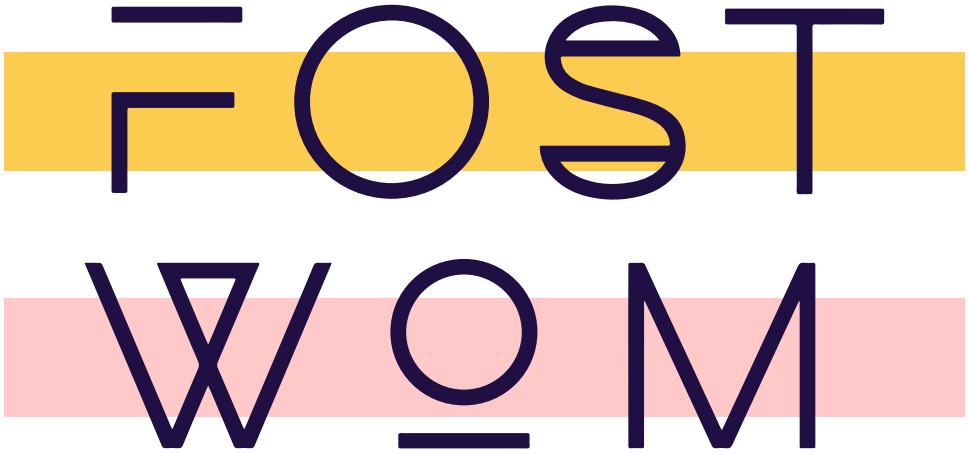

Women in STEM and STEM MOOCs

Why women are underrepresented in STEM and gender-balanced STEM MOOCs and how to use STEM MOOCs to fill the gap

The FOSTWOM project

FOSTWOM is a three-year project (2019-2022), co-funded by the European Commission's Erasmus+ for Higher Education (Erasmus+ KA2 Cooperation for Innovation and the Exchange of Good Practices – Strategic Partnerships for Higher Education).

FOSTWOM intends to use the inclusive potential of Massive Open Online Courses (MOOCs) to propose STEM subjects free of stereotypes on gender skills. FOSTWOM also intends to use MOOCS to propose STEM subjects free of stereotyping assumptions on gender abilities. The consortium is interested in attracting girls to STEM education and raising the number of young women that pursue careers in science and technology.

The consortium consists of the following partners:

- UNIVERSITAT POLITÈCNICA DE VALÈNCIA (Spain) - Coordinator
- INSTITUTO SUPERIOR TÉCNICO (IST) - Universidade de Lisboa (Portugal)
- METID - POLITECNICO DI MILANO (Italy)
- CONSERVATOIRE NATIONAL DES ARTS ET MÉTIERS (CNAM) (France)
- KTH ROYAL INSTITUTE OF TECHNOLOGY (Sweden)
- COLÉGIO AMOR DE DEUS (Portugal)
- I.I.S. BENEDETTO CASTELLI (Italy)

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1 INTRODUCTION

1 Introduction

According to the European Schoolnet[1], skills in Science, Technology, Engineering and Mathematics (STEM) are becoming an increasingly important part for basic literacy in today's knowledge economy, since they are requested in order to ensure the citizens' confidence, knowledge and competences to participate actively in an increasingly complex scientific and technological world (EU Commission Report, 2015). With this framework, European policies are demanding a need to build capacities and develop innovative ways of connecting science to society, namely among young people intending to attract them to STEM subjects in secondary and higher education and related careers (EU Commission Report, 2015). However, it is also known that there are multiple disparities in participation in science education across regions, cultures and gender in Europe which are blocking the full involvement and the empowerment of all citizens and talents.

Both education and gender equality are an integral part of the 2030 Agenda for Sustainable Development, adopted by the United Nations General Assembly in 2015, as distinct Sustainable Development Goals (SDGs) but also as catalysts for the achievement of all other SDGs. STEM underpins the 2030 Agenda for Sustainable Development, and STEM education can provide learners with the knowledge, skills, attitudes and behaviours required for inclusive and sustainable societies. Women and girls want to know how STEM will be used to make a difference in the world.

Thus, special attention must be paid to science education of girls and young women, since their voices, expertise and creativity are crucial elements for sustainable development progress[2]. However, they are being held back by discrimination, biases, social norms and expectations that influence the quality of education they receive. Indeed, while evidence shows that there are only a few reliable differences between boys' and girls' brains relevant to learning or education (Eliot, 2013) according to Unesco's Working Paper 1 integrated with SAGA Project[3] (Unesco, 2016), society takes these small differences in the cognitive skills of girls and boys (Schleicher, 2018), and makes them much bigger, supporting boys' ability in math and science, and discouraging girls who study these subjects. With this context in mind, FOSTWOM intends to

[1] http://www.eun.org

[2] https://en.unesco.org/sustainabledevelopmentgoals

[3] https://en.unesco.org/saga

use the inclusive potential of Massive Open Online Courses (MOOCs) to propose STEM subjects free of stereotyping assumptions on gender abilities. Moreover, the consortium is interested in fostering young women to science and technology, through accessible online content with relevant real-world applications within strong conceptual frameworks.

The consortium planned, as a starting point of the project, a benchmark on gender balance in STEM education and a diagnosis on STEM barriers implemented with secondary schools and higher education institutions, which is the present report.

