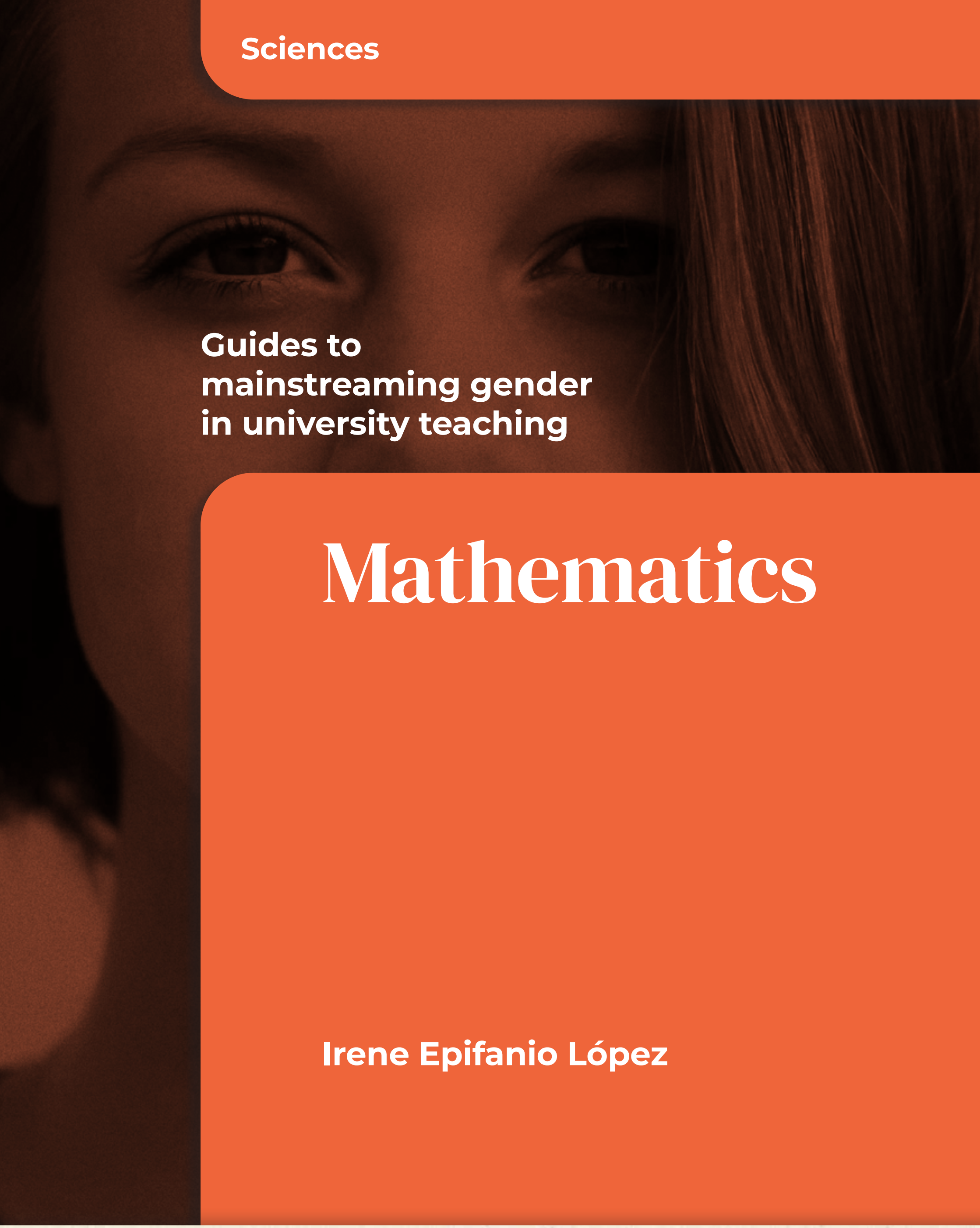

Sciences

Guides to mainstreaming gender in university teaching

Mathematics

Irene Epifanio López

Xarxa Vives d'universitats

MATHEMATICS
Guides to mainstreaming gender in university teaching

Irene Epifanio

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FOREWORD

What is the gender perspective and what relevance does it have in teaching undergraduate and graduate programmes? When applied to a university setting, the gender perspective or gender mainstreaming is a comprehensive policy to promote gender equality and diversity in research, teaching and university management —all areas affected by different gender biases. As a cross-cutting strategy, it involves all policies taking into account the characteristics, needs and interests of both women and men, and distinguishing biological aspects (sex) from culturally and historically constructed social representations (norms, roles, stereotypes) of femininity and masculinity (gender) based on sexual difference.

The Xarxa Vives d'Universitats (XVU, Vives Network of Universities) encourages a cohesive university community and reinforces the projection and the impact of academe in society by promoting the definition of common strategies, especially in the gender perspective scope of action. It should be highlighted that policies that do not take into account these different roles and diverse needs and are, therefore, gender-blind do not help to transform the unequal structure of gender relations. This also applies to university teaching, where we offer students a compendium of knowledge to understand the world and intervene in their future professional practice, providing sources of reference and academic authority and seeking to promote critical thinking.

Knowledge transfer in the classroom that is sensitive to sex and gender offers different benefits, both for teachers and for students. On the one hand, deepening the understanding of the needs and behaviours of the population as a whole avoids partial or biased interpretations —both theoretically and empirically— that occur when using man as a universal reference or when not taking into account the diversity of the female or male subject. In this way, incorporating gender perspective improves teaching quality and the social relevance of (re) produced knowledge, technologies and innovations.

On the other, providing students with new tools to identify stereotypes, social norms and gender roles helps to develop their critical thinking and skill acquisition that will enable them to avoid gender blindness in their future professional practice. Furthermore, the gender perspective allows teachers to pay attention to gender dynamics that occur in the learning environment and to adopt measures that ensure that the diversity of their students is addressed.

The document you are holding is the result of the biannual 2016-2017 work plan of the XVU Gender Equality Working Group, focused on gender perspective in university teaching and research. At an initial stage, the report entitled *La perspectiva de gènere en docència i recerca a les universitats de la Xarxa Vives: Situació actual i reptes de futur* (2017) [Gender Perspective in Teaching and Research at Universities in the Vives Network: Current Status and Future Challenges], coordinated by Tània Verge Mestre (Pompeu Fabra University) and Teresa Cabruja Ubach (University of Girona), found that the effective incorporation of gender perspective in university teaching remained a pending challenge, despite the regulatory framework in force at European, national and regional levels of the XVU.

One of the main challenges identified in this report in order to overcome the lack of gender sensitivity in curricula on undergraduate and postgraduate programmes was the need to train teachers in this skill. In this vein, it pointed out the need for educational resources that help teachers provide gender-sensitive learning.

Consequently, the XVU Gender Equality Working Group agreed to develop these guidelines for university teaching with a gender perspective, under the coordination of Teresa Cabruja Ubach (Universiy of Girona), M. José Rodríguez Jaume (University of Alacant) and Tània Verge Mestre (Pompeu Fabra University) in a first stage and M. José Rodríguez and Maria Olivella in a second one.

