studies, where there are more girls in the first few years than in the last few years and there is a common conception among young men that 'girls cannot do it'[9].

Gender stereotypes

As STEM careers are male-dominated fields, women can often run into challenges. For example, a woman researcher can feel isolated at her workplace after having a child in a male-dominated environment; a woman STEM professional might be given menial tasks more often than her male peers; or a woman entrepreneur/leader might feel pressured to strike a balance between commanding authority and acting as a caring figure in a male-dominant team[10]. In line with this, women have shorter academic careers than men (Amon, 2017; Huang et al., 2020), and family responsibilities are possibly one reason behind this difference (Abele & Spurk, 2011). This is just an illustration of what young women experience in terms of gender bias in their early career. In fact, gender stereotypes start at a very early age, and can come from media content, teachers, parents, and peers.

According to a STEM education report in Vietnam (Giang et al., 2020), even though teachers believed that there was no gender discrimination in policies or curriculum, more than half of them stated that there was a big gender difference in the content and format of textbooks. The image of male and female was not in balance; and females did not appear as often as males in the text or illustrations.

[9] Based on discussions during the event.
[10] Based on discussions during the event.

A recent article[11] published by the British Council states that teachers are unconsciously biased towards boys when asking questions to a classroom. According to the article, most teachers in the study disagreed with the statement 'Teachers allow boys to dominate in mixed classrooms'.

Another study showed that teachers tended to ask more questions to boys than girls, give boys more chances to take turns, allow boys to hold the floor for longer, and allow them to interrupt their classmates (Swann & Graddol, 1988). Teachers are also inclined to believe boys are more talented in mathematics and that maths is more difficult for girls than for equally achieving boys (Copur-Gencturk, Thacker, & Quinn, 2021; Tiedemann, 2000). There is also evidence suggesting that girls' maths performance is lower in classes with gender-biased mathematics teachers (Carlana, 2019).

Parents also believe girls do not perform as well as boys in maths. When they offer help to their daughters with their math homework, this help is perceived by girls as an indication of their lower academic performance than boys' (Bhanot & Jovanovic, 2005). When talking to the parents of STEM-aspiring students, the parents of male students are more likely to have university aspirations for their children compared to the parents of female students (Lloyd et al., 2018). Girls are more influenced by their mothers' support in choosing and persisting in STEM (del Rio et al., 2021; Hoferichter & Raufelder, 2019; Leaper, Farkas, & Brown 2012). However, research also shows that fathers can have a positive or negative influence on their daughters' choices, as fathers' stereotypes can have an impact on girls' own stereotypes (Aidy et al., 2021; Galdi, Mirisola & Tomasetto, 2017).

A study by Nominet[12] on 2,128 parents in the UK shows that parents tend to steer girls away from STEM career tracks. The top preferred careers by parents for their girls were: becoming a doctor (24%), teacher (20%), lawyer (17%), scientist (17%), nurse/paramedic (14%) and business manager (11%). Interestingly, according to a report in the US[13], in high-income families the gender stereotype of boys being good at maths seems to be more dominant than in low-income families. The Gender Scan survey in 2021[14] indicated that 4 out of 10 women university students were discouraged either by their teacher or by a member of their family regarding STEM studies. Moreover, parents with traditional views are more biased towards

[11] "Challenge gender bias in the classroom with language" - https://www.britishcouncil.org/voices-magazine/teachers-challenge-gender-bias-classroom-language
[12] "British parents steering daughters away from jobs in tech" - https://www.nominet.uk/british-parents-steering-daughters-away-from-tech-jobs/
[13] "The Myth of the Male Math Brain" - https://www.aauw.org/resources/article/the-myth-of-the-male-math-brain/
[14] The Gender Scan Survey 2021 - https://genderscan.org/Docs/Infographie_Etudiant_Gender_Scan_2021_GS_21.pdf

their daughters concerning their maths homework, and use more scientific explanations when speaking to their sons (Lindberg, Shibley-Hyde & Hirsch, 2008).

Gender stereotypes are present from a very early age in children (Miller et al., 2009). A study conducted at informal science learning sites (e.g., museums, zoos, aquariums) indicated that younger children were less likely to report that both boys and girls are usually, should be, and can be good at STEM (McGuire et al., 2020). In a study that measured the implicit gender bias of students, more than half of the students in the class associated men more with science, and saw this association as normal (McCullough, 2015). A study by Archer and MacRae (1991) suggested that although young children do not have in-depth knowledge of science related topics, they attribute masculine traits to physics, IT, craft and technology, and feminine traits to social sciences at an early age. In some cases, girls can have even stronger views on STEM than boys: a study showed that girls perceived mathematics, physics, and chemistry as masculine subjects at an equal level, while boys viewed mathematics as a more masculine field than physics and chemistry (Makarova, Aeschlimann, & Herzog, 2019).

Cultural differences - The gender equality paradox

Interestingly, fewer women enrol in higher STEM education tracks in countries with high gender equality, like Norway and Finland, than in countries with lower gender equality, like Algeria and Iran (Stoet & Geary, 2018). Women in societies with high gender equality and with more economic opportunities possibly do not suffer negative consequences for choosing a non-STEM career and can choose one according to their personal interests and strengths. In other words, women might be choosing non-STEM fields not because they think they do badly in STEM, but simply because they do better in social sciences. In fact, this interpretation is supported by an analysis on the PISA data from 300,000 girls. The PISA data indicates that girls with high math skills are more likely to have even better reading skills, and that this is the primary factor that determines their intention to study maths (Breda & Napp, 2019). Their reading skills were a stronger predictor of their intention to (not) pursue maths than their self-concept in maths or attitude towards maths.

In contrast, for women in societies with a poorer economy, a well-paid STEM career is a good incentive to choose a study in STEM. Economic welfare could be one underlying factor for the overall low provision of STEM graduates in the job market in Europe, as young adults can still have a secure job in non-STEM fields which they may perceive as less demanding. This situation has been referred to as ‘the gender equality paradox’. The paradox perhaps indicates how important it is to raise awareness in girls about STEM careers and how they can still apply

their personal strengths, even if they think their personal skills are more in line with non-STEM jobs.

Cultural differences

A cross-cultural study comparing American and Turkish pupils showed that self-motivation was the most influential factor for American students in their career choice. On the other hand, for Turkish students, their mother's influence was the most influential factor (Bahar & Adiguzel, 2016). Therefore, when rolling out interventions to target gender biases, cultural differences and religious sensitivities need to be considered. For instance, a religious school might not allow course books for STEM subjects that include images of girls, or might prefer women role models only meeting with girls. It is important to be aware of such sensitivities and have a workaround, which might be better than not implementing any intervention at all.