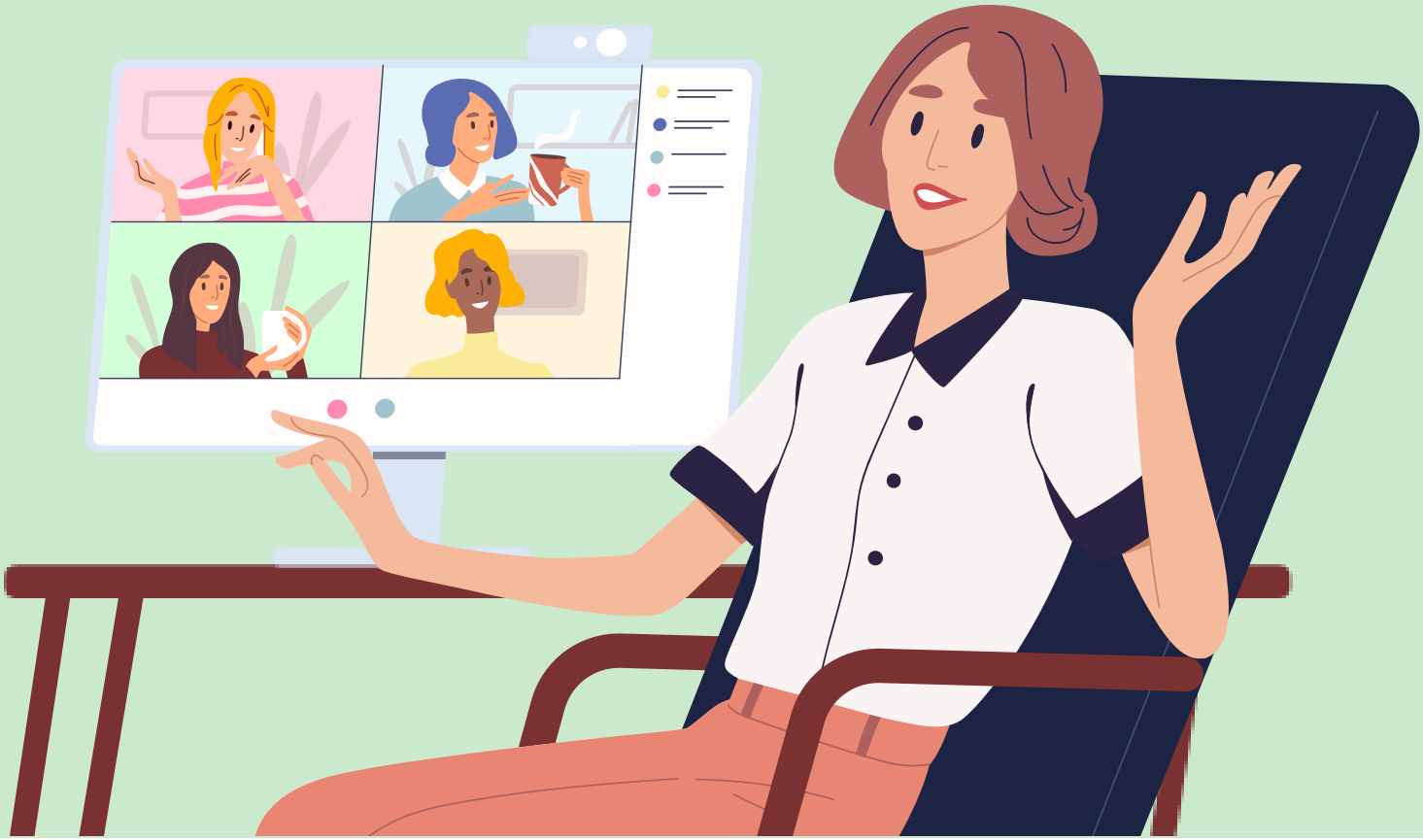
1.1 Methodology

The motivation behind this project is based on the project team members' experiences on an everyday basis while teaching in STEM higher education institutes (HEI), designing and producing MOOCs, and even applying MOOCs in blended learning methodologies. We know from experience that a lot of students are using MOOCs in flipped classroom strategies within UPV, IST and POLIMI's curricula (Despujol et al., 2018; Gomes et al., 2018; Raffaghelli et al., 2018), but only very recently the teachers started to write research papers on this topic (Moura Santos & Costa, submitted 2020).

To better understand in which context the gender gap in STEM exists, and how girls and women perceive STEM-related education and careers, each FOSTWOM's partner conducted desk research, searching for reports, papers and books, using the keywords "Girls/Women" or "Gender", "STEM", "MOOC". The relevant literature and research found on the theme have been studied and analysed. Additionally, examples of initiatives aiming to decrease the gender gap have been studied and some of them are highlighted in this report.

Based on the results and the analysis of data from the desk research, and the project teams' own experiences, we propose some very general recommendations for filling the gap, and in particular, we advance several conclusions that we consider to be the important actions to take into account while building a gender balance Toolkit (see also section 6) and the project's MOOCs. By a gender balance Toolkit, we mean a collection of recommendations and resources for instructional designers and teaching staff to apply while designing and preparing storyboards for MOOCs, so that future MOOCs have a greater chance to be better gender-balanced.