Altogether, 17 guides have been developed so far, eleven in the first phase and six in the second, by expert lecturers and professors from different universities in applying a gender perspective in their disciplines:

ARTS AND HUMANITIES:

Anthropology: Jordi Roca Girona (Universitat Rovira i Virgili)

History: Mónica Moreno Seco (Universitat d'Alacant)

History of Art: M. Lluïsa Faxedas Brujats (Universitat de Girona)

Philology and Linguistics: Montserrat Ribas Bisbal (Universitat Pompeu Fabra)

Philosophy: Sonia Reverter-Bañón (Universitat Jaume I)

SOCIAL AND LEGAL SCIENCES:

COMMUNICATION: Maria Forga Martel (Universitat de Vic – Universitat Central de Catalunya)

LAW AND CRIMINOLOGY: M. Concepción Torres Díaz (Universitat d'Alacant)

SOCIOLOGY, ECONOMICS AND POLITICAL SCIENCE: Rosa M. Ortiz Monera and Anna M. Morero Beltrán (Universitat de Barcelona)

EDUCATION AND PEDAGOGY: Montserrat Rifà Valls (Universitat Autònoma de Barcelona)

SCIENCES:

MATHEMATICS: Irene Epifanio López (Universitat Jaume I)

PHYSICS: Encina Calvo Iglesias (Universidade de Santiago de Compostela)

LIFE SCIENCES:

NURSERY: M. Assumpta Rigol Cuadra and Dolors Rodríguez Martín (Universitat de Barcelona)

MEDICINE: M. Teresa Ruiz Cantero (Universitat d'Alacant)

PSYCHOLOGY: Esperanza Bosch Fiol and Salud Mantero Heredia (Universitat de les Illes Balears)

ENGINEERING:

ARCHITECTURE: María Elia Gutiérrez-Mozo, Ana Gilsanz-Díaz, Carlos Barberá-Pastor and José Parra-Martínez (Universitat d'Alacant)

COMPUTER SCIENCE: Paloma Moreda Pozo (Universitat d'Alacant).

INDUSTRIAL ENGINEERING: Elisabet Mas de les Valls Ortiz and Marta Peña Carrera (Universitat Politècnica de Catalunya)

Learning to incorporate the gender perspective in subjects merely implies a reflection on the different elements that constitute the teaching-learning process based on sex and gender as key analytical variables. In order to review your subjects from this perspective, the guidelines for university teaching with a gender perspective provide recommendations and instructions that cover all the following elements: objectives; learning outcomes; content; examples and language used; selected sources; teaching methods and assessment, and management of the learning environment. After all, incorporating the principle of gender equality is not just a matter of social justice but also teaching quality.

M. José Rodríguez Jaume and Maria Olivella Quintana, coordinators

01. INTRODUCTION

In this guide, Irene Epifanio López (Universitat Jaume I) offers a detailed roadmap for incorporating the gender perspective (and, in her own words, the queer perspective as well) into mathematics teaching and research in higher education. Mathematics, like other disciplines in this collection, is one of the STEM fields (science, technology, engineering and mathematics) with the lowest proportions of female students and researchers in the entire university context. Extensive research over the years has identified this disparity as a serious problem because, in the context of an ever-increasing demand for mathematically trained professionals to keep up with the rapid growth of the technology industry, the lower proportion of women gives rise to marked bias in the production of knowledge and technologies. Epifanio not only sees the lack of women in mathematics as a problem, but also points out that the general lack of diversity in this field may have a critical impact in the coming years.

This guide begins by exploring the causes of gender blindness in STEM and in mathematics in particular. It shows that the lack of women (and LGBTIQ+ people) may be due not only to restrictive gender roles found at all stages of socialisation (which would greatly impact the process of selecting an educational path to follow as well as the conceptual construction of the discipline), but also to the patriarchal culture of academic and professional mathematics, which would exclude women and other groups that diverge from normative masculinity.

Epifanio then presents a series of general recommendations for transforming teaching at all stages of higher education that focus on teaching content as well as teaching methods. Based on these recommendations, Epifanio then explores the transformation of both university mathematics and statistics degree curricula and the mathematics and statistics subjects offered in non-mathematics degree programmes. In both cases, she examines the difficulty of explicitly incorporating gender content in mathematics and draws attention to the need to introduce it indirectly through the examples that educators give and the methods they employ for teaching and assessment. A key point of interest is the emphasis Epifanio places on the importance of providing students with examples of women and LGBTIQ+ people in mathematics and the works written by members of these groups.

The significant amount of research and specific teaching materials for incorporating the gender perspective that Epifanio has compiled clearly shows just how many people are dedicated to solving the problem of inequality in this field. However, the fact that the diversity of content, students and practitioners remains as low as it is highlights the ongoing need to continue insisting and delving deeper, a goal that this guide more than satisfactorily achieves.

02. GENDER BLINDNESS AND ITS IMPLICATIONS

The gender gap is most pronounced in STEM fields (science, technology, engineering and mathematics). The figures speak for themselves. In 2016, in Spain, the graduation rate for men aged 20–29 in science, mathematics, computer science, engineering, industry and construction per 1,000 inhabitants was 30.1‰, while for women it was 13.0‰ (Spanish National Statistics Institute, 2018). In 2012, the percentage of female and male graduates in science, mathematics and technology as a proportion of the total number of graduates for each sex was considerably higher for men (36.6%) than for women (12.9%). As for PhDs awarded in mathematics and statistics, in 2016, 232 women earned doctorates in mathematics and statistics, compared to 364 men, making the percentage of women obtaining PhDs in these fields 38.9% in 2016 (EC, 2019), a slight increase over 2013, when it was 32.3%. In any case, women are underrepresented.

The scissor graph that typically depicts the representation of women and men in research in other fields is not found when comparing the proportions of men and women at different research grades in STEM fields in the European Union (EU), as the gap is evident even at the earliest grades and broadens as the grades advance. Specifically, women in the EU account for 35% of staff in grade C, 28% in grade B and 15% in grade A (EC, 2019). Grade A is the highest classification and includes full professors. Grade B is the next level on the scale, which in Spain is equivalent to senior lecturers. Grade C includes adjunct lecturers and other post-doctoral positions.

Specifically considering Spain and the different areas of mathematical knowledge in the academic year 2016–2017, the percentage of female professors (i.e., grade A on the researcher scale) was 14% in algebra, 5% in mathematical analysis, 21% in didactics of mathematics, 19% in statistics and operations research, 5% in geometry and topology and 12% in applied mathematics (Puy, 2019). What this suggests is that rather than calling it a glass ceiling, we should be talking about a concrete ceiling. The *White Paper on the Position of Women in Science in Spain* (2020) provides a more detailed picture of the situation of women in mathematics.