Evaluation of interventions

To evaluate the impact of an intervention on increasing girls' interest in STEM, it may be easier to quantify their change in attitude, self-efficacy, and interest in STEM. However, it is a challenge to track whether these girls actually enrol in STEM studies and work in the STEM field, a task that would require very costly, longitudinal studies (González-Pérez et al., 2020). In fact, there is often no clear evidence whether interventions have had a meaningful impact on girls, as in the case of STEM initiatives in Australia (Mckinnon, 2020).

In contrast, there is a positive example in the Flanders region, which set up the STEM action plan[15] in 2012, aimed at increasing the proportion of students — especially women — in STEM career tracks. From 2012 to 2019, the proportion of females in STEM tracks in secondary education has risen by 5 percentage points and the proportion of women in vocational and academic STEM undergraduate studies has increased by 4 percentage points. The activities in the schools are multifaceted and, consequently, the most effective activities are not clearly identifiable. However, the creation of STEM schools (which have to meet clear criteria) has boosted the uptake of STEM courses in secondary education.

When longitudinal studies are not feasible, interventions can still monitor factors such as confidence in STEM skills/self-efficacy and interest in STEM. Teachers can do action research (Lufungulo, Mambwe & Kalinde, 2021) to evaluate their activities while being part of the process, and assess their students' attitude towards STEM, as well as their gender

[15] Insight into STEM with the STEM monitor 2021 (in Dutch) - https://www.eduzine.be/artikel/inzicht-in-stem-evoluties-met-de-stem-monitor-2021

stereotypes. As research centres, universities have the expertise in research methods and therefore can collaborate with schools and teachers in the evaluation of programmes for engaging girls in STEM in the classroom. Universities can also support teachers, schools, and Ministries of Education (MoEs) in developing projects with a strong evaluation plan. Teachers and project investigators can involve girls in the evaluation of their interventions, as a great example of how mathematics and statistics can be used to meet real-world needs.

The way forward in STEM programmes for girls and young women

There are a number of barriers to engaging and maintaining girls and young women's interest in STEM. Understanding these challenges can help stakeholders better appreciate how to address them. During the seminar discussions, participants shared many existing programmes and research studies that were effective. These examples provided ideas on how stakeholders can create successful professional development and interventions, and indicate that it is necessary to approach the issue from multiple angles, from considering semantics and communication style to identifying the role of all stakeholders, including parents and career guidance counsellors.

Role models

A common stereotype about scientists is that they lack social skills or have an unattractive physical appearance, which work against girls' interests as they are potentially looking for a social and collaborative job. Role models that do not fit this stereotype were presented to girls to challenge their preconceived ideas (e.g., a successful STEM professional with good social and communication skills) (González-Pérez et al., 2020). A programme supported by L'Oréal to encourage girls to take up STEM studies and STEM careers in French schools showed that the role models helped increase the number of girls enrolling in STEM fields in which they are underrepresented (Breda et al., 2021).

Role models can also show the humane aspect of STEM careers. For example, a career chat[16] was recently organised by the European Commission Joint Research Centre project about the Three R's in animal testing in science[17]. Scientists who are looking for alternatives to animal

[16] The Three Rs - Online Chat Sessions with Experts: Monica Piergiovanni - https://youtu.be/k4-EvAa8ybo
[17] The Three Rs and Animal Use in Science Rerun - https://www.europeanschoolnetacademy.eu/courses/course-v1:ThreeRs+AnimalsInScience+2021/about

testing through new high-tech and biological innovations can also be a counter-stereotypical and attractive role model for girls.

Professional role models can be even more effective in challenging gender stereotypes. According to a Microsoft research project[18] on 11,500 girls and young women aged 11 to 30, STEM professionals seem to be more impactful role models than STEM researchers. For instance, the professional role models involved in the summer schools at the project GEM[19] demonstrated that it is possible to combine a STEM career and a balanced social and family life.

Tackling gender stereotypes in the classroom

Besides their educational role, teachers have the tough task of monitoring student assignments and behaviour in the classroom. On top of classroom management, teachers can have difficulty identifying gender-biased behaviour and counteracting it. As mentioned earlier, teachers could also be unaware of their own actions, unwillingly maintaining gender inequality. To promote girls and boys equally in STEM, teachers must reflect on their own gender stereotypes. Teachers can use a self-assessment, such as the one developed by Purdue University[20], to reflect on how fair their classroom teaching is gender-wise.

One way to target stereotypes is to debunk myths[21] about girls and boys regarding science and mathematics. For instance, girls perform just as well as boys in science and mathematics (Hammond et al., 2020). Teachers can start watching out for gender stereotypes at an early age. ECEC schoolteachers can randomise the allocation of colours (e.g., blue and pink) and the type of toys (e.g., cars and dolls) given to girls and boys in their classrooms.

Gender stereotypical behaviour can emerge during collaborative and competitive situations. Experts at GEM have observed that when pupils work in groups, boys tend to speak more, and girls tend to give in. Teachers can construct groups to provide more space for girls and have a balance of more vocal and assertive girls and boys. Teachers have the responsibility

[18] "Women in STEM: a cornerstone of Europe's digital economy" - https://blogs.microsoft.com/eupolicy/2018/04/25/women-in-stem-a-cornerstone-of-europes-digital-economy/

[19] "Empower Girls to Embrace their Digital and Entrepreneurial Potential" (GEM) is a pilot project co-funded by the European Union with the goal of increasing girls' interest in STEM and ICT subjects, studies and careers through two main actions: (1) summer schools/camps for girls aged 12-18, where they can experience STEM activities; (2) a network of schools, higher education institutions, companies and policymakers to exchange best-practices to support girls in STEM.

[20] Achieving Gender Fair Teaching Checklist - https://gems.education.purdue.edu/wp-content/uploads/2019/02/AchievingGenderFreeTeaching.pdf

[21] "Myths and Misperceptions: Reframing the narrative around women and girls in STEM" - https://blogs.worldbank.org/education/myths-and-misperceptions-reframing-narrative-around-women-and-girls-stem

to create equal opportunities for everyone to participate in activities. They need to be mindful of their students' individual needs and talents. Teachers can use differentiation strategies to promote inclusion in their STEM class activities.

Learning material, whether textbooks or digital resources, should also be gender neutral. Curriculum designers should make sure that textbooks are gender neutral, with an equal representation of male and female as a minimum. For instance, the publishing companies Pearson[22] and Rizzoli [23] have recently started a project to make their textbooks gender neutral.