2 OVERVIEW OF THE CURRENT SITUATION



2 Overview of the current situation

During the past 50 years (World Economic Forum Report, 2020), women have made tremendous progress in the education and labour sectors. Even in historically male fields such as business management, law, and medicine, women have made impressive gains. In scientific areas, however, women's educational gains have been less dramatic, and their progress in the workplace is still slower and men continue to outnumber women, especially at the senior management level of these professions.

Globally, less than 30% of the world's STEM researchers are women. Why are there so few women working as scientists and engineers? (Chavatzia, 2017) One possible reason is that there are not enough young women studying STEM subjects[4]. As a result, there are few female role models in the STEM-related labour market. In this report, we want to focus first on the underlying causes of WHY this is the case and, secondly try to answer WHAT can be done to help to solve the problem?

Starting with education it is known that in elementary and middle school, girls and boys take math and science courses in roughly equal numbers. It is only when entering High school that the gender gap starts to emerge[5]. A study in the United Kingdom (UK) (Bauer, 2017) found that, at the age 10-11 years, boys and girls were almost equally engaged with STEM, with 75% of boys and 72% of girls reporting that they learned interesting things in science. The secondary school setting represents a critical point in helping adolescents become aware of potential STEM careers and connecting these career decisions to educational decisions (Lazarides & Lauermann, 2019).

Among first-year college students, women are much less likely than men to say that they intend to major in STEM. In higher education, women represent only 35% of all students enrolled in STEM-related fields of study according to Chavatzia for Unesco (2017), but this percentage varies from country to country (World Economic Forum, 2020).

The women's representation in science and engineering declines further at the graduate level and yet again in the transition to the workplace.

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[4] It is possible to check the numbers of female enrolment in STEM studies by country in the World Economic Forum's report of 2020.

[5] The gap begins in High school, but it's very hard to find numbers in reports for this level of education.

According to the 2018 Women in Tech Index[6], whereas in the five EU countries of the FOSTWOM consortium the percentage of female STEM graduates is around 27%, the percentage of women working in the information and communication technology sector is around 17%.

The research for this report indicates that there are several reasons why there are fewer female students enrolled in STEM subjects. There are multiple and overlapping factors that influence girls' and women's participation, achievement and progression in STEM studies and careers, all of which interact in complex ways. External factors such as family and teachers in the girls' direct proximity as well as more abstract impact from the surrounding society in terms of available role models and stereotype portrayals in media have a great effect on girls' subjective self-evaluation and interest in STEM subjects. This leads to poor female enrolment rates.

2.1 Family of High school students

Prior research indicates that parental influence is especially important to adolescents during the High school years in career considerations and that they value their parents' input (Keller & Whiston, 2008; O'Brien, Friedman, Tipton, & Linn, 2000). Parents' own beliefs, attitudes and expectations are themselves influenced by gender stereotypes, which can cause differential treatment between girls and boys in care, play and learning experiences.

Parents with higher socioeconomic status and higher educational qualifications tend to have a more positive attitude towards STEM education for girls than parents with lower socioeconomic status and education. This is a conclusion from the Unesco's Working Paper 4 integrated with SAGA Project (Unesco, 2018). The knowledge of parents about STEM careers is often cited as key influences in students' choice of major, however, it was found to have limited knowledge of STEM careers, especially regarding information technology and engineering. Without the support and encouragement of parents to explore options in the STEM fields, many students may never even consider these fields.

Parental attitudes play an important role in encouraging students to consider various career options, including career exploration, gender-typing, and future occupational plans. Girls' career choices are more influenced by their parents' expectations, whereas boys' career choices are more influenced by their interests (Schleicher, 2018). By creating a

[6] https://www.honeypot.io/women-in-tech-2018/

"growth mindset"[7] environment, parents can encourage girls' achievement and interest in math and science. Although parents' influence is very important, this factor is out of the direct scope of FOSTWOM's project. Therefore, we will not specifically consider raising awareness among parents by any of the tools we ought to develop within the FOSTWOM project. However, we will support other initiatives in this direction.

2.2 Teachers and other High school staff

STEM teachers have a positive influence on students' performance and engagement, in particular girls' performance and motivation, with further STEM studies and careers. Girls also appear to perform better when teaching strategies take into consideration their learning needs, and when teachers have higher expectations of them in STEM subjects and treat them equally. Finding effective ways to attract and retain well-qualified teachers in STEM fields is critical. Teachers need to be aware that emotional and subjective factors can impact on girls' interests to participate and continue in STEM education (see next section). Teachers should take in consideration of the influence their biases could have on their teaching, advising, and evaluation of students and can work to create an environment in the classroom that counters gender-science stereotypes[8].

Hence, one important measurement to mitigate the lack of interest of STEM subjects among girls is to educate teachers on stereotype biases and the benefits of a growth mindset environment in their classrooms (Hill et al., 2010).

Within our research, we also found special concerns about the limited knowledge of science and math secondary teachers and counsellors concerning STEM careers, especially information technology and engineering (Smith, 2009; Cruz & Kellam, 2018). As we will see in section 3.1, there are currently several initiatives, both globally and locally, that seek to increase girls' interest in STEM subjects by bringing High school students and teachers closer to the university and promoting awareness on STEM-related careers.