Demand for STEM professionals is expected to grow by approximately 8% in 2014–2025 (EC, 2019), while the average growth in demand for all occupations over the same period is forecasted at 3%. Obviously, the lack of sufficient numbers of STEM personnel, together with the low numbers of women in these areas, is of concern to the EU, so much so that in 2015 the European Parliament

(European Parl., 2015) called on member states and the European Commission to adopt measures to improve the situation and to attract young people, especially women, to these fields. This under-use of female talent is a missed opportunity for the European economy and for European society as a whole.

But it is not only a European problem, it is a global concern. According to UNESCO (2017), women's access to STEM studies and careers must be guaranteed for three key reasons: a) for human rights reasons, because all people must have equal opportunities; b) for scientific reasons, because the exclusion of women causes bias and conducting research correctly can save lives and money (Gendered innovations, 2019; Barker *et al.*, 2014; Olías, 2019); and c), for developmental reasons, because gender inequalities in STEM have repercussions in terms of the propagation of gender inequalities in income and status.

Nevertheless, the 2019 *Shadow Report Regarding the Application of CEDAW in Spain* (the Convention on the Elimination of All Forms of Discrimination against Women, whose implementation is monitored by the Committee on the Elimination of Discrimination against Women) states in Point IX, the section on education, that 'despite the fact that campaigns have been introduced to encourage young women to study STEM careers, it has not been incorporated into the academic curriculum in early education, but it is done in a timely manner and in non-compulsory education' and 'there is no compulsory equality training in teaching careers neither in master's degree courses related to teaching.'

The reasons that few women choose academic pathways in STEM or drop out of them (known as the 'leaky pipeline') have been addressed in Scottish Parliament, to give one example, with the aim of closing the gender pay gap (Scottish Parliament, 2017). Research indicates that boys and girls adopt the concepts of 'women's jobs' and 'men's jobs' starting in the earliest years of school (Education and Employers, 2016), which may influence subsequent choices. Further down the line, the lack of female role models and sexism influence choices made at university. In the labour market, women tend to receive fewer promotions, which exacerbates the creation of a negative environment for women. Women are also penalised for motherhood and responsibilities related to caring for others, which affect their careers. It is important to note that women in the above circumstances may suffer a loss of confidence from time spent not working, especially in sectors that change rapidly. In the mathematical sciences, according to the study on occupational integration presented at the 14th Meeting of the Conference of Deans and Directors of Mathematics (CDM) in 2019 (Arias *et al.*, 2019), female mathematicians are primarily engaged in teaching, although they also have a significant presence in consultancy, public administration, finance, computer science, and science and technology. Gender differences are also found in these career paths. For example, the percentage of women in public administration and pre-university education is higher, while in technology women face significant career barriers, such as those described in Botella *et al.* (2019).

The pronounced lack of statistics (Yod and Mattheis, 2016) on the situation for sexual minorities (LGBTIQ+) in mathematics and STEM in general is alarming. According to Langin (2018a) and Hugues (2018), men who identify as LGBTIQ+ are more likely to drop out of STEM, while LGBTIQ+ women are more likely to persist than heterosexual women. Therefore, according to Bonato (2017), there is a need for gender parity and queer awareness in mathematics. Bonato also posits that when a government criminalises a person's identity, it is much more difficult to think in terms of number theory. This is currently the case in 40% of the world's countries. Even in Spain, considered one of the more tolerant countries in the world, the degree of LGBTI-phobia in the classroom is intolerable (Arroyo, 2014).

Gender blindness has had important consequences throughout history for mathematics. Only recently have women been granted access to an education that was denied to them merely due to the fact that they were women. They were also not allowed to attend or teach university classes, as in the case of Sofia Kovalevskaya (1850–1891), who was unable to attend a lecture by her instructor, Weierstrass, at the University of Berlin despite already holding a doctorate and being the recipient of the Bordin Prize. Only a century ago, mathematician David Hilbert famously said, 'I do not see that the sex of the candidate is an argument against her admission as a Privatdozent. After all, the Senate is not a bathhouse' (Figueiras *et al.*, 1998 b), in an effort to convince his male colleagues to allow mathematician Emmy Noether (1882–1935) to hold a dignified position at the university, which she was never able to do. Figueiras *et al.* (1998 b) provides other examples of mathematicians who had to use pseudonyms to have their work accepted, or their work was attributed to male colleagues (called the Matilda effect).

There are also paradigmatic examples of how gender blindness affects us today, which are addressed in Section 6 of this guide. Decisions are often based on mathematical models, but if the data on which they are based contain biases, those biases are reproduced, leading to weapons of "math" destruction (O'Neil, 2016). A recent example that received considerable press coverage was when

Amazon ceased using its recruitment tool because it discriminated against women (Rubio, 2018).

As educators, we need to be aware that the education men and women receive is different and can have major repercussions (Dossi *et al.*, 2019); and although families and schools claim to educate for equality, the message of society is pervasive. The anthropological studies Margaret Mead conducted in New Guinea (Alvarez, 2012) challenge the biological view of masculine and feminine prototypes, which are culturally based.

In our culture, engaging in mathematics or another scientific or technological field such as computer science is not 'feminine' and clashes with gender roles. In contrast, in Malaysia, computer science is dominated by women (Mellström, 2009), because working in closed spaces such as software development is considered more suitable for them (Gil-Juárez *et al.*, 2011). The self-concept of male and female students also tends to be different. Male students have more self-confidence in mathematics (Nurm *et al.*, 2003). Male students think their success in mathematics is due to their natural ability, so they see trying harder as a solution for dealing with difficulties. Female students, however, think success in mathematics is the result of hard work and effort, so when they are faced with difficulties, they think they must lack a natural ability and should give up (Figueiras *et al.*, 1998). As early as the age of six, girls begin to consider brilliant people to be primarily male, a perception they did not have at the age of five, and this affects their interests (Bian, Leslie and Cimpian, 2017). This is true even though girls receive better grades. Another cliché in the field of mathematics is men's superiority in visual-spatial skills, which is a misleading simplification that can perpetuate stereotypes (Sanchis-Segura *et al.*, 2018). Lastly, we should be aware of educators' expectations for male and female students in mathematics and science (Lav and Sand, 2015), which can lead to the so-called Pygmalion effect, or the self-fulfilling prophecy (Sciama, 2009; Gutbezahl, 1995; Feldman and Theiss, 1982), in which students assume beliefs held by others about their performance. Ceci *et al.* (2014) argue that current barriers to the full participation of women in STEM begin in the pre-university stage.

Reuben *et al.* (2014) studied how stereotypes affect science (along the lines of the famous John-Jennifer effect, in which teaching staff considered student John more competent than student Jennifer despite both having the same merits (Moss-Racusin *et al.*, 2012)). The stereotype that women are worse at mathematics is so ingrained that men are twice as likely to be hired as women for jobs involving mathematics, whether the employer is a man or a woman and even if the employer has no information other than the applicant's sex. After a maths test, discrimination continues if the candidates themselves report the result, since men tend to boast about their performance, while women tend to downplay it. What is even more concerning is that discrimination is reduced —but not eliminated— when complete information on test performance is provided.