Since gender stereotypes manifest themselves in the way we communicate and can be spread through language, communication and language skills are very important. Teachers can explore with pupils how language can be gender biased or gender neutral. Teaching about gender neutral language can be integrated in the design and content of digital resources and applications for language learning. Educational technologies can also be a good example for girls on how IT and programming skills can be used in applications that have social impact, such as educational technologies. The language learning application Elias Robot[24] is a good example, because it combines robotics and programming for a human-like interactive instruction of language, which can help both pupils and young immigrants learn foreign languages (Ahmed, 2021; Kouri et al., 2020). Another insightful resource, the FeSTEM Toolbox[25], provides ideas for developing gender-sensitive learning activities and resources. Although the toolbox is intended for higher education, it can provide inspiration for teachers in developing their own gender-sensitive content.

Finally, an informal way of engaging with STEM could be a regular 'introduction day' to STEM in schools, supported by the local or national authorities and in collaboration with science centres. The design of informal events can also have a positive impact. For example, during the national finals of the International Science and Engineering Fair (STEM STARS) in Greece, behind each student exhibition table, there was a beautiful poster with information about an important woman in science, which caught the attention of many students[26].

[22] "Equality in our books" (In Italian) - https://it.pearson.com/parita-genere/parita-libri.html
[23] "Equality goal" (In Italian) - https://www.rizzolieducation.it/la-nuova-educazione-civica/pari-opportunita/obiettivo-parita/
[24] Elias Robot - https://www.eliasrobot.com/
[25] Female Empowerment in Science, Technology, Engineering and Mathematics in Higher Education (FeSTEM) is a project co-funded by the Erasmus+ programme of the European Union. It aims to develop and promote a gender-sensitive teaching methodology to enable higher education teachers and students to create meaningful, shareable exhibits that will ultimately encourage girls and women to remain active in STEM.
[26] A recent podcast indicates how the early pioneers in coding were women, which could also help challenging pupils' conceptions about STEM: https://www.npr.org/sections/money/2016/07/22/487069271/episode-576-when-women-stopped-coding

School counsellors and careers education

Professional school counsellors play a crucial role in student career development and are trained to assist students in developing their skills, interests, and abilities. They can encourage the career development of every student and address opportunity and achievement gaps that may impact career decision making (see ASCA standards[27]). They can provide career development programmes designed to have a positive impact on student self-efficacy, interest, and outcome expectations for STEM careers.

A report by the Aspires 2 project[28] indicates that less than two thirds of students receive career advice. Moreover, students with high aspirations for a career in science are more likely than their non-science aspirant peers to have received careers guidance and be satisfied with the service offered. Careers education and apprenticeships can encourage more students to want to work in STEM fields.

Collaboration with industry

The role played by companies is extremely important, as students can see the real-world application of what they learn in the classroom. Moreover, as STEM professionals appear to be more effective role models than researchers in STEM, industry plays a vital role in linking pupils with role models. One important point is that there should be collaboration with educators to create experiences that connect with what students are learning in the classroom. Some existing initiatives can provide an example for new programmes:

- The non-profit organisation Taasieda in Israel offers courses to schools to engage girls in computer science and introduce them to careers in the high-tech industry.
- The Mind the Gap[29] programme in Israel was a collaboration between Google and the Israeli Institute of Technology and Science that aimed to increase the number of women in Israeli tech companies. Pupils had the chance to both meet young women enrolled in STEM studies at the university, and to visit Google offices.
- Currently, the Future Female Engineers[30] programme is a joint venture run by Tel Aviv university and Israeli Aerospace Industries. The programme is for girls around the age

[27] School Counselor Professional Standards and Competencies - https://www.schoolcounselor.org/getmedia/a8d59c2c-51de-4ec3-a565-a3235f3b93c3/SC-Competencies.pdf
[28] Aspires 2 Project Spotlight - https://kclpure.kcl.ac.uk/portal/files/64130618/ASPIRES_2_Project_Spotlight_1.pdf
[29] Mind the gap - https://sites.google.com/site/mindthegapprogram
[30] Female Future Engineers - https://www.israelscienceinfo.com/en/hightech/des-centaines-de-lyceennes-de-tout-israel-pour-tech-women-2016-au-technion/

of 15 (9th grade in the Israeli school system). The main aim of this programme is to increase the number of female students at Science and Technology faculties in Israeli universities.

- The European Leadership Academy[31], supported by Huawei EU, organises summer and winter schools for young women of 18 or older to develop leadership skills and learn about career opportunities available in areas including AI, cybersecurity, and data privacy.
- Deloitte organises events[32] where graduate and undergraduate women in STEM discuss challenges and the importance of becoming a female leader in today's workforce. The European Commission has also started the project ESTEAM Fests[33], together with Deloitte, the European Women Association and Vlajo, to empower women and girls by boosting their digital and entrepreneurial competencies.
- FIA Girls on Track events[34] aim to inspire young women between the ages of 8 and 18 years old with enjoyable educational activities that provide a unique insight into what a potential career in the vibrant world of motor sport can offer. Karting, pit-stop challenges, media tutorials, practical STEM activities as well as fitness and well-being workshops are designed to engage and motivate young girls and open their minds to a world of possibilities in the sport.

Intervention age

As previously discussed, targeting stereotypes from an early age is important, because gender stereotypes can already be observed at ECEC when boys and girls choose specific types of toys and colours (e.g., blue for boys, pink for girls) (Saramourtsi, Zafiri, & Pliogou, 2020).

Girls can start losing interest at ECEC stage if the teacher does not engage them with STEM in an exciting way. It is also important to intervene at ECEC level because at this stage teachers tend to be less informed about STEM. Kindergarten teachers are also more likely to be women than men[35], unwillingly reinforcing prejudice.

[31] European Leadership Academy - https://www.europeanleadershipacademy.eu/about/
[32] Women in STEM Summit - https://www2.deloitte.com/ca/en/pages/careers/articles/women-stem-summit.html
[33] The ESTEAM Fests are an initiative of the Digital Education Action Plan, which is coordinated by DG EAC of the European Commission. - https://eismea.ec.europa.eu/news/empowering-women-and-girls-through-digital-and-entrepreneurial-competences-esteam-fests-and-2022-03-07_en
[34] "ABB announces global partnership with FIA Girls on Track" - https://new.abb.com/news/detail/77913/abb-announces-global-partnership-with-fia-girls-on-track
[35] Data from Eurostat 2015 - https://ec.europa.eu/eurostat/documents/2995521/7017572/3-02102015-BP-EN.pdf/5a7b5406-4a0d-445b-8fa3-3558a8495020

In early adulthood and during higher education, young women talk to mentors and role models about both positive and negative experiences. Women in STEM fields adopt diverse coping strategies in response to barriers in their career (Amon, 2017; Robnett, 2014). Exchanging more information about these strategies can reduce the feeling of isolation for young women enrolled in STEM studies, ultimately decreasing the likelihood of dropouts. Finally, when graduates start their job search, they can practice building a positive self-narrative that can help them do better in job interviews. There are existing initiatives to support women scientists in academia and to promote collaboration between researchers and schools. For instance, in Greece, the network R.E.A.L. Science[36] aims to support students by offering mentoring opportunities and open workshops for all students around Greece.