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[7] This term will be used a lot through this report. By a growth mindset environment we mean an environment where the main message is that intellectual skills can be acquired and that anyone who works hard can succeed.

[8] See for instance the implicit association tests at https://implicit.harvard.edu to gain a better understanding of what biases one can have.

We hope that the Toolkit and the MOOCs which we intend to develop within the FOSTWOM project will also foster the awareness on High school teachers and counsellors about STEM higher education and careers.

2.3 Girls' self-evaluation/self-perception and interest in STEM

The results of the PISA 2018 study, indicate that in mathematics and science, gender differences are generally small. "However, in claiming victory for closing gender gaps in the cognitive skills of girls and boys, education may have lost sight of other social and emotional dimensions about learning that may have a stronger impact on children, when they think about what they want to be when they grow up" (Schleicher, 2018).

Among 15-year-olds assessed by PISA, only 1% of girls reported that they wish to work in ICT-related occupations, compared with 8% of boys who did, on average in OECD countries (Schleicher, 2018). A recent report by OECD indicates that girls' expectations regarding their future career when they reach the age of 30, is mostly to be a doctor, followed by a teacher. On the other hand, boys reported that they would like to become engineers, followed by business managers (Schleicher, 2018).

Research profiled in the report finds that girls assess their mathematical abilities lower than boys with similar mathematical achievements. More so, girls hold themselves to a higher standard than boys in subjects like math, believing that they have to be exceptional to succeed in "male" fields. One result of girls' lower self-assessment of their math ability - even in the face of good grades and test scores - and their higher standards for performance is that fewer girls than boys aspire to STEM careers. By emphasizing that girls and boys achieve equally well in math and science, parents and teachers can encourage girls to assess their skills more accurately.

Studies have identified personal interest as a key influencing factor of students' choices towards a STEM career (Blotnicky et al., 2018). Interest plays an important role in girls' engagement in STEM at school, their subject choices in higher education and their career plans. If a student has never been exposed to a particular area, then their interest cannot develop (Cruz & Kellam, 2018). Interest is also influenced by girls' overall learning experience in school, especially at earlier grades, including the influence of STEM teachers and their teaching strategies, the curriculum as well as opportunities for practice, exposure to role models and mentorship.

2.4 Stereotypes and role models

Stereotypes influence girls' self-assessments in math, which influence their interest in pursuing STEM careers. Girls and women seem to voluntarily decide to avoid STEM careers are influenced by the cultural belief that science and math are male domains. Most people associate science and math fields with "male" and humanities and arts fields with "female," according to research that conducted to this report (Hill et al., 2010). Implicit bias is common, even among individuals who actively reject these stereotypes. Negative stereotypes about girls' and womens' abilities in mathematics and science persist despite girls' and women's considerable gains in participation and performance in these areas during the last few decades (Chavatzia, 2017). Explicit or implicit gender stereotypes that communicate the idea that STEM studies and careers are male-dominated can negatively affect girls' interest, engagement and achievement in STEM and discourage them from pursuing STEM careers. Researchers also believe that stereotypes can lower girls' aspirations for science and engineering careers over time. Even if girls do not endorse these stereotypes themselves, knowing that people in their immediate environment hold such beliefs can undermine girls' confidence and, consequently, their performance and intention to pursue a STEM career (Chavatzia, 2017).

Unfortunately, most girls don't have a STEM female role model in the family, and among teachers, to look up to. So, it's with no surprise that, when asked to describe a typical scientist, engineer, mathematician, or computer programmer, 30% of girls say that they envision a man in these roles. As do almost 40% of adult women and 43% of women in STEM and ICT fields (Kesar, 2018)[9]. Girls and young women have a hard time picturing themselves in STEM roles. Lack of role models continues to channel girls' career choices away from STEM fields. Girls who have STEM role models report more passion for all STEM subjects. The number of girls interested in STEM almost doubles when they have role models compared to those who do not (26% of girls without a role model report an interest in STEM subjects, versus 41% with role models). Over half (51%) of girls with role models can imagine a future career in STEM (KTH, 2019). Exposing girls to successful female role models can help mitigate stereotypes because girls see that people like

[9] See more Microsoft's studies and actions for Closing the STEM Gap: https://www.microsoft.com/en-us/corporate-responsibility/skills-employability/girls-stem-computer-science

them can be successful and stereotype threats can be managed and overcome.

Later on this year, an online survey will be conducted, to contribute to better understand which are the actual barriers for secondary school girls in pursuing a STEM career and how open they are to MOOCs to help them overcome the gender gap. The survey will be conducted in a two-step model where the first survey, with only a few respondents, serves as a test survey for the development of the second and final survey. In the first stage, a test survey for a small group of High school students representing the project's High school partners will answer a questionnaire that consists of a mix of closed and open questions (more open than closed questions). In the second stage, a questionnaire with validated questions from the test survey will be sent to selected groups of students from all the educational institutes within the consortia of FOSTWOM.

