GENDER AND INNOVATION IN STE(A)M EDUCATION

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Abstract

Gender aspects continue to play an important role in science education, conditioning study choices or shaping beliefs about one's own capacities and those of others. Performing arts based initiatives are on the forefront of innovative science education approaches and have participatory, dialogic and dialectic qualities to engage students in democratic, inclusive and reflective ways of learning. Both these dimensions can be brought together in order to explore how arts-based science education can contribute to address gender bias and stereotypes in educational and team-collaborative settings.

Key words: Science, Technology, Engineering and Mathematics Education (STEM education), Science, Technology, Engineering, Arts and Mathematics Education (STEAM Education), gender stereotypes, arts, gender bias, collaboration.

Introduction

Scientix, the community for science and mathematics education in Europe, initiated by the European Commission (Research and Innovation DG), has set up the Scientix observatory to provide a regular overview of the state of play of different themes related to STEM education. The themes and initiatives examined vary in duration, scope, audience and methodology yet all of them include elements of the project management and STEM education areas.

This article draws, to some extent, from the discussions between project coordinators, managers and representatives together with science educators participating in the 12th Science Projects Networking Event (SPNE12) organized by Scientix, PERFORM AND GEDII

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on Gender and Innovation in STE(A)M education.

The aim of this SPNE12 was to share experiences and initiatives addressing gender aspects in science education through innovative ways; to reflect upon the role of arts-based approaches for combating gender stereotypes within science, and to explore how arts-based approaches provide with an opportunity for renewing science education and for tackling gender bias in educational and collaborative contexts.

The event brought together 30 participants from 22 STEM education projects, organizations and schools. These included: European Schoolnet, IN3-UOC, UNESCO, CERN, University of Bristol, European Commission, University of Bayreuth, DLI - Digital Muse, Innoviris, Ecsite – HEIRRI, European Training and Research Association for a Cooperation Key to business, Ecsite – Hypatia, ICTA-UAB, High School, KU Leuven Association, EEB4, Sint-Lievenscollege, NEA GENIA ZIRIDIS SCHOOL, INS Sabadell, EU-Track, SIEMPRE vzw and the NEMO Science Museum.

The gender gap in STEM

Research has shown that, globally, women remain underrepresented in STEM not only as students, but also as teachers, researchers and workers[1], resulting in a significant gender gap.

In terms of students' achievement in STEM at secondary level, gender differences are not pronounced. Worldwide, 2015 PISA[2] results showed that, although a larger share of the top performers are boys, average gender differences in science performance remain minor. Moreover, the results also revealed that, in the European Union, disparities in the shares of low achievers in mathematics and science between boys and girls have been insignificant for a number of years.[3]

Nonetheless, it is gender disparities in interest towards STEM that are quite substantial, particularly in lower and/or upper secondary education. Indeed, girls start losing interest in STEM as they get older and in a bigger proportion than boys. In addition, the 2015 edition of

[1] UNESCO (2017) *Cracking the code: Girls' and women's education in science, technology, engineering and mathematics (STEM).* United Nations Educational, Scientific and Cultural Organization, France. Accessible: http://unesdoc.unesco.org/images/0025/002505/250567e.pdf

[2] The Programme for International Student Assessment (PISA) is a triennial international survey which aims to evaluate education systems worldwide by testing the skills and knowledge of 15-year-old students. In 2015 over half a million students, representing 28 million 15-year-olds in 72 countries and economies, took the internationally agreed two-hour test. Students were assessed in science, mathematics, reading, collaborative problem solving and financial literacy.

[3] OECD (2018). *PISA*, *PISA 2015 results in focus*. Accessible: http://www.oecd.org/pisa/test/

TIMSS Advanced[4] showed that the majority of upper secondary students taking advanced courses in mathematics and physics (in most of the participant countries) were boys. This is quite significant considering that pupils who study advanced STEM courses in upper secondary schooling are more likely to choose STEM-related degree programmes, in tertiary education.

Along these lines, in tertiary education, segregation in STEM education endures, too. According to UNESCO, female students represent only 35% of all students enrolled in STEM-related degrees, worldwide.[5] The same gendered patterns exist, altogether, in the European Union. The latest edition of the Gender Equality Index – which, among other variables, measures gender segregation in the fields of education, health, welfare, humanities and arts in different EU member states-– indicated that, out of all female students in tertiary education, almost half studied one of the mentioned fields, in contrast to a limited 21% of male tertiary students, in 2015[6].