Focus on the collaborative and benevolent aspects of STEM

A series of investigations suggest that women tend to dislike STEM fields because they perceive them to be less in line with communal goals that involve working with and helping others. Moreover, when a STEM job was advertised as more collaborative, women perceived the job more positively (Diekman et al., 2011). Women also put less value in monetary gains when evaluating jobs (Wiswall, 2018), and a study using the Schwartz Values Survey (Schwartz, 2012) also indicates that women attach more importance to benevolence and universalism (defined as 'understanding, appreciation, tolerance, and protection for the welfare of all people and for nature') and less to self-enhancement (Schwartz & Rubel, 2005). Therefore, one way to make STEM fields more attractive to girls would be to emphasise that STEM professions can also be benevolent and collaborative.

Student-centred STEM activities can provide motivation and get boys and girls alike interested in STEM topics. Methods such as Inquiry-Based Science Education (IBSE) and Project-Based Learning (PBL) can also indirectly contribute to making STEM fields more attractive to girls, because connecting STEM to real-world problems will inevitably show that STEM is everywhere, making life easier not only for the general public, but also for the disadvantaged and those with specific needs, such as children, elders, minorities and those who are psychologically vulnerable. IBSE is also a learning-by-doing approach that can help girls build confidence. An inquiry-based science literacy programme implemented in ECEC was shown to remove differences in interest in science between boys and girls, showing that interventions as early as in ECEC can be beneficial (Patrick et al., 2009). STEM is also crucial for maintaining biodiversity and ecological sustainability. IBSE and PBL help students learn in a more cooperative/collaborative setting and in a more applied than abstract manner. Both are good

[36] R.E.A.L Science (In Greek) - https://realscience.gr/

at engaging boy and girls in STEM, but according to research, girls benefit even more from collaborative learning and connecting STEM to real-world applications (Geist & King, 2005; Wang, 2012).

Bringing social science and natural sciences together

STEM education aims to promote interdisciplinary collaboration and problem solving skills because real-world problems are complex and interdisciplinary (English, 2016). Therefore, it is in the benefit of the society to bring STEM professionals closer to social sciences and social science professionals closer to STEM. Not every single woman can be expected to pursue a STEM career, but everyone can create more of a connection between their expertise and science and technology. For instance, women sociologists and psychologists can connect their work to statistics, data science, user experience design and other technical areas where they can collaborate with scientists and engineers. In turn, those in STEM fields can also develop communication skills to better explain science to the wider community, promote data literacy and increase the attractiveness of their field.

Bringing social sciences and STEM closer can also make STEM fields more attractive to women. Women are more interested in life sciences and social sciences (Makarova, Aeschlimann, & Herzog, 2019). This is possibly because these fields appear more collaborative and social to them (Diekman et al., 2011). However, stakeholders in STEM fields can explain to girls that working in STEM fields can lead to a collaborative and social job. During the seminar, it was noted that this point could be 'playing into the hands of gender stereotypes'. However, one can argue that the end goal is attracting more women into STEM, and achieving this, as well as making both social sciences and STEM fields more interdisciplinary in nature, can lead to a society that can better tackle world problems.

There is a need to highlight how girls can benefit from entering STEM professions. In addition to emphasising the collaborative nature of STEM fields, a benefit for girls can be that STEM fields can help solving world's biggest problems, such as sustainable energy, food, and well-being. For instance, projects like URBANAGE[37] illustrate how STEM can be combined with social science and how information technology can improve the life of citizens —in this case, elderly people. Such projects also demonstrate the collaborative nature of STEM, as they bring together 12 institutions from six different countries.

[37] URBANAGE (a combination of the word "urban" and "age") is an initiative that received funding from the European Union's Horizon 2020 programme, aimed at helping urban planners and policy makers harness new technologies for more inclusive cities. It supports the development of age-friendly cities through the roll-out of a decision-support ecosystem co-created by public servants and citizens and the use of city data in Big Data analysis, Artificial Intelligence modelling and simulation algorithms.

As mentioned earlier, Elias Robot is a good example of how technology can be used for the betterment of society (e.g., supporting migrants to learn the local language). Another example of combining STEM with social sciences, in this case ethics, is Notebloc[38], an application designed by women entrepreneurs with inclusion in mind (e.g., compatible with older devices). Both applications are by start-ups supported by the Impact EdTech[39] incubator initiative.

The role of science centres and museums

Informal learning events were found to be more effective on interest in STEM careers than formal learning events (Wang et al., 2021). Science centres and museums can offer many possibilities for informal learning. Science centres and museums can help connect STEM subjects to real-world situations with themes based on gender stereotypes and engaging girls. For instance, the Planetarium of Turin[40] is very active in the education field. Similar planetariums can be approached to organise school visits with the goal of engaging girls.

Science centres and museums have more creative freedom in demonstrating scientific phenomena to pupils, because they are not working within the boundaries of a curriculum like teachers. They can lead methodology and innovation in actions for girls in STEM. Science centres and museums often make use of game-based learning, role playing and laboratory demonstrations, which can inspire girls as a nice change from the usual daily activities at school. In turn, teachers can also be inspired to design their STEM content in different ways.

As research carried out on interactive spaces in science exhibits suggests, a single visit to a science museum can have a positive impact on pupils' gender stereotypes concerning STEM (Law et al., 2021).

Professional development and teacher education

Teachers play an important role in inducing gender stereotypes and being role models for pupils (e.g., Alan, Ertac, & Mumcu, 2017; Thomas, 2016). However, gender stereotypes are rarely addressed in teacher education and most STEM programmes directly target pupils (Kollmayer et al., 2020). For example, a survey by Let Toys Be Toys[41] in the UK suggests that initial teacher education often does not address the topic of gender stereotypes and how to

[38] Notebloc - https://www.notebloc.com/
[39] "Impacting Best-in-class Start-ups" - http://www.scientix.eu/news/news-all/news-detail?articleId=1090691
[40] Planetarium of Turin - https://www.planetarioditorino.it/en/
[41] "Survey finds gender stereotyping missing from teacher training" - https://www.lettoysbetoys.org.uk/research/teacher-training-survey/

tackle them in the classroom. There seems to be much untapped potential, as teachers could act as multipliers, reaching out to many students throughout their careers.