3 FOSTERING GIRLS' INTEREST AND MOTIVATION IN STEM

3 Fostering girls' interest and motivation in STEM

Based on previous section´s benchmark and on further research conducted for this report, for example, the book/report conducted by the American Association of University Women's (Hill et al., 2010)[10], we conclude that although women have made impressive gains in science and engineering they remain a distinct minority in many sciences and engineering fields. In this section, we first present several relevant and inspirational initiatives which are directed to raise girls' interest in STEM and then, following on what our research suggests, we will focus on what can be done to create environments that support girls' achievements and interest in STEM. Later on, in section 5, we will discuss on what extent MOOCs in STEM areas can help increase girls' interest in these topics.

3.1 Initiatives fostering girls in STEM

Worldwide, several initiatives seek to increase girls' interest in STEM subjects and STEM-related careers among High school students and female undergraduates (Allueva-Pinilla et al., 2019; Delgado et.al., 2019; Sullivan & Bers, 2019). There are international, national and local initiatives all over the world. In this section, some of these will be presented.

In December 2015, the UN General Assembly adopted a resolution that proclaimed the 11th of February of each year the International Day of Women and Girls in Science. This implies that all member states, organisations, civic societies, etc. are encouraged to develop public, raising awareness and education activities to promote equal participation of girls and women in STEM-related education, employment and decision-making processes (United Nations, 2016).

On a more local scale, there is a range of activities evidencing the issue. One example is an interdisciplinary network created in 2010 at the

[10] More information can be seen in https://www.aauw.org/about/

University of Zaragoza (Spain) that developed two projects aimed at High school students: “Wikinformática! in Aragon”[11] and “Women in STEM by EuLES”[12]. “Wikinformatics! in Aragon” is a contest for groups of students in which a wiki[13] is developed about women who stand out in the history of Information and Communication Technologies (ICT). The objective of the project Women in STEM is to offer testimonials from women in the areas of STEM to stimulate scientific vocations, especially among young people and girls (Allueva-Pinilla et al., 2019). The experiences reported by the interviewed women demonstrate the difficulties encountered in the field of work, but also highlight the changes that have been occurring in recent years in favour of gender equality, as well as the self-realisation for choosing to study in the areas of STEM. Another Spanish initiative is the Girls4STEM project, which started in 2019 at Universitat de València, Spain[14]. This project works towards breaking the stereotypes linked to STEM fields, addressing both boys and girls aged from 6 to 18, but especially trying to open the range of career options for young women through the interaction with female STEM experts (Benavent et al., 2020). All these projects aim to bring High school students closer to the university and to promote the incorporation of students, mainly young women, in their first scientific and technical courses (Delgado et.al., 2019).

Another example of an initiative that aims to make High school girls aware of and interested in STEM education and their future perspectives generated by these areas of education, is the campaign ‘Giant’ at the Royal Institute of Technology (KTH), Stockholm. The annual campaign’s main objective is to incentive female High school students towards educational programmes at the university that have less than 30% of female students enrolled. The programmes are, for example: engineering physics, electrical engineering and computer technology. With the motto “*The future is too important to be left to men*” KTH runs an yearly festival and several workshops. KTH also contracts female students ambassadors for inspiration, public newsletters, etc to inspire Swedish girls to enrol in these programmes. From the 220 participants at the Giant festival 2019, 69 applied for one or more of the engineering

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[11] https://wikinformatica.unizar.es/wiki/Página_principal

[12] http://micro.eules.org/#Women

[13] A wiki is a hypertext publication collaboratively edited and managed by its own audience directly using a web browser. A typical wiki contains several pages for the subjects or scope of the project and may be either open to the public or limited to use within an organization for maintaining its internal knowledge base (taken from Wikipedia).

[14] Similar initiatives can be found in IST, see for instance https://tecnico.ulisboa.pt/pt/tag/ciclo-women-in-science-and-engineering/

programmes presented at the festival[15] (KTH, 2020). The initiative 'Cloud Girls' from Brazil is also another example of an initiative that wants to inspire and empower women within ICT areas[16]. It was initiated in 2015 and includes mentor and educational programmes, career guidance workshops and networking events, by women for girls and women, to encourage and empower them to enter or stay in the ICT educational and/or work environment (Cloud Girls, 2020)[17]. Another example is the international initiative ´Girls who code' where it states that "*we're on a mission to close the gender gap in tech*". They operate in the US, Canada, UK and India. The four tools this organization advocates, to increase girls participation in computer science are: tracking and reporting data on computer science participation, an expansion of computer science to all middle-class schools, increasing exposure to women in tech and lastly, funding of gender inclusion training within professional development (Girls who code, 2020)[18].

3.2 Recommendations to foster girls' interest in STEM

Here we advance several ideas and recommendations that could raise, from the perspective of published literature and our own experience, the number of female High school students applying for STEM subjects. These are teaching measures on cultivating girls' achievement and interest in science and engineering, and by raising awareness among teachers on how they can teach and what kind of expectations they can mediate between girls and boys, mitigating bias.