A perfect storm of inequality forms when the fact that women tend to underestimate their own mathematical skills when they apply for a job is combined with the fact that female bosses also underestimate the mathematical skills of other women when hiring them. In addition, in terms of cooperation between same-sex individuals at different hierarchical levels, it turns out that senior women collaborate less with lower-seniority women than senior men do with lower-seniority men (Benenson *et al.*, 2014).

And, even worse than all of this, one of the most serious issues in the discussion on inequality is situations of gender-based violence at universities, which may go undetected by the victims (Valls Carol *et al.*, 2008) and are often covered up (Jara, 2018). This violence exacts a price, referred to as the 'harassment tax' (Zepeda, 2018). According to NASEM (2018), women in STEM professions in the United States suffer the highest rate of sexual harassment (58% in universities and 46% in the private sector) of any profession, after the military (69%). Among men this rate is 16%. In terms of LGBTIQ+ exclusionary practices, according to APS (2016), 40% of physicists have experienced it and 85% of students have experienced some form of harassment.

This guide makes an effort to examine contents, methods, interactions and goals in order to respond to the relationship between gender and mathematics.

03. GENERAL PROPOSALS FOR INCORPORATING A GENDER PERSPECTIVE INTO TEACHING

The Isonomia study (2010) on the status of gender mainstreaming in the curricula of the Universitat Jaume I, which can probably be extrapolated to university studies throughout the Vives region, found that there is often a lack of content that would allow students to acquire required competences related to gender and equality between men and women. This makes it difficult to address the issue of differentiating between sex and gender in maths courses and to re-examine androcentrism in science and specifically in mathematics in terms of explicit curricular content (see Figueiras *et al.* (1998b) as an excellent reference in this matter).

Consequently, to incorporate the gender perspective in teaching, we will focus on the aspects listed below (Cantero, 2016). These will be examined in greater detail in following sections (according to the glossary published by UN Women (2019), approaches to gender actions in education range from gender-negative, to gender-neutral, to gender-sensitive, to gender-positive to gender-transformative).

- Classroom management. Actions in this area may include giving the floor equally to women and men (gender-sensitive), going a step further and assigning non-gendered roles to teams (gender-positive), or taking yet another step to the gender-transformative level, and intentionally encouraging the participation of women. This might also consist of examining and taking action on gender conflicts and any other possible discrimination (based on physique, sexual orientation, etc.), such as sexist jokes, microsexism, etc.
- The contribution of women to mathematics. This might consist of occasionally bringing to light the contributions of a female mathematician (gender-sensitive), to habitually incorporating the contributions of female mathematicians (gender-positive), to critical reflection on the biases throughout history and today (gender-transformative).
- Non-sexist language and literature review. This can range from the occasional use of non-sexist language (gender-sensitive), to habitual use (gender-positive) to promoting its use among students and in the educational environment (gender-transformative). In the reference section, complete names should be used to give female authors visibility and, especially, both text and graphic components should be re-examined

to avoid androcentrism ([case studies/ science/ textbooks] Gendered Innovations, 2019).

- Methods. Collaboration, cooperation, the desire to excel and to complete a job well done should be promoted over competitiveness and individualism. Problem solving, teamwork (not to be confused with group activities without interaction), project work, and presentations are useful activities to this end. In short, educators should engage in active teaching. This does not mean that lectures should disappear, but rather that the concept of 'learning mathematics by doing mathematics' should be promoted. Also, in traditional teaching, where the instructor explains and the pupils listen and receive content, the passive role associated with femininity is reinforced, but we believe that it is important for all students to do intellectual work, in other words, to think.

  Verbal expression also improves learning (Figueiras *et al.*, 1998b). Telling another person about what one has learned is often necessary to complete the learning process. Verbal expression is an implicit part of group work.

- Fostering values. Continuing from the previous point, the aim of fostering values is to promote autonomy, teamwork, equity, social justice, cooperation, and to question all forms of discrimination, especially discrimination based on sex. To do this, problems can be humanised (Figueiras *et al.*, 1998b). In other words, problems, projects, etc. can be contextualised and related to students' interests, to the academic degree they are pursuing (if it is not mathematics) and their everyday interests in order to dispel the stereotype that mathematics is far removed from everyday life.

  For example, an uncontextualised statistical problem might be to find the regression line of a set of values for two variables, X and Y, in a table. A poorly contextualised problem might be to pose the same question with an economic or engineering context to students studying healthcare. To humanise the problem and foster values, the students can be asked to choose two variables that are of interest to them using all the public data available on Google (Google, 2019), which allow different graphical representations to be made. With the free version we could first ask students to consider life expectancy versus fertility rates in all countries from 1960 to the present in order to determine the impact of contraception and to critically examine the fact that only women are asked about contraception in certain surveys (Remacha, 2018). This activity would also involve using new technologies. Computers are required for statistics in today's world. However, as we will discuss below, the use of computers in mathematics generally offers a number of advantages, and promotes ICT use among women, who due to societal norms are often at a disadvantage to their male peers in the use of ICTs (Mateos and Gómez, 2019).

Some of the reasons why the use of computers in mathematics is highly desirable are (Figueiras *et al.*, 1998b): a) they promote the acquisition of concepts; b) they facilitate approaches to diversity that respect the pace and peculiarities of each student; c) they allow for group work; d) they convert errors into something positive (since computers give error warnings, which can then be overcome and corrected, there is no cause for anxiety or need to equate them with failure); and e) they motivate learning because young students are generally digital natives and interested in computer science. As these advantages illustrate, the computer is a tool that can be used to work on values beyond mere content, by applying those values in a real-world context, which is how they are internalised.

- Assessment. Students must be evaluated in line with the above points. Assessments that failed to take the above points into consideration would be inconsistent with incorporating a gender perspective. Another factor to consider, according to Figueiras *et al.* (1998b), is that test-type examinations can be detrimental to women's grades in mathematics.
- Interpersonal relationships. In addition to the above considerations, another fundamental factor that is an integral part of all of them is empathy (Pakarinen *et al.*, 2014). Empathy has to be sincere, in other words the instructor really has to care (Blašková and Blaško, 2017). Some ways of showing empathy include learning students' names at the beginning of the course, getting to know them (remembering details), listening to them, being open to their concerns and helping them. This promotes a positive atmosphere in which students feel at ease, it increases motivation, and enables students to develop their abilities.

The ideas presented here can be found in Gondeck (2000) —organised somewhat differently— along with very illustrative practical examples. It is highly recommended reading, especially for those engaged in the didactics of mathematics.

04. SPECIFIC PROPOSALS FOR INCORPORATING THE GENDER PERSPECTIVE INTO THE TEACHING OF MATHEMATICS

4.1 Subject/module objectives

As mentioned above, promoting equal opportunities for men and women is not usually an aim in mathematics studies, but mathematics is taught in many other degree programmes, especially in the fields of engineering and science (STEM disciplines), in which promoting equal opportunities for men and women is not a typical objective either. However, there are exceptions, like the University of Alicante subject Statistics in Multimedia Engineering (Migallón, 2019). Its objectives include, 'to give visibility to men and women whose scientific contributions serve to advance the field of statistics', 'to be able to apply statistics to measure audiences, marketing and positioning in an inclusive manner', 'to be able to apply statistics to decision making and quality control for products developed, considering the needs, use patterns and expectations of men and women' and 'to be able to apply statistics to different domains to identify biases, especially gender and race biases, and to promote respect for diversity, equity and equality'.