Teacher education should not only focus on training them to talk about stereotypes, but should also look at how to notice stereotypical language and behaviour in their practice. Many observations by teachers point to the fact that sometimes teachers are not even aware that stereotypical behaviour is taking place in their classroom. At a primary school level too, a survey run by Pearson Italia revealed that teachers tend to miss the signs of stereotypical language and behaviour (Della Giusta & Curatori, 2022). This is more pronounced in primary schools because teachers think their pupils are too young to have developed gender biases.

Spotting one's own gender stereotypical language is as important as spotting it in pupils. Considering how gender stereotypes are stamped into society, it is quite normal that teachers might also be unaware of their own stereotypical attitudes and language when teaching in the classroom. Therefore, teacher education should start from self-reflection and reviewing any of their own actions that promote gender stereotypes. A good example comes from a pilot training programme for teachers called REFLECT, which incorporated reflection on teachers' own implicit assumptions, by designing activities, trying them in the classroom and exchanging experiences with other teachers (Kollmayer et al., 2020). The training was effective in making teachers less biased and better able to address gender biases in the classroom, while their students' knowledge of gender differences improved.

Teacher education should target both STEM and non-STEM teachers, because closing the gender gap is not only about making science topics more attractive, but also about neutralising society's approach to different career paths by making communication as free from gender bias as possible. Furthermore, the unfamiliarity of non-STEM teachers about the issue could be a point of improvement: an observation by Pearson Italia suggests that non-STEM teachers, especially at pre-secondary level, might have low confidence in their knowledge of STEM fields because they mostly come from a social sciences background. Indeed, teachers from non-STEM subjects have lower confidence and a less positive attitude towards numeracy than STEM teachers (Ferme, 2018). Teacher's attitudes may also affect students negatively and reinforce misconceptions about STEM.

School leaders can arrange workshops or on-site learning opportunities for teachers on how to deal with gender stereotypes in general and gender stereotypes in STEM. In turn, policymakers can provide professional development opportunities at a national scale. Professional development can combine online and face-to-face modalities to promote a learning community and knowledge exchange among teachers, both locally and at a larger

scale, among teachers from different regions or countries. INTEF[42] in Spain is a good example of how professional development can be scaled up through MOOCs for teachers, as well as an online repository of resources.

Finally, learning communities can promote the exchange of knowledge and practices among teachers, both formally and informally. For instance, the Greek Women in STEM[43] group helps women connect with each other to exchange knowledge and experience, and provides a good support network for mentoring and collaboration.

Involving parents and the community

Parents' biases about STEM influence their children's self-concept regarding STEM, even if they are doing well in STEM. According to a UNESCO report on gender inequality in STEM education in Asia, gender difference cannot be attributed simply to lower interest. Sociocultural and psychological factors influence girls' interest and participation in STEM studies and professional fields. The location (e.g., rural, or urban) seems also to have an influence on academic success. Therefore, the report recommends that all STEM programmes should involve parents and the wider local community to raise awareness of the gender gap issue (UNESCO, 2020).

Training sessions for teachers, as well as other interventions, can also involve parents. If parents become familiar with evidence from research and get professional guidance on how to deal with stereotypes, they can support teachers to increase girls' interest in STEM subjects. For instance, the Teen Science Café[44] programme in Malta tries to counter discouraging effects on girls by addressing the biases of parents. The STEM Ambassador programme in the United Kingdom also brings parents on board (e.g., the guidance for the guardians and parents of mentees[45]).

[42] The National Institute of Educational Technologies and Teacher Training (INTEF) is the national agency funded by the Spanish Ministry of Education and Vocational Training. It is responsible for the teacher training plans and for the projects focused on promoting and integrating technologies in schools at national level. INTEF offers a repository of resources for teachers in Spain, and both face-to-face and online trainings for teachers (e.g., MOOCs).
[43] Greek Women in STEM (In Greek) - https://greekwomeninstem.com/
[44] Teen Science Café - https://newsbreak.edu.mt/2021/11/10/teen-science-cafe-women-in-stem/
[45] Guidance for parents and guardians of mentees on mentoring by STEM Ambassadors - https://www.stem.org.uk/sites/default/files/pages/downloads/M4%20-%20Guidance%20for%20parents.pdf

Upscaling interventions and professional development

Online learning opportunities can be a cost-effective alternative to on-site interventions and training. For instance, in support of the Digital Education Action Plan's goal[46] to increase the participation of women in STEM, the project 'Girls Go Circular[47]',' funded by the European Union, aims to equip schoolgirls aged 14-18 with digital and entrepreneurial skills through an online learning programme about the circular economy. The project has been going on for two years and 16,000 girls have been involved. Similarly, 'Science is Wonderful!'[48], a Marie Sklodowska-Curie action by the European Commission, offers activities that introduce cutting-edge science examples to pupils in primary and secondary schools all over Europe.

Finally, INTEF has created a ChicaSTEM section on their website[49] to increase the visibility of initiatives for girls in STEM. The ChicaSTEM webpage provides resources (including videos by Scientix Ambassadors) and news about girls in STEM community with a specific focus on coding.

Collaborative networks in each country, such as the network of Scientix Ambassadors, could also help to upscale activities. In Greece, Scientix Ambassadors have initiated a STEAM competition[50] with the motto that STEM is a language for all. The competition aims to encourage primary school teachers to carry out a STEAM activity that requires low-cost materials, engages all students in the class, and includes instructions with pictures or videos that can be uploaded on a platform accessible to all. The competition also aspired to help teachers include immigrant students in the classroom.

Finally, it is important to get other ministries on board working in the areas of labour, health and science, and not only telecommunications and education. More attention from policymakers can make more funding available from the government for schools to organise STEM activities.

Dissemination and media

Online promotion has the advantage of reaching a wider audience, as well as the possibility of targeting a specific audience through targeted campaigns on LinkedIn, for example, where teachers of a specific age group or subject can be selected. Dissemination can also reach

[46] Digital Education Action Plan Action 13 - https://education.ec.europa.eu/focus-topics/digital-education/about/digital-education-action-plan/digital-education-action-plan-action-13
[47] Digital and Entrepreneurial Skills for the Circular Economy - https://eit-girlsgocircular.eu/
[48] "Science is Wonderful!" - https://marie-sklodowska-curie-actions.ec.europa.eu/science-is-wonderful
[49] INTEF website section for girls-in-STEM resources - https://code.intef.es/chicastem/
[50] "STEAM for All" competition in Greece - https://anatolia.edu.gr/el/elementary/nea/5883-steam-for-all-2021

other stakeholders such as parents, science centres and policymakers who are not aware of the challenges of engaging girls in STEM fields. Communication experts and media producers can bring their expertise on board to design engaging material with educators for pupils about gender stereotypes or promotional campaigns on social media (e.g., Twitch).