Differences between males and females in tertiary education are also observed within STEM disciplines, in the European Union. A particularly salient case is found in connection to engineering, manufacturing and construction studies (the second most common higher education field of study) where almost three quarters of students in it are male. On the contrary, health and welfare, being the third largest field of study, accounted for close to three quarters of female students, of all students within this field.[7] Worldwide, trends are similar. Female enrolment in Information and Communication Technology and in engineering, manufacturing and construction fields remains low, although a significant increase in female enrolment has been found in natural sciences, mathematics and statistics, where women now account for a higher proportion in enrolment.[8]

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[4] TIMSS 2015 and TIMSS Advanced 2015 are the latest international assessments in mathematics and science conducted by IEA (the International Association for the Evaluation of Educational Achievement). TIMSS 2015 is conducted at fourth and eighth grades and TIMSS Advanced 2015 for students in the final year of secondary school enrolled in special advanced mathematics and physics programs or tracks. Accessible: http://timssandpirls.bc.edu/

[5] UNESCO (2017). *Cracking the code: Girls' and women's education in science, technology, engineering and mathematics (STEM).* United Nations Educational, Scientific and Cultural Organization. France. Accessible: http://unesdoc.unesco.org/images/0025/002534/253479e.pdf

[6] European Institute for Gender Equality (2017) *Gender Equality Index 2017 Measuring gender equality in the European Union 2005-2015.* Accessible: http://eige.europa.eu/rdc/eige-publications/gender-equality-index-2017-measuring-gender-equality-european-union-2005-2015-report

[7] European Commission, EUROSTAT. (Data extracted in June 2017) *Tertiary education statistics.* Accessible http://ec.europa.eu/eurostat/statistics-explained/index.php/Tertiary_education_statistics#Gender_distribution_of_participation

[8] UNESCO (2017) *Cracking the code: Girls' and women's education in science, technology, engineering and mathematics (STEM).* United Nations Educational, Scientific and Cultural Organization, France. Accessible: http://unesdoc.unesco.org/images/0025/002534/253479e.pdf

Finally, in the EU labour market, women embody less than half of the entirety of professionals employed as scientists and engineers, in possession of a tertiary degree.[9] Furthermore, in all sectors combined, the proportion of male researchers surpasses that of women, in most EU countries. In addition, in top level positions, women accounted for only 20,1% of the heads of institutions and 28% of board members (including leaders), in the EU-28 in 2014 [9].

Factors influencing girls' relationship with STEM

A large number of elements, from individual, family and peer level factors, to school factors and societal ones, is likely to determine participation and progression of girls in STEM studies.[1]

At an individual level, psychological factors, such as self-perception and confidence in one's own potential, can be a major variable[10]. For instance, in fields where it is presumed innate talent is required to succeed (a quality generally associated with males), women tend to be underrepresented[11].

These psychological factors are influenced and shaped by broader social variables. Through family values, parents can have a strong influence in girls' access and achievement in STEM education, whether positive or negative. This means that parents with a traditional outlook of boys and girls might perpetuate gendered perceptions and support behaviours that reinforce negative stereotypes about girls and STEM.

School, in all its dimensions, will also be a very important determinant of girls' relationship with STEM. The educational materials used in the classroom can have a detrimental impact in girls' decisions to follow STEM degrees, as long as they provide with sexist and/or stereotypical depictions of men and women, especially in relation to scientific and academic activities. Also, teachers' beliefs and attitudes, their behaviour and their expectations of students, can have a profound effect on girls' academic interest and performance in STEM subjects. Likewise, several studies have revealed that interactions between teachers and pupils *"can influence girls' engagement, self-confidence, performance and persistence in STEM studies*".[1]

[9] Directorate-General for Research and Innovation. European Commission. (2015) *She Figures 2015.* Luxembourg: Publications Office of the European Union. Accessible https://ec.europa.eu/research/swafs/pdf/pub_gender_equality/she_figures_2015-final.pdf

[10] UNESCO (2017). *Cracking the code: Girls' and women's education in science, technology, engineering and mathematics (STEM).* United Nations Educational, Scientific and Cultural Organization, France. Accessible: http://unesdoc.unesco.org/images/0025/002534/253479e.pdf

[11] Meyer, M. Cimpian, A. and Leslie S.J. (2015*) Women are underrepresented in fields where success is believed to require brilliance.* Front Psychol. 2015; 6: 235.Accessible: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4356003/

Last, at societal level, social and cultural norms also have a strong impact on the roles that women and men play in society. These stereotyped attitudes, behaviours, and expectations related to gender have huge potential to limit girls' aspirations in STEM.