Mathematics subjects are also included in social science degree programmes such as economics, finance and business administration. In addition to the degree programmes mentioned above, statistics is also taught as part of other social science programmes (tourism, labour relations, etc.) and in healthcare courses (medicine, nursing, etc.).

Focusing on mathematics degree programmes, and excluding cases in which a specific subject with a section on science and gender is included in the curriculum (like in the subject Topics in Current Science within the bachelor's degree in Mathematics programme at the Autonomous University of Barcelona), we will examine, in general, the objectives which might be considered in mathematics subjects in accordance with the aspects laid out in Section 3. One competence that might be considered would be, 'working as a team, promoting respect for diversity, equity and gender equality', which is found, for example, in the Data Mining subject of the bachelor's degree in Computational Mathematics at the Universitat Jaume I. Another competence that could be proposed is, 'the ability to recognise the role of women in mathematics and their practical contributions throughout history'.

In any case, teaching objectives should include contributing to the understanding of and advancement of human rights, democratic principles, the principles of equality of women and men, solidarity, protecting the environment, universal accessibility and design for all, and fostering a culture of peace. This could translate to a competence such as 'the ability to solve real problems and cases in technology, science and society, with a commitment to ethical values and equality'. As mentioned earlier, this can be done in mathematics subjects by humanising the problems posed to students. Statistics subjects, however, are perhaps best suited for analysing data related to peace, human rights, environment, equality, etc. In addition to the objectives, it is important to bear in mind that the behaviour and actions of the teaching staff (hidden curriculum) have a significant impact. These might include, for example, encouraging the reduction of paper use; proposing different classroom materials for those who want to explore certain concepts in greater depth or who, in contrast, need to reinforce their understanding (i.e., need to take diversity into account); facilitating studies for students with special needs or other types of difficulties; etc.

4.2 Subject/module content

Mathematics includes disciplines of a more theoretical nature as well as those of a more applied nature, such as statistics. Moreover, as mentioned earlier, these subjects are not only taught in mathematics-related degree programmes, but also in many other degree programmes in a wide variety of scientific fields. Although many aspects related to gender will be discussed for all the subjects, there are other aspects that should be addressed separately, especially in subjects that introduce students to statistics, due to their specific characteristics. These ideas can also be used for other subjects related to data analysis, such as multivariate analysis. The example of a statistics subject for degrees other than mathematics is used because it offers the possibility of including more students.

4.2.1 Statistics in non-mathematics degree programmes

The main example we will consider is the subject of statistics (although its official name is Mathematics II), a compulsory subject in the second semester of the first year of the bachelor's degree programme in Industrial Design and Product Development Engineering (GIDIDP) at the Universitat Jaume I. The number of students in these subjects tends to be high. Although it is an engineering subject, the percentage of women and men is well balanced. At the end of this section, we will also address some important considerations for basic statistics subjects in degree programmes in other branches.

The content for these types of subjects usually includes sampling, descriptive statistics, probability and statistical inference. Going into greater detail, when designing the syllabus for this course first we should ask what kind of statistics we want to cover, considering what the students will need for their chosen field of study. In many cases, statistics is considered mathematical, theoretical, far removed from the data, perhaps due to tradition or convenience, or to the simple repetition of what has always been done. In contrast, here we are considering statistics in a more applied manner, based on data and interpretation of data, as suggested by the American Statistical Society (ASA) and the Mathematical Association of America (MAA). These bodies formed a committee to study the teaching of introductory statistics, and they made three recommendations (Cobb, 1992): 1) help students think like statisticians; 2) provide more data and concepts and fewer theories and formulas, with an emphasis on the use of computers (Moore, 1997); and 3) encourage active learning. Several authors have also recommend learning statistics by doing statistics (Smith, 1998) and through cooperative learning (Garfield, 1993; Magel, 1998).

In general, students enrolled in this subject are not very interested in mathematics. Conversely, many students also have the preconception that statistics are not useful for industrial design and so are not very motivated from the outset. However, many of the concepts covered are used in subjects that come later in the degree programme, for example, in Ergonomics (ergonomic risks are greatest for women, especially pregnant women), Emotional Design and Design Methodologies. It is always a challenge to teach a subject when many students are not interested in it from the start, and teaching statistics to non-specialists is particularly complex (Yilmaz, 1996). We can seek to eliminate bias through problems applied to the field of industrial design and with the use of the students' own data (Neuman, Neuman and Hood, 2010) (students collect data on height, cigarettes smoked by gender and group, etc.). This allows students to see how statistics come to bear in their daily lives and in social issues of great interest. This approach makes use of a tactic similar to that set out in Phua (2007). These humanised problems (or projects) are where, above all, values can be worked on, especially on issues such as inequalities and gender gaps (analysing data disaggregated by gender), which will be examined in greater detail later.

With regard to sampling, within the field of engineering it is essential to note the importance of considering samples of potential users in terms of sex, gender and other characteristics in the design phase of the product or technology as well as in other phases, for example, in usability testing (see details in the Engineering Checklist of Gendered Innovations, 2019). Sampling is equally important in fields other than engineering, especially in healthcare and social sciences. In healthcare, for example, careful sampling is essential for clinical trials and other research practices.

De Cabo, Henar and Calvo (2009) are a great reference for incorporating a gender approach in the creation of Spanish statistics, and Bauer (2012) writes about including gender diversity in health statistics and questionnaires. GenIUSS (2014) offers a two-step method for asking if a person is trans in health questionnaires: 1) asking for sex assigned at birth, and 2) asking for current gender identity. In the first version, the options for question 2 were male, female, or transgender, which is not fully recommended, as many transgender people identify as male or female. The second version expanded the options to include male, female, transgender man, transgender woman, genderqueer or other (please specify). The European Union Agency for Fundamental Rights (FRA, 2014) also includes a methodological reflection on this issue (starting on page 103). For transgender participants, a decision was made to leave an open field to specify the answer 'other'. Many people (25%) provided self-determinations beyond the binary (see explanation from page 104 onwards). This study is part of a broader study on the situation of LGBT people (FRA, 2013).

In the other parts of the subject, especially the descriptive and inference part, the aforementioned humanised problems can be used to highlight the importance of the gender perspective in every area of interest. Gendered Innovations (2019) offers examples of applications and the serious consequences of biased samples, including discrimination based on race and gender (Zou and Schiebinger, 2018).