Positive narrative

Making the narrative more positive can further encourage stakeholders in the pursuit of engaging girls in STEM. For instance, constructive hope, meaning the belief that one can do something to change things positively, is an important predictor in taking action about climate change (Ojala, 2012). Interventions in the classroom do not always have to focus on the negative or try to debunk the myths and misconceptions. Instead, teachers can appeal to the natural curiosity of their pupils, emphasise that we are all born scientists, curious to explore the world and find answers to things around us, with the key message that science is a method to look for answers.

Involving boys

Boys as well as young men tend to be left out of initiatives for women in STEM, because they are not the main target. However, gender-specific language and stereotypes related to boys can also have a negative impact on girls (Dasgupta & Stout, 2014). Boys could also be trained to change their gender biases, but interventions that involve boys should be designed carefully, in a way that will not be detrimental to the participation of girls. For instance, in the GEM summer school for girls, the organisers clearly observed that girls felt empowered, inspired and more engaged when boys were not around. Interestingly, in an all-girls school in the UK, girls who chose to study A level Physics gained more confidence and achieved higher grades than girls educated in a mixed gender school (Gillibrand et al, 1999), suggesting that the presence of boys can have a negative impact on girls' choice of STEM subjects. These observations show that teachers can have a positive impact by creating girls-only science clubs in schools, where the competitive spirit of boys would be absent. However, this should not lead to a complete avoidance of competition, because research confirms that participating in STEM competitions raises interest in STEM significantly (Miller, Sonnert, & Sadler, 2018). Teachers can also involve girls in competitions traditionally perceived as 'for boys' to simultaneously raise interest and challenge stereotypes. For instance, Formula 1 competitions in schools are considered to be 'for boys', but in Greece teachers have also created girls-only teams, which were also supported by the Girls on Track initiative.

There are also negative stereotypes about boys that can contribute to maintaining gender stereotypes. For instance, a Scientix Ambassador observed that when they had to lead a boys-only team for a European Space Agency competition, colleagues commented that it was a challenge because boys are less organised.

Finally, interventions to improve girls' performance and interest in STEM can at the same time aim to improve boys reading skills and hence their interest in humanities subjects (Breda & Napp, 2019). While this recommendation seems to work against meeting the demand of STEM professionals in the job market, it can ultimately reduce gender stereotypes by targeting the gender gap both in STEM and non-STEM fields.

Conclusion

There are many initiatives that have been successful in engaging girls in STEM. However, stakeholders face many challenges, such as a gap in teacher competency in addressing the topic, the gender stereotypes of teachers, parents, and peers that impact on girls' self-efficacy and interest, and the need to adapt interventions to age and culture. There is also the challenge of investigating whether interest in STEM translates to action in the form of enrolment in STEM subjects and choice of a career in STEM. Role models seem very effective in raising girls' interest in STEM. However, the type of role model seems to be important, and the seminar experts emphasised that they should have good science communication skills. Furthermore, all children are clearly exposed to gender stereotypes from an early age, which means interventions need to start from ECEC. There is a need to upskill all teachers to address both STEM education and gender stereotypes, and to develop class material to support them. Existing initiatives outlined in the report can provide an example for the development of new material. Finally, the question remains as to whether existing gender stereotypes should be used to the advantage of interventions aimed at raising girls' interest in STEM, for example, by emphasising the communal and collaborative aspects of STEM fields. The seminar experts agreed that interventions can appeal to girls' interest in communal and collaborative professions by emphasising the social aspects of STEM fields and proposed that inquiry-based science education and project-based learning methods are ideal to accomplish this. In any case, all children should be encouraged to develop their full potential, regardless of their gender, and whether they conform to stereotypical generalisations or not. Otherwise, actions to avoid 'negative stereotypes' may end up promoting the stereotypes that need to be disassembled.

Acknowledgements

This paper is part of the Scientix observatory series. Scientix, the community for science and mathematics education in Europe, was started by the European Commission (Research and Innovation DG), and has set up the Scientix Observatory to help the development and dissemination of different science education projects and document good practices in various aspects of STEM education. The Observatory provides short synthesising articles, focused on one or several related themes or initiatives, or the state of play of different topics related to science education (http://www.scientix.eu/observatory).

The work presented in this document has received funding from the European Union's H2020 research and innovation programme – project Scientix 4 (Grant agreement N. 730009), coordinated by European Schoolnet (EUN). URBANAGE is an initiative that received funding from the European Union's Horizon 2020 programme. GEM is co-funded by the European Union under grant no. LC-01380173. The content of the document is the sole responsibility of the organisers and the authors. It does not represent the opinion of the European Commission (EC), and the EC is not responsible for any use that might be made of information contained.

References

Abele, A. E., & Spurk, D. (2011). The dual impact of gender and the influence of timing of parenthood on men's and women's career development: Longitudinal findings. International Journal of Behavioral Development, 35(3), 225-232.

Ahmed, E. (2021). Design implications for the virtual language learning companion robot - Considering the Visual Appearance, Behavior and Rewarding. Unpublished master's thesis). University of Tampere, Faculty of Information Technology and Communication Sciences, Tampere, Finland.Aidy, C. L., Steele, J. R., Williams, A., Lipman, C., Wong, O., & Mastragostino, E. (2021). Examining adolescent daughters' and their parents' academic-gender stereotypes: Predicting academic attitudes, ability, and STEM intentions. Journal of adolescence, 93, 90-104.

Aidy, C. L., Steele, J. R., Williams, A., Lipman, C., Wong, O., & Mastragostino, E. (2021). Examining adolescent daughters' and their parents' academic-gender stereotypes: Predicting academic attitudes, ability, and STEM intentions. Journal of Adolescence, 93, 90-104.

Alan, S., Ertac, S., & Mumcu, I. (2017). Gender Stereotypes in the Classroom and Effects on Achievement. (December), 1–54.

Amon, M. J. (2017). Looking through the glass ceiling: A qualitative study of STEM women's career narratives. Frontiers in psychology, 8, 236.

Archer, J., & MacRae, M. (1991). Gender-perceptions of school subjects among 10–11-year-olds. British Journal of Educational Psychology, 61(1), 99-103.