School constraints in addressing gender equality in STEM education

As stated in the previous section, school factors can strongly contribute to gendered patterns in STEM education. Certainly, (STEM) educators do not work in isolation, but plan and implement their work inside multi-layered environments that can limit them in many different ways, resulting in very specific and possibly conditioned science education programmes and activities. (Achiam & Marandino, 2014)[12] The constraints in these environments can be explicit or implicit and, while some of them might appear to be beyond educators' immediate control, not all will. For this reason, in situations where control is possible, STEM educators should understand the existence of this many limits, and try to remedy them, with the ultimate goal of promoting gender equality.

As a way to counterbalance these constraints and correct possible unequal situations, teaching strategies implemented in the classroom will need to be updated, in order to support girls and boys equal opportunities. Indeed, TIMSS 2011 found that the way in which the curriculum is taught in primary and lower secondary education significantly affects students' opportunities to learn mathematics and science[13]. More specifically, student-centred strategies, inquiry-based or participatory schemes are regarded to influence girls positively and to reduce the gender gap in STEM achievement, while being beneficial for all students. Several initiatives have been put in place to solve this. For instance, the HYPATIA project has developed a toolkit made of a digital collection of innovative activities aimed at teenagers with a focus on gender-inclusive ways of communicating STEM.

A particular, innovative approach that has been accounted to have an influence in the improvement of gender equality in the STEM classroom is the introduction of the arts in the teaching of STEM disciplines, in line with current trends that push for a broader acknowledgement of the introduction of the STE(A)M[14] approach in developing science, technology engineering and mathematics lessons.

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[12] Achiam, M., Holmegaard, H.T. (2017) *Criteria for gender inclusion.* Hypatia project. University of Copenhagen, UCPH. Accesible: http://www.expecteverything.eu/file/2017/02/Hypatia-Theoretical-Framework.pdf
[13] UNESCO (2017). *Cracking the code: Girls' and women's education in science, technology, engineering and mathematics (STEM).* United Nations Educational, Scientific and Cultural Organization, France. Accessible: http://unesdoc.unesco.org/images/0025/002534/253479e.pdf
[14] Acronym for Science, Technology, Engineering, Arts and Mathematics.

STE(A)M and the promotion of gender equality

The intersection between STEM education and the arts

While it is generally agreed that the STE(A)M acronym refers to the intersection of sciences and arts, there are numerous approaches to its definition. Many of these understand STEAM as a learning framework that incorporates the influence of arts – arts being a set of disciplines including languages and liberal arts like sociology, philosophy or history.[15] Nonetheless, it can also be understood as the integration of STEM with specific artistic disciplines –-such as design, creative writing or visual and performing arts, among others.

However this is, a common trend among all of these approaches lies in the fact that innovative thinking in STEM disciplines is very much linked to overcoming the distinction between traditionally seen as creative fields – like the arts or music – and STEM disciplines, normally understood as more rigid or focusing on logical thinking (Catterall, 2002).[16] For this reason, a number of initiatives have been set up, in recent years, with the aim of overcoming these barriers.

For instance, the PERFORM project has been working on investigating the effects of the use of innovative science education methods based on performing arts in fostering STEM motivation and engagement among youngsters from France, Spain and the United Kingdom. The project explores a creative, participatory STEM educational process by using scenic arts with secondary school students, their teachers and early career researchers. It also analyses how human-centred, science-arts education contributes to the improvement of students' motivations towards the learning of science and towards strengthening the transversal competences (or transferable skills) they will need for potential STEM careers.

The use of arts to promote gender equality in STEM education

One of the most recent PERFORM experiences focused on reflecting on gender stereotypes in science while designing arts performances. A set of workshops were developed partly inspired by the results of J. Tveita study, in *"Can Untraditional Learning Methods used in Physics Help Girls to be more interested and Achieve more in this Subject?"* (1999), in which the author explored the use of role-games in science education for learning physics models by

[15] Yakman, G. (2010) *What is the point of STE@M? – A Brief Overview.* Accessible: http://www.academia.edu/8113832/What_is_the_Point_of_STEAM_A_Brief_Overview_of_STEAM_Education
[16] Henriksen, D. (2014). Full STEAM Ahead: Creativity in Excellent STEM Teaching Practices. *Integrated perspectives. The STEAM journal.* Vol. 1. Iss. 2. Michigan State University. Accessible: http://scholarship.claremont.edu/steam/vol1/iss2/15/

focusing on the gender gap among 12 to 16 year-old students. Findings of this study showed that both girls and boys engaged in the role-game activity and gained more understanding of the topic than using traditional teaching methods. Such a result contrasted with girls' performance when learning through traditional teaching methods - which was worse than boys performance, suggesting that girls might engage more in physics learning more through these artistic experiences.[17]