4.2.2 Mathematics subjects (in general)

Firstly, in all mathematics subjects it is possible to make women's work visible in many different ways and to seek balance among the mathematicians discussed. As each new topic is introduced, a brief overview can be given of an important female and male mathematician in the area in question. For example, in the introduction of differential and integral calculus, Gabrielle Émilie de Breteuil or Marquise de Châtelet (Molero and Salvador, 2008a) might be introduced, or Emmy Noether (Molero and Salvador, 2008b) in algebra, or Florence Nightingale in statistics (Macho, 2017), etc., and the obstacles society imposed on them when they devoted themselves to mathematics could be highlighted. Alternatively, quotes from male and female mathematicians and statisticians (Epifanio and Ibáñez, 2013) could be presented to start a small debate or, more importantly, students could be tasked with researching, in equal measure, the 'mathematical life' of important male and female figures in mathematics. Not only historical figures should be considered, but also present-day mathematicians (see Section 5, Resources, for more on this idea).

Section 5 also offers ideas on how to humanise problems while Section 6 addresses how to incorporate the gender perspective into mathematics applications.

Students should also be made aware of the implicit gender biases they will encounter in their future careers. See Section 5 for more on this idea. Biases can be approached by means of activities, which are addressed later with a few specific examples. What is fundamental, however, and what we must keep in mind as a priority, is **eliminating implicit stereotypes and biases** (of both the teaching staff and the students). This is especially important in mathematics education to ensure that girls and women are not alienated from STEM fields (Boston and Cimpian, 2018).

4.3 Subject assessment

Students should be evaluated based on a range of different assessment types with explicit assessment criteria in order to recognise diversity in the student body. They should not be assessed exclusively on the 'much-dreaded' maths exams. For example, in the Statistics subjects of the GIDIDP degree, which tends to have a high number of students, the final problem solving exam (with statistics formula sheets) accounts for 55% of the final grade. The remainder of the final grade is based on observation of student performance and laboratory reports (each student works with different data and submits a report at the end of each session), group problem solving (four-person groups) and an individual project worked on throughout the course (also done in pairs in large classes). A rubric is used to assess the project. Other types of assessment can be used in subjects with fewer students, such presenting a project with applications or extensions of the content covered in class. Alternatives should be provided in all subjects so that students who are unable to attend classes for legitimate reasons (illness, caring for family members, etc.) are not penalised for the part of the grade that corresponds to continuous assessment.

Figuerias *et al.* (1998b) and Salvador and Salvador (1994) discuss the possible bias of multiple-choice tests, which may give men (although not all men) an advantage over women. But it is also important to note that, for example, item types that favoured women were removed (Hanna, 1996) from the famous SAT (the US university admissions exam on which men consistently score higher than women), such as those that ask whether there is sufficient data to solve the problem. So, the issue may be not only about the type of assessment, but also about biases in content (Karp and Yoels, 1992, offer a detailed analysis of this).

Different types of obstacles to problem-solving should also be taken in account, especially if they affect men and women differently (Figuerias *et al.*, 1998b). Fear of failure, being wrong, and ridicule is more common among women. This, for example, has to be taken into account in situations like going up to the board, as women will take fewer risks (they will only do it if they are sure they can do it well) out of fear of failing or receiving critiques about any small mistake they make. Another obstacle that affects women more than men is a socio-cultural obstacle, from the stress caused by the 'double burden'. Exam performance can also be undermined by the (negative) stereotype threat, and even reinforced in the exam itself, as with the 2016 SAT (Hartocollis, 2016), which asked questions about a graph showing that there were more males than females in mathematics classes. An analysis of the Programme for International Student Assessment (PISA) results suggests that the gender gap in maths scores disappears in countries with more gender-equal cultures (Guiso *et al.*, 2008). To mitigate the impact of the stereotype threat, students should be made aware of it (John *et al.*, 2005) and given examples of success (Furrer, 2013).

Other studies (Carlana, 2018) have found that bias may exist at the pre-university level in mathematics grades that favour men based on the prejudiced belief that women are worse at maths (Nosek *et al.*, 2002; Nosek *et al.*, 2009). So, educators must be aware of unconscious biases in order to avoid them, especially those with less teaching experience (Hofer, 2015). Anonymous assessments can also be used, such as exams in which student names are omitted in favour of identity card numbers. This can also eliminate the halo effect (Malouff *et al.*, 2014), in which students who tend to get better marks generally receive better treatment than students who have more difficulties or get worse results. The same precautions should be taken with peer- or self-assessment (recall that women tend to undervalue their own work as well as the work of other women). For bachelor's and master's final projects and theses assessments, rubrics can be used with details of each level of achievement of the objectives and competences to ensure the assessment is as equitable as possible (Jaume-i-Capó *et al.*, 2012). In this regard, Bengoechea (2014) is an invaluable resource that provides insight into the possible discrimination against female students with strong academic records who obtained worse results in the defence of their bachelor's final projects than their male peers with similar records. As Bengoechea (2014) points out, it is not a matter of favouring women, but of not succumbing to possible biases that favour men.

4.4 Organisational approaches to teaching

The importance of group work was mentioned earlier, though it should not detract from the importance of individual work, which is also a necessary part of the learning process. Given their similarities in language and conceptual frameworks, interactions between students are conducive to learning. Cooperative work benefits both women and men. Working in small groups alleviates female students' fear of making mistakes. This lack of inhibition allows them to be more creative, which in turn boosts their self-esteem. Similarly, group work reduces competitive behaviour among male students. Groups should be made up of students with similar motivations and skills (see Figueiras *et al.*, 1998b, on criteria to be taken into account when forming groups), and students should be given the tools needed to manage conflict in case frictions arise. In this regard, the work of Oakley *et al.* (2004) on 'hitchhikers and couch potatoes' is a powerful resource, as is the work of Del Canto *et al.* (2009). The assignation of roles among the members of the group (moderator, organiser, spokesperson and secretary) should not reinforce stereotypes, and roles can be rotated.

Women and men have different communication and participation styles both in group work and other activities (Rodríguez-Jaume *et al.*, 2017). It is important to take this into consideration if displays of power and domination are used to inhibit or limit participation, such as interrupting someone's (usually a woman's) turn to speak, using silence (even when called upon), and changing the subject. Humour and jokes are also often used by men as a form of domination and to gain status among their peers. The decalogue of best feminist practices for assemblies (Marea Atlántica, 2019) is very clear about what not to do, which includes things like when you intervene, you reinforce the main intervention; never try to explain what a woman colleague meant to say; moderate your tone of voice; consider your nonverbal expression, etc.

Martínez (2012) (pp. 29–33) provides an excellent account of a series of aspects to consider to ensure that classroom interactions are equitable (it seems that teachers pay more attention to male students than to female students, according to Sadker and Sadker, 1994). A useful exercise in this regard is for instructors to record themselves or ask a colleague to attend a class to look for internalised biases that lead to differentiated behaviour towards women and men. Special care should be taken to recognise and avoid what is called 'benevolent sexism', which consists of adopting patronising attitudes towards women, like mansplaining.

4.5 Teaching methods

As noted above, active learning is the preferred approach to classroom learning (Alexakos and Antoine, 2003) as, in addition to being more beneficial to women in masculinised domains (Boaler, 1997), it improves the performance of both women and men (Freeman *et al.*, 2014; Han *et al.*, 2015). In fact, it is the approach recommended by many mathematics associations (Buckmire, 2019) focusing on modernising curricula, teaching methods and equity (see Braddy's presentation (2019)).