Ayuso, N., Fillola, E., Masia, B., Murillo, A. C., Trillo-Lado, R., Baldassarri, S., Villarroya-Gaudó, M. (2020). Gender gap in STEM: A cross-sectional study of primary school students' self-perception and test anxiety in mathematics. IEEE Transactions on Education, 64(1), 40-49.

Bahar, A., & Adiguzel, T. (2016). Analysis of factors influencing interest in STEM career: Comparison between American and Turkish high school students with high ability. Journal of STEM Education: Innovations and Research, 17(3), 64–69.

Beaudry, C., & Larivière, V. (2016). Which gender gap? Factors affecting researchers' scientific impact in science and medicine. Research Policy, 45(9), 1790-1817.

Bhanot, R., & Jovanovic, J. (2005). Do parents' academic gender stereotypes influence whether they intrude on their children's homework? Sex roles, 52(9), 597-607.

Blickenstaff, J. C. (2005). Women and science careers: Leaky pipeline or gender filter? Gender and Education, 17(4), 369–386.

Bloodhart, B., Balgopal, M. M., Casper, A. M. A., Sample McMeeking, L. B., & Fischer, E. V. (2020). Outperforming yet undervalued: Undergraduate women in STEM. Plos one, 15(6), e0234685.

Breda, T., Grenet, J., Monnet, M., & Van Effenterre, C. (2021). Do female role models reduce the gender gap in science? Evidence from French high schools.

Breda, T., & Napp, C. (2019). Girls' comparative advantage in reading can largely explain the gender gap in math-related fields. Proceedings of the National Academy of Sciences of the United States of America, 116(31), 15435–15440.

Carlana, M. (2019). Implicit stereotypes: Evidence from teachers' gender bias. The Quarterly Journal of Economics, 134(3), 1163-1224.

Cheung, D. (2018). The key factors affecting students' individual interest in school science lessons. International Journal of Science Education, 40(1), 1-23.

Copur-Gencturk, Y., Thacker, I., & Quinn, D. (2021). K-8 teachers' overall and gender-specific beliefs about mathematical aptitude. International Journal of Science and Mathematics Education, 19(6), 1251-1269.

Dasgupta, N., & Stout, J. G. (2014). Girls and Women in Science, Technology, Engineering, and Mathematics: STEMing the Tide and Broadening Participation in STEM Careers. Policy Insights from the Behavioral and Brain Sciences, 1(1), 21–29.

Della Giusta, M., Muratori, C. (2022). Un'indagine sulle tematiche di genere nella scuola, in Educare alla parità. Principi, metodologie didattiche e strategie di azione per l'equità e l'inclusione, a cura di M. Della Giusta, B. Poggio, M. Spicci, Pearson Italia 2022 ("Pearson Academy. Insegnare nel XXI secolo")

del Río, M. F., Susperreguy, M. I., Strasser, K., Cvencek, D., Iturra, C., Gallardo, I., & Meltzoff, A. N. (2021). Early sources of children's math achievement in Chile: The role of parental beliefs and feelings about math. Early Education and Development, 32(5), 637-652.

Diekman, A. B., Clark, E. K., Johnston, A. M., Brown, E. R., & Steinberg, M. (2011).

Malleability in communal goals and beliefs influences attraction to STEM careers: Evidence for a goal congruity perspective. Journal of Personality and Social Psychology, 101(5), 902–918.

Eccles, J. S., Jacobs, J. E., & Harold, R. D. (1990). Gender role stereotypes, expectancy effects, and parents' socialization of gender differences. Journal of social issues, 46(2), 183-201.

English, L. D. (2016). STEM education K-12: perspectives on integration. International Journal of STEM Education, 3(1), 1–8.

European Commission, Directorate-General for Research and Innovation, She figures 2021: gender in research and innovation: statistics and indicators, Publications Office, 2021.

Ferme, E. (2018). A Comparison of STEM and Non-STEM Teachers' Confidence in and Attitudes towards Numeracy. Mathematics Education Research Group of Australasia, 298–305. Retrieved from https://eric.ed.gov/?id=ED592420%0Ahttps://files.eric.ed.gov/fulltext/ED592420.pdf

Fraillon, J., Ainley, J., Schulz, W., Friedman, T., & Duckworth, D. (2020). Preparing for life in a digital world: IEA international computer and information literacy study 2018 international report (p. 297). Springer Nature.

Galdi, S., Mirisola, A., & Tomasetto, C. (2017). On the relations between parents' and children's implicit and explicit academic gender stereotypes. Psicologia sociale, 12(2), 215-238.

Geist, E., & King, M. (2005). Different, not better: Gender differences in mathematics learning and achievement. Journal of Instructional Psychology, 35 (November 2020), 43–52.

Giang, T.T.H, Minh, N.D., Huong, D.T.T, (2020). Reality of STEM education for girls in Viet Nam. In STEM education for girls and women: breaking barriers and exploring gender inequality in Asia. UNESCO Office Bangkok and Regional Bureau for Education in Asia and the Pacific.

Gillibrand, Eileen & Robinson, Peter & Brawn, Richard & Osborn, Albert. (2010). Girls' participation in physics in single sex classes in mixed schools in relation to confidence and achievement. International Journal of Science Education. 21. 349-362.

González-Pérez, S., Mateos de Cabo, R., & Sáinz, M. (2020). Girls in STEM: Is It a Female Role-Model Thing? Frontiers in Psychology, 11(September).

Hammond, Alicia; Rubiano Matulevich, Eliana; Beegle, Kathleen; Kumaraswamy, Sai Krishna. 2020. The Equality Equation: Advancing the Participation of Women and Girls in STEM. World Bank, Washington, DC.

Hoferichter, F., & Raufelder, D. (2019). Mothers and fathers—Who matters for STEM performance? Gender-specific associations between STEM performance, parental pressure, and support during adolescence. In Frontiers in Education (Vol. 4, p. 14).

Huang, J., Gates, A. J., Sinatra, R., & Barabási, A. L. (2020). Historical comparison of gender inequality in scientific careers across countries and disciplines. Proceedings of the National Academy of Sciences, 117(9), 4609-4616.

Kollmayer, M., Schultes, M. T., Lüftenegger, M., Finsterwald, M., Spiel, C., & Schober, B. (2020). REFLECT – A Teacher Training Program to Promote Gender Equality in Schools. Frontiers in Education, 5(July), 1–8.

Kouri, S., Köpman, E., Ahtinen, A., & Ramirez Millan, V. (2020). Customized Robot-Assisted Language Learning to Support Immigrants at Work: Findings and Insights from a Qualitative User Experience Study. In Proceedings of the 8th International Conference on Human-Agent Interaction (pp. 212-220).