3.2.1 Spread the word about girls' and women's achievements in math and science.

Avoid reproducing the stereotype that men are better than women in STEM areas, since it can affect girls' performance, how they self-assess their performance, and their aspirations (Hill et al., 2010)[19]. In particular, give examples about the increasing number of girls and women that are

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[15] https://intra.kth.se/aktuellt/nyheter/giants-kampanjen-ger-resultat-1.938226

[16] See other Brazilian initiatives for girls in STEM in: https://www.igualdadestem.com

[17] https://www.cloudgirls.com.br/sobre/index.html

[18] https://girlswhocode.com/about-us/research

[19] See also Microsoft Action Guide in https://www.microsoft.com/en-us/corporate-responsibility/skills-employability/girls-stem-computer-science

achieving at higher levels in STEM subjects. Support initiatives that bring High school students closer to the university and promote the incorporation of female students in STEM degrees. The results of the FOSTWOM project will count as one of these initiatives.

3.2.2 Teach girls the effects of self-improvement and hard work.

Teach girls that every time they work hard and learn something new, their brains form new connections, and over time they become smarter (Hill et al., 2010). Support passion, dedication, and self-improvement, not simply innate talent or "gift", in your students. Communicate with girls and boys that seeking challenges, working hard, and learning from mistakes are valuable.

3.2.3 Promote a growth mindset environment.

Girls in a growth mindset environment[20] are less affected by stereotype threat in science and math, namely in high stakes tests (Schleicher, 2018)[21]. Therefore, a growth mindset environment should be created in the classroom by emphasizing that intellectual skills can be improved with effort and perseverance and that anyone who works hard can succeed[22].

3.2.4 Help girls recognise their career-relevant skills.

Girls are less likely than boys to interpret their academic successes in math and science as an indication that they have the skills necessary to become a successful engineer, physicist, or computer scientist (Plant et al., 2009). Help them recognise what skills are relevant, first to succeed in STEM studies, and then in a related career.

3.2.5 Help yourself to become aware of bias.

Teachers must be aware of gender bias and be able to interrupt the unconscious thought processes that lead to bias. Moreover, being conscious of the influence of biases have a positive influence on

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[20] Growth mindset means that, with effort, it's possible to increase intelligence levels, talents, and abilities. Applied to education, this means that whenever a student faces a learning challenge, the teacher can help the student to avoid the temptation to give up and reinforce the idea that we as humans often learn from mistakes.

[21] High-stakes tests are for instance final exams to enter a new cycle of studies.

[22] Microsoft Action Guide in https://www.microsoft.com/en-us/corporate-responsibility/skills-employability/girls-stem-computer-science

teaching, advising, and evaluating students in a more gender balanced way. The aim of FOSTWOM's project is that the gender balance Toolkit and the MOOCs can be of use in this topic.

4

RETAINING FEMALE UNDERGRADUATES IN A STEM DEGREE

4 Retaining female undergraduates in a STEM degree

The subject of undergraduates' enrolments and careers in STEM is a topic which emerged in our desk research with almost all references, reports and papers, from USA, UK or global organizations such as Unesco and World Economic Forum. It seems that there is a lack of analysis in the current literature from other countries, particularly in the FOSTWOM's partner countries, like France, Italy, Portugal, Spain and Sweden, about female dropouts in STEM degrees[23] during the first years of the University. Nevertheless, our experience while teaching undergraduates in STEM higher education institutes, and even when applying MOOCs in blended learning methodologies, tell us that this is a relevant topic to learn more about on how to achieve our goals, i.e., decreasing female dropouts and raise the number of enrolled female students in STEM education and STEM careers.

In this section, we firstly report our research findings of the main problems faced by female undergraduates in a STEM degree, and then expose several ideas and recommendations that, from our everyday teaching experience, could attract, raise, and retain the number of female undergraduate students in STEM subjects.

4.1 Undergraduates' enrolment and thoughts of a career in STEM

Although many young women graduate from High school are well prepared to pursue a science or engineering major, relatively few women pursue majors in STEM, and when they do, many of them leave their majors before graduation or don't pursue a STEM career after graduation (Unesco, 2017; World Economic Forum, 2020). Even fewer women are present on science and engineering faculties (Kesa, 2018). The data from the Global Gender Gap Report 2018[24] show that gaps

[23] The word "degree" is more often used in continental EU countries, than "major", which reflects a different curriculum organization when compared with curricula in UK and USA.

[24] https://reports.weforum.org/global-gender-gap-report-2018/assessing-gender-gaps-in-artificial-intelligence/

within the Artificial Intelligence talent pool reflect the broader gender gaps within specializations in STEM studies, across industries, and in the acquisition of emerging skills.

Globally, within the female student population in higher education, only around 30% choose STEM-related fields of study. Differences are observed by disciplines; female students' enrolment is particularly low in ICT (3%), natural science, mathematics and statistics (5%) and engineering, manufacturing and construction (8%); the highest is in health and welfare (15%) studies (Chavatzia, 2017).

4.2 Measures to meet the challenges and to attract and retain more female students in a STEM degree

Low female participation in STEM Higher education and consequently underrepresentation of women in STEM careers has been a concern voiced by countries around the globe.

Here we expose several ideas and recommendations, inspired partially by the desk research, our everyday teaching experience (Moura Santos & Costa, 2020), that could attract and raise the number of female undergraduate students applying for and enrolled in STEM subjects. These are measures by creating university environments that support young women in STEM together with raising awareness among university teachers on how they teach and what kind of expectations they mediate with their students. Research shows that teachers can reduce stereotype threats in their classrooms and change students' mindsets from fixed to growth through the messages they send to their students (Hill et al., 2010)[25]. This will be done in the form of recommendations for teachers, this time directed to HEI faculty members, as we have done in the previous section.