4.5.1 Statistics

In introductory statistics, Cobb (1992) understood active learning as: (a) group problem solving and discussion (Joan Garfield was no longer giving lectures; her method is now known as the flipped classroom); (b) laboratory exercises, i.e., working directly with data (and computers) and also with manipulatives; (c) data-based demonstrations; (d) students preparing written and oral presentations; and (e) project work (in groups or individually).

Some of the positive experiences involving universities in the Vives region include those described in Corberán-Vallet *et al.* (2012) and Epifanio and Ibáñez (2013). The latter also explains how the gender perspective was integrated into an introductory statistics course. Using an active classroom approach resulted in an increase in the percentage of students who passed (all the women who took the subject passed), and students who repeated the subject stated they were more satisfied and learned more after the change in method. For mathematical statistics, the use of case studies may also be beneficial (Nolan, 2003).

4.5.2 General mathematics

Braun *et al.* (2017) describe what is meant by active learning in mathematics. Of these methods, the most gender-sensitive are: a) the flipped classroom, b) inquiry-based learning (IBL), and c) modelling and computer laboratories. The *Guidelines for Assessment and Instruction in Mathematical Modelling Education* published by the Society for Industrial and Applied Mathematics (SIAM, 2016) provides examples of modelling activities in the university curriculum that actively engage students, and discusses related aspects like assessment. Braun *et al.* (2017) also review what can be expected from student-centred learning and what educators might be concerned about.

It seems that the active approaches of the flipped classroom (Chen *et al.*, 2016) and inquiry-based learning (Laursen *et al.*, 2014 and Kogany Laursen, 2014) may be capable of reducing the gender gap, although teaching method alone is certainly not the key factor (Andrews-Larson *et al.*, 2018 and Karim *et al.*, 2018). This may also hold true for its implementation because the idea is to reduce competition and emphasise collaboration while increasing confidence in one's own abilities (self-efficacy) and reducing stereotype threat, as discussed above, as well as to improve the feeling and mindset of belonging, and to consider intelligence not as something innate, but something malleable like a muscle, that, with training and effort, can gain mass (Karim *et al.*, 2018).

With the inquiry-based learning approach, the anxiety sometimes found in the mathematics classroom can be expressed as 'I can't learn like this', which is the tip of an iceberg of fears and misconceptions. Yoshinobu (2018) discusses these factors and offers suggestions to change the mindset. It is important to bear in mind that the flipped classroom increases the workload of the teacher, and that teachers need to have a certain degree of experience in order to identify the concepts that may be more difficult for students (Calvo, 2017a).

In any case, it is important to remember that computers should be used in all subjects because of the many advantages mentioned above, and educators must ensure the visibility of women and the humanisation of problems, which can involve current issues (especially gender equality) to motivate students.

05. SPECIFIC TEACHING RESOURCES FOR INCORPORATING THE GENDER PERSPECTIVE

5.1 Resources for inclusive education

It matters if you are named or unnamed, if you are included or excluded (Consorcio Palencia Social, 2008). Therefore, using and promoting inclusive oral, written, visual and non-verbal communication is crucial. Language guides for oral and written expression can be found on the websites of the equality units and bodies of the universities in the Vives area. For succinct guidelines, the UJI's decalogue (2011) can be consulted in Spanish and Catalan. The Steilas guide (2016) contains a section on language beyond binarism, and advice about images that reproduce stereotypical roles and recommendations on how to avoid sexism in the visual communication section. Gutiérrez (2007) reviews the importance of non-verbal expression in interactions in terms of personal space, eye contact, posture, etc. It is important to ensure coherence between what you do and what you say.

Situations, behaviours and comments that are gender-biased (*Sexist or Sexual Humor* by Spertus (1991) provides several examples of what not to do) or that reinforce gender stereotypes must be avoided, and this is especially important in the problems and examples presented to students. Throughout the course, contextualised problems should include a balance of male and female protagonists (a balance of girls and boys, and of adults of different ages, cultures, with functional diversity, etc. is especially important in didactics of mathematics; in short, diversity must be represented), and it is important to avoid reinforcing stereotypes related to professions, relationships, etc. For instance, bad practices are found in all statistics and mathematics textbooks for engineering, which use male engineers or scientists as the protagonist in the problems, and never female engineers or scientists. Another example of a bad practice found in a current textbook is a probability exercise in which there are seven pairs of boyfriend-girlfriend couples. Students are asked to find the probability that if two people are selected at random, one will be a man and one a woman. That statement assumes the only possible couples are heterosexual. Another exercise in the same textbook reinforces the stereotype that men must take the initiative, that the boy has to call the girl.

If there is any doubt as to whether a certain situation is sexist, you might try using the 'rule of inversion', which consists of changing the subject to the opposite gender. If the change makes the situation seem awkward, then the situation is surely sexist.

Chapter 4 of Figueiras *et al.* (1998b) offers a series of guidelines similar to the Bechdel test, which measures the gender gap in works of fiction. The guidelines are used to analyse mathematics textbooks and determine their (non-sexist) coeducational value. They are based on activities in which women and girls appear in problems, mentioning women mathematicians, group activities, etc. Figueiras *et al.* (1998b) also analyses secondary school textbooks. In most cases they do not get a passing mark for coeducational content. Several suggestions to improve the textbooks are proposed with concrete examples for problems in sports, geometry, statistics, etc., ideas that can also be used in university introductory mathematics and statistics classes. Shamefully, at present, references to women in secondary school textbooks is 5% in science and 1% in technology (Kohan, 2017; López-Navajas, 2014).

Ideally, written and graphic materials (notes, books, slides, etc.) used in the classroom should be inclusive in terms of language, situations (according to the roles presented), the protagonists of problems, the presentation of important historical figures in mathematics, and the subject matter of the problems (to draw the interest of both boys or girls, etc.). If that is not possible, either because references and materials are determined by decisions made when teaching shared subjects or because such materials do not exist, bring students into these situations and at least verbally correct the materials, and discuss non-inclusive situations. But, more importantly, you should propose and use alternatives, as discussed below.

A good introductory activity for the virtual classroom to get to know the students, to learn about their concerns, their feelings about the subject (especially fear of mathematics in mathematics courses), and any difficulties they might be facing (for example, conflicts with work, family, health, etc.), and to be able to provide individual feedback and connect on an emotion level is to encourage students to introduce themselves privately and talk about what they want (openly, but with a few guidelines), as suggested in Epifanio and Ibáñez (2013), as part of a treasure hunt activity to introduce the subject.