Law, F., McGuire, L., Winterbottom, M., & Rutland, A. (2021). Children's Gender Stereotypes in STEM Following a One-Shot Growth Mindset Intervention in a Science Museum. Frontiers in Psychology, 12, 641695. Leaper, C., Farkas, T., & Brown, C. S. (2012). Adolescent girls' experiences and gender-related beliefs in relation to their motivation in math/science and English. Journal of youth and adolescence, 41(3), 268-282.

Lindberg, S. M., Shibley-Hyde, J. S., & Hirsch, L. M. (2008). Gender and Mother-Child Interactions during Mathematics Homework: The Importance of Individual Differences. Merrill-Palmer Quarterly, 54(2), 232–255.

Lloyd, A., Gore, J., Holmes, K., Smith, M., & Fray, L. (2018). Parental influences on those seeking a career in STEM: The primacy of gender. International Journal of Gender, Science and Technology, 10(2), 308–328.

Lufungulo, E., Mambwe, R., & Kalinde, B. (2021). The Meaning and Role of Action Research in Education. 4. 115-128.

Makarova, E., Aeschlimann, B., & Herzog, W. (2019, July). The gender gap in STEM fields: The impact of the gender stereotype of math and science on secondary students' career aspirations. In Frontiers in Education (Vol. 4, p. 60).

McCullough, C. L. (2015). Problem-based Learning as a Tool in Addressing Gender Bias. In 2015 ASEE Annual Conference & Exposition (pp. 26-1255).

McGuire, L., Mulvey, K. L., Goff, E., Irvin, M. J., Winterbottom, M., Fields, G. E., Rutland, A. (2020). STEM gender stereotypes from early childhood through adolescence at informal science centers. Journal of Applied Developmental Psychology, 67).

McKinnon, M. (2022). The absence of evidence of the effectiveness of Australian gender equity in STEM initiatives. Australian Journal of Social Issues, 57(1), 202-214.

Miller, C. F., Lurye, L. E., Zosuls, K. M., & Ruble, D. N. (2009). Accessibility of gender stereotype domains: Developmental and gender differences in children. Sex Roles, 60(11–12), 870–881.

Miller, K., Sonnert, G., & Sadler, P. (2018). The influence of students' participation in STEM competitions on their interest in STEM careers. International Journal of Science Education, Part B: Communication and Public Engagement, 8(2), 95–114.

Nugent, G., Barker, B., Welch, G., Grandgenett, N., Wu, C. R., & Nelson, C. (2015). A Model of Factors Contributing to STEM Learning and Career Orientation. International Journal of Science Education, 37(7), 1067–1088.

OECD (Organisation for Economic Co-operation and Development). (2015). The ABC of Gender Equality in Education: Aptitude, Behaviour, Confidence.

OECD (2020), "Girls' and boys' performance in PISA", in PISA 2018 Results (Volume II): Where All Students Can Succeed, OECD Publishing, Paris,

Ojala, M. (2012). Hope and climate change: The importance of hope for environmental engagement among young people. Environmental Education Research, 18(5), 625–642.

Patrick, H., Mantzicopoulos, P., & Samarapungavan, A. (2009). Motivation for learning science in kindergarten: Is there a gender gap and does integrated inquiry and literacy instruction make a difference. Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 46(2), 166-191.

Preston, A. E. (2004). Plugging the leaks in the scientific workforce. Issues in Science and Technology, 20(4), 69-74.

Raabe, I. J., Boda, Z., & Stadtfeld, C. (2019). The social pipeline: How friend influence and peer exposure widen the STEM gender gap. Sociology of Education, 92(2), 105-123.

Riegle-Crumb, C., Farkas, G., & Muller, C. (2006). The role of gender and friendship in advanced course taking. Sociology of Education, 79(3), 206-228.

Robnett, Rachael. (2014) Girls' and Women's Preferred Methods of Coping with Gender Bias in STEM. International Journal of Gender, Science and Technology, 8 (1), p. 19-37.

Rodriguez, S., Regueiro, B., Piñeiro, I., Estévez, I., & Valle, A. (2020). Gender differences in mathematics motivation: Differential effects on performance in primary education. Frontiers in psychology, 3050.

Sáinz, M., & Eccles, J. (2012). Self-concept of computer and math ability: Gender implications across time and within ICT studies. Journal of vocational behavior, 80(2), 486-499.

Saramourtsi, E., Zafiri, M., & Pliogou, V. (2020). Gender Stereotypes in Children's Play, Pro-social and Aggressive Behavior in the Kindergarten Class: The Kindergarten Teachers' Stance. Universal Journal of Educational Research, 8(12A), 7992–8009.

Schneider, J., & Eckl, V. (2016). The difference makes a difference: Team diversity and innovative capacity.In OECD Blue Sky, Volume III, Ghent, Belgium.

Schwartz, S. H. (2012). An Overview of the Schwartz Theory of Basic Values. Online Readings in Psychology and Culture, 2(1), 1–20.

Schwartz, S. H., & Rubel, T. (2005). Sex differences in value priorities: cross-cultural and multimethod studies. Journal of personality and social psychology, 89(6), 1010.

Siddiq, F., & Scherer, R. (2019). Is there a gender gap? A meta-analysis of the gender differences in students' ICT literacy. Educational research review, 27, 205-217.

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

Swann, J., & Graddol, D. (1988). Gender inequalities in classroom talk. English in education, 22(1), 48-65.

Thomas, A. E. (2016). Gender Differences in Students' Physical Science Motivation: Are Teachers' Implicit Cognitions Another Piece of the Puzzle? XX(X), 1–24.

Tiedemann, J. (2000). Parents' gender stereotypes and teachers' beliefs as predictors of children's concept of their mathematical ability in elementary school. Journal of Educational psychology, 92(1), 144.

Viarengo, M. Gender Gaps in Education: Evidence and Policy Implications. EENEE Analytical Report 46, August 2021, https://eenee.eu/en/resources/library/gender-gaps-in-education-evidence-and-policy-implications/

Wang, N., Tan, A. L., Xiao, W. R., Zeng, F., Xiang, J., & Duan, W. (2021). The effect of learning experiences on interest in STEM careers: A structural equation model. Journal of Baltic Science Education, 20(4), 651–663.

Wang, M. Te. (2012). Educational and career interests in math: A longitudinal examination of the links between classroom environment, motivational beliefs, and interests. Developmental Psychology, 48(6), 1643–1657.

Wiswall, M., & Zafar, B. (2018). Preference for the workplace, investment in human capital, and gender. The Quarterly Journal of Economics, 133(1), 457-507.

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