4.2.1 Spread the word about women's achievements in STEM careers.

Avoid reproducing the stereotype that men are better than women in STEM areas and give examples about the increasing number of women who are achieving at higher levels in STEM subjects (Hill et al., 2010). When teaching in early STEM courses, try to find examples of real-life applications relevant to STEM careers, especially attractive careers for

[25] See also Microsoft Action Guide in https://www.microsoft.com/en-us/corporate-responsibility/skills-employability/girls-stem-computer-science

women. This measure will help building female students' interest and confidence in their skills (Hill et al., 2010)[26].

4.2.2 Strategies to upgrade STEM knowledge.

For women who arrive at university underprepared, continuous support can be given in the form of study groups during the semesters. Prepare introductory online content, in particular MOOCs, that appeal to students with different levels of preparation or background when entering the university. These measures can be critical for identifying and recruiting talented STEM students from diverse backgrounds (Hill et al., 2010). The MOOCs developed in the FOSTWOM project are a tool aiming to support teachers in this goal.

4.2.3 Foster active learning strategies and formative assessment in teaching.

Foster students' active learning behaviours through out-of-class preparation, participation in group dynamics, and critical thinking, just to mention a few activities. The tutorial/exercises classes with group discussions, comments from peers and tutors on the participants assignments, together with formative online assessments (Moura Santos & Ribeiro, 2017)[27] helping to build confidence, can benefit the female audience.

4.2.4 Benefits of performance standards and expectations clearly stated.

Extremely low average test scores are common in many university science and engineering courses. Low scores increase uncertainty in all students, but they have a more negative effect on students who already feel like they don't belong, as many women in STEM studies feel (Pollack, 2015). By clarifying the students on what is expected and accurately judge their performance, this will help them greatly, in particular the female undergraduates.

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[26] See also Microsoft Action Guide in https://www.microsoft.com/en-us/corporate-responsibility/skills-employability/girls-stem-computer-science

[27] See also the Polimi's MOOC: https://www.pok.polimi.it/courses/course-v1:Polimi+ASS101+2019_M9/about

5
STEM MOOCs

5 STEM MOOCs

In this section, we want to reveal the research that can answer the question to what extent MOOCs in STEM areas can help increase girls' engagement in STEM. These girls, eventually, can act as role models in the future, creating a positive spiral.

Attracting and retaining more women in STEM careers will maximise innovation, creativity, and competitiveness (World Economic Forum, 2020). Increasing female's participation in STEM fields is crucial for strengthening the STEM workforce and a country's tech global competitiveness.

5.1 Can MOOCs be part of the solution?

Despite the girls' lower stated interest in science and engineering compared with boys, recent research suggests that there are ways to increase girls' interest in STEM areas (Turner & Lapan, 2005; Eisenhart, 2008; Plant et al., 2009). MOOCs have been tremendously spreading among STEM academic disciplines and have served an agglomeration of various learner groups across the world. MOOCs have attracted tens of millions of learners around the world. Theoretically, anyone with an Internet connection can freely access these online courses, which are often provided by professors from elite universities. Well-known MOOC providers, like edX and Coursera, continue to claim for several years that MOOCs provide an affordable and flexible way to learn new skills and deliver quality educational experiences at scale[28]. Further evidence from our direct experience shows that these statements are correct, through the use of MOOCs in blended learning methodologies.

MOOCs have the potential to democratise education by providing learners with access to rich sources of information. MOOC proponents argue that MOOCs can democratise higher education and provide learning opportunities not only for traditionally underserved populations but also for college-educated populations, who may benefit from the extra coursework to improve their employment opportunities (Koller, 2013). They can also help reduce the gap between High school and university.

[28] https://www.mooc.org; https://www.coursera.org

A good example of this can be given with the Finish MOOC on Computer Science produced by the Department of Computer Science at the University of Helsinki and developed as a course completely online, open to pupils and students from all schools in Finland (Kurhila & Vihavainen, 2015). There are not many relevant topics in high school curricula that are related to Computer Science (CS), in general. On the other end, the scarcity of female students in CS programs is one of the most addressed challenges facing our society as it can be seen in the Assessing Gender Gaps in Artificial Intelligence Report[29]. The MOOC was produced to alleviate this problem for school students in Finland. The schools have offered the MOOC as an elective CS course for their students and granted formal school credits for completing (parts of) it. It is beneficial for the schools: MOOC is a way to extend optional course offerings for schools because the complete operation is conducted outside the school.

Therefore, to take MOOCs in topics not taught in schools and to explore different disciplines is a way forward for High school students to have the opportunity to make more informed academic and career choices.

5.2 What can young women expect from MOOCs?

It seems that there is a lack of analysis in the current literature about how MOOCs are used in High schools, or even in the first years of the university. We know from experience that a lot of students are using MOOCs in blended learning strategies within Universitat Politècnica de València (Spain), Instituto Superior Técnico (Portugal) and Politecnico di Milano (Italy) curricula[30] (Despujol et al., 2018; Gomes et al., 2018; Raffaghelli et al., 2018), but only very recently published studies on that aspect are starting to emerge. Several teachers at ours HEIs are using MOOCs, produced together with in-house MOOCs' development teams and launched within our platforms[31], for flipped classroom strategies, and it is relevant to support them in the publication of their results to have scientific evidence on how MOOCs can in general benefit the STEM students learning experience, and, in particular, the female students performance, (Raffaghelli et al., 2018).