A specific PERFORM workshop to address gender stereotypes in science and STEM education was performed in Bristol and in Barcelona in 2017. In Bristol, facilitators introduced links between gender and STEM careers and jobs for further discussion with students. They also showed contrasting perspectives about science and gender by showing first the video "Science it's a girl thing"[18] and ensuing, a protest video, understood as a parody. Girls seemed to be more enthusiastic in the related discussion than boys were and gave arguments to break gender stereotypes. In Barcelona, school facilitators applied a role-play game to engage students in a debate to promote their reflection about gender stereotypes in science and about the roles of women and men in science, in the past and nowadays.[19]

Gender and innovation in STE(A)M education

Following these activities carried out by the PERFORM project to introduce arts in the classroom and to promote gender equality, a related workshop was organized during the 12th Scientix Project Networking Event. In it, a number of discussions took place, the objective of which was (1) to identify the three greatest challenges participants had faced in introducing arts in science education; (2) to identify what kind of support would be helpful in overcoming such obstacles (specifically in terms of policies, plans, or support systems from agencies including government ministries, universities, schools or international organizations); and (3) to identify how arts can help in dealing with gender stereotypes in STEM education and what is the added value of arts in this regard, if any.[20] The results of the discussions showed different elements:

[17] Ruiz-Mallén, I., Muller J., Kim. E., (2017). *How to address gender stereotypes in science education through innovation based on arts-based approaches?* Accessible: https://www.slideshare.net/Scientix/spne12-workshop-how-to-address-gender-stereotypes-in-science-education-through-innovation-based-on-artsbased-approaches/

[18] This video was funded by the European Commission and later on removed following widespread criticism. Copies of the video can still be found in YouTube.

[19] Ruiz-Mallén, I., (2017) *Participatory engagement with Scientific and Technological Research through performance*. Accessible: https://www.slideshare.net/Scientix/spne12-perform-participatory-engagement-with-scientific-and-technological-research-through-performance

[20]Kim, E. (2017) *#SPNE12 - Reflect and identify best practices on gender and innovation in STE(A)M education*. Accessible: https://www.slideshare.net/Scientix/spne12-reflect-and-identify-best-practices-on-gender-and-innovation-in-steam-education

- Concerning the greatest challenges faced introducing arts in the science education; institutional challenges, such as lack of flexibility in schools, funding restrictions and the absence of structures that support interdisciplinary and cross curricula approaches. In addition, lack of recognition, of coordination and joint efforts, disparity in practice and a lack of evidence were highlighted as a burden to the instruction of the arts, too.
- Concerning the identification of what kind of support would be helpful to overcome the mentioned obstacles, three main points were raised. The first one in relation to more training opportunities for educators in terms of Responsible Research and Innovation (RRI); the second one in terms of improving science communication and networking between policy makers, science advisors and educators; the third one claiming the need for more engagement causes that could bring about more meaningful science results. It was claimed that an improvement in this matter would attract better funding in initiatives of the kind, which in turn would improve different stakeholders' engagement in RRI. Other comments referred to the usage of new educational methodologies, such as project based learning.
- Regarding the last part of the workshop, dedicated to discuss about how to deal with gender stereotypes in STEM, several ideas were pointed out, mostly related to the promotion of ones' self-expression and to the development of creativity, as open doors to engage girls in scientific disciplines.

Conclusions

As recent data has shown, the gender gap in STEM education is still prevalent, particularly in terms of motivation and interest. Furthermore, the factors that influence girls' uptake of STEM educational paths and careers are manifold, interconnected, and affect most aspects of ones living. Even if only focusing on the school environment, the array of elements affecting girls' behaviour towards STEM is quite extensive (from instruction strategies and methods, to educators' behaviours, not to mention school facilities and learning materials).

Nonetheless, educators still hold great influence towards students. For this reason, it will be crucial to educate and to provide them with resources and strategies that will support them in the promotion of gender equality in the classroom. One of these being the introduction of the arts in STEM lessons, as a way to integrate and to hold girls interest in STEM disciplines.

As we learned from the many stakeholders participating in the 12th Scientix Project Networking Event, while this educational approach was widely regarded as being beneficial for female students, there are still many barriers for the integration of the arts in STEM, mostly related to institutional constrains. Nonetheless, during the same event, several ways of supporting this approach were detected, including increasing the training opportunities for educators and the communication between STEM stakeholders. And overall, it was noted how more empirical research is needed to validate the weight of the factors influencing the gender gap in STEM education and to explore and evaluate solutions.

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