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[29] https://reports.weforum.org/global-gender-gap-report-2018/assessing-gender-gaps-in-artificial-intelligence/

[30] See also the Polimi's MOOC: https://www.pok.polimi.it/courses/course-v1:Polimi+FC101+2020_M4/about

[31] At the Spanish UPVx (https://www.upvx.es), the Portuguese MOOC Técnico (https://mooc.tecnico.ulisboa.pt), and the Italian POK (https://www.pok.polimi.it) platforms, respectively.

The virtual classroom offered by MOOCs may provide a more comfortable learning space for many female students. The free and easy access to the online courses provided by elite universities may spark females' interest in STEM fields and facilitate course enrolment, despite social expectations and cultural scripts. MOOCs may be providing opportunities for females to take STEM courses, especially females from less gender-egalitarian and less economically developed countries. On average in a STEM MOOC, only 1 in 5 learners is female (Ho et al., 2015).

6 CONCLUSIONS: FILLING THE GENDER GAP WITH STEM MOOCS

6 Conclusions: filling the gender gap with STEM MOOCs

Finally, in this last section, based on the recommendations made on sections 3.2 and 4.2, we aim to conclude what should be FOSTWOM actions towards using the bridging and inclusive potential of MOOCs (see previous section 5) to offer STEM subjects free of stereotyping assumptions on gender abilities. Recall that the consortium is interested in fostering young women in science and technology through a Toolkit and a MOOC that helps to design and evaluate gender balance in MOOCs, and through the creation of two MOOCs with relevant real-world STEM applications within strong conceptual Math frameworks.

Developing a gender balance Toolkit for MOOC design and development, to support females in pursuing STEM careers, based in our findings, is the very first step. Hence, we want to address instructional designers and teaching staff precisely when they prepare and design (Stumpf et al., 2020) the content for their MOOCs[32] so that new MOOCs will have a greater chance in being better gender-balanced in the future.

Another use for the toolkit is to support MOOC stakeholders (Teachers/tutors, MOOCs team development members, participants/students) in analysing existing STEM MOOCs so that they can raise awareness on biases against women in STEM.

More specifically, the toolkit should address the following topics in a MOOC:

- Awareness of gender stereotypes in STEM content and activities;
- Female visibility in the STEM subject;
- Female visibility in the MOOC (whenever possible): female teachers, tutors and/or research representatives (role models) in the subject;
- Welcoming gender balance discourse, helping girls recognise their career's relevant skills;

[32] See also the SAGA Indicators https://en.unesco.org/saga that measure gender equality according to UNESCO, an the Toolkit on Gender-sensitive Communication produced by EIGE https://eige.europa.eu

- Use of discourse that value study, exercise, growth and enhancement, not “talents” or great abilities, during the running of the course;
- Use of inclusive MOOC graphic design, where its images, colours, avatars and videos do not resonate exclusively with male participants;
- Real-life applications of the relevant content towards STEM careers, especially attractive for women;
- Assessment and other activities that are aligned with the content and promote formative feedback and group interactions to build confidence;
- Clear statements in advance, about the intended learning outcomes, performance standards, and expectations formulated in the gender-balanced way MOOC.

The FOSTWOM’s Toolkit shall later be disseminated through conferences and the project’s webinars and website. Moreover, the production of the MOOC targeted at teaching staff, instructional and graphic designers, shall include awareness to present gender-balanced STEM content and activities, which includes instructions on how to use the Toolkit.

Furthermore, based on the recommendations from sections 3.2 and 4.2[33], we can infer that bridging MOOCs, produced by a university MOOC team, can provide female High school students with extracurricular learning possibilities and expand their STEM knowledge. At the same time, we also refer that it is important to produce introductory online courses that can appeal to students with different levels of preparation or background before entering university. In section 5.2, there is a claim that virtual classrooms offered through MOOCs may provide a more comfortable learning space for many female students. Equally important are the MOOCs targeted at undergraduates that foster inclusive environments which support young women in science and engineering, apart from a relevant topic choice. Every such MOOC shall address/include the same topics that we bulleted above.

[33] Recalling also the example of the Finish MOOC on Computer Science produced by the University of Helsinki in section 5.1.

Concluding remarks

With the support of selected academic articles, recent reports from United Nations, Unesco, World Economic Forum, etc., and empirical material gathered and analysed within the frames of this report, this FOSTWOM report is the consortium's first step in the direction of contributing to decrease the gender gap within STEM education by attracting girls and raise the number of young women pursuing careers in science and technology.

Putting light on the current situation of an entire educational and professional area (STEM) that has a significant unbalanced proportion of men and women is one way to raise awareness and address this global challenge. FOSTWOM tackles the challenge not only by addressing the issue but above all, by developing a practical proposition that consists of a Toolkit and the design of MOOCs free of stereotyping assumptions on gender abilities.

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