Group problems such as those presented in Epifanio and Ibáñez (2013) can also be used in introductory statistics subjects to connect with students' everyday lives. A WebQuest like the one described in Epifanio (2010) requires students to take part in activities to examine the gender pay gap (students collect data not only on wages, but also on time spent working at home and outside the home, and whether there are work-life balance issues), statistics in clinical analysis, abuse of statistics in the media, the history of statistics, claims of overcharges on water bills with erroneous estimates, statistical analysis of the student's ecological footprint as its relation to climate change, and a research activity on the design of aircraft cabins (in which students have to consider anthropometric differences). With WebQuest, in addition to working with statistics, students also work in groups and with a computer. Epifanio (2010) also includes databases on statistics WebQuests in Spanish. Group problems and WebQuests are available at <http://www3.uji.es/~epifanio/TEACHINGP/gender.tar>, along with the material needed for a project like that described in Epifanio and Ibáñez (2013). In the project, students follow guidelines to collect data and analyse it using all the tools studied in the course. It is open-topic, and provides a model project on the gender pay gap and time spent on caring and domestic tasks. Both female and male GIDIDP students general undertake numerous projects with social implications.

A very interesting WebQuest about women in mathematics is described in Huertas and Tenorio (2006). In it, students adopt the role of researchers and present their work to the rest of their classmates. Huertas and Tenorio (2006) offer a compilation of websites with WebQuests on mathematics for primary and secondary school, which can be of use in mathematics education for group activities. Another type of collaborative learning is through gamification, such as escape rooms, as described in Diago and Ventura-Campos (2017) or in virtual form in Dubón *et al.* Salvador (2010) provides an exhaustive review of games as a teaching resource, especially cooperative games.

5.2 Resources for including women mathematicians

As mentioned in Section 3, present-day female mathematicians should be considered as well as historical figures (especially if they have received a prize, and if they are the first woman to do so, such as Fields Medal recipient Maryam Mirzakhani and Abel Prize recipient Karen Uhlenbeck). Young mathematicians should also be included as well as mathematicians who share the students' cultural background to provide a sense of familiarity and establish greater relevance. Research can be done in groups (with each group responsible for researching one male and one female mathematician). The results can then be shared in the virtual classroom and/or presented in class, depending on the number of students enrolled in the subject. Success stories should also be shared, for example, of former students or women who studied at the postgraduate level, in order to break down stereotypes that imply things like women are less competent than they actually are.

For more information on resources like activities, projects, and introductions to each topic that make women mathematicians more visible (Padrón and Timón, 2017) Chapter 6 of Figueiras *et al.* (1998b) is of special interest. It presents the stories of noteworthy women mathematicians and provides related mathematics classroom activities, which are along the same lines as the CCOO's Teaching Federation manual (2011) on *Women's Contributions to Mathematics*, Figueiras *et al.* (1998a), Macho-Stadler (2019), Verdejo (2017), Nomdedeu (2000), Salvador and Molero (2019), and Mestre (2016). An example in a university setting is offered by Beltrán and Monterde (2019). Also, *Mujeres y matemáticas. 13 Retratos* (13 Portraits of Spanish women mathematicians) by Comisión de Mujeres y Matemáticas (2008) can be used in both book and presentation form. More materials can be found on their website: <http://mym.rsme.es>. The *Mujeres con Ciencia* (Women with Science) blog of the Cátedra de Cultura Científica de la Universidad del País Vasco (2019) is also a good reference for resources. For mini-biographies, see Verdejo (2013a) as well as those included in Verdejo (2013b). For didactics of mathematics, Calvo (2019) has compiled a selection of stories to introduce women scientists and inventors to children and young people. Particularly in statistics, which is taught in many non-mathematics degrees, Wikipedia (2019) lists women statisticians from all times and places, as well as their fields of research. This can be used to discover how statistics are applied in all the sciences, in everything from human rights to sexual violence to neuroscience. Wilson and Billard (1999) can be referenced to compare the different paths of important men and women in statistics. Golbeck *et al.* (2017) reviews the contribution of women to statistics. There are several significant women pioneers in mathematics education, including Emma Castelnuovo (Guerrero, 2014) and Maria Antonia Canals (Sacristán, 2018). Another way to raise awareness of women mathematicians and scientists is through activities such as those described in Calvo (2017b) or by writing biographies using a Wikipedia format (Calvo and Sanmarco, 2017).

Male and female mathematicians from minoritised groups should also be given visibility, as should sexual minorities (Madhusoodananan, 2018), and it is important to highlight the high price people such as Alan Turing and Mariasilvia Spolato (Agencia EFE, 2018) were made to pay. As mathematician Marina Logares explains, this is a group that has been greatly invisibilised (Ansede, 2019). It is important to use them as examples —people like mathematician (better known as a model) Nyle DiMarco (Cid, 2019), who received the Alan Turing Award for his activism, who is also deaf and an activist for the rights of people with hearing disabilities. Park and Lee (2015) review male and female mathematicians with functional diversity through examples such as Leonhard Euler and John Nash. Henrich *et al.* (2019) complied the stories of people who, for different reasons, have overcome great difficulties in mathematics, such as a single mother, a transwoman, and a woman of Mexican origin.

In terms of visual materials to give women mathematicians greater visibility, RTVE's Colección Universo Matemático offers *Mujeres Matemáticas* (Women Mathematicians) (2010) as well as related activities. Other video shorts on women mathematicians include that by Sáenz de Cabezón (2015), the monologist known for winning FameLab 2013 with *Un teorema es para siempre* (A Theorem Is Forever), or for a glimpse of current-day women mathematicians from all over the world, the video Faces of *Women in Mathematics* (Macho, 2018) or the video *Journeys of Women in Mathematics* (Díez, 2018). Molero and Salvador (2019) offer a video on the life of Sofia Kovalevskaya, a pioneer in many areas.

Films, series and documentaries showing the role of women in science that can be recommend to students (Penalva, 2018) include *Agora* and *Hidden Figures* (which depicts two forms of discrimination: against women and against African-Americans), or the biographical film on Alan Turing, *The Imitation Game*, with some much-needed corrections (Peirano, 2015), and *A Beautiful Mind* about John Nash. Other very interesting initiatives in the area of culture include introducing women mathematicians through film and literature, as in Calvo and Verdejo (2018), and also through theatre, in *¿Son raras las mujeres de talento?* (Are Talented Women Rare?) (Macho and Lorente, 2013) and *Científicas: pasado, presente y futuro* (Women Scientists: Past, Present and Future) (Fernández *et al.*, 2019), a short version of which can be found online and which has related activities. Another fun way to discover women mathematicians is through mathemagic games (Maestre, 2017). Although not specific to mathematics, the *Mujer tenía que ser* (It Had to Be a Woman) section (Sabatés, 2019) of the TV programme El Intermedio is of interest. It is a prime-time talk show that interviews women fighting for equality, like the engineer Sara Gómez, scientist Margarita Salas or historian Mary Beard.

5.3 Resources for implicit gender biases

In addition to the biases discussed in Section 2, here we examine other biases and propose some possible solutions to address them.

In doctoral programmes, many universities are starting to offer cross-disciplinary training courses on research and the gender perspective. However, these courses are rarely offered in undergraduate mathematics programmes, despite the importance of relational skills. Since they are not included in curricula, biases might be addressed in the classroom (which we will discuss below) to encourage students to later enrol in courses specifically on gender. These courses can be organised by university equality units, as they are at the Universitat Jaume I.

The first task at hand is to make students aware of the existence of gender gaps in their environment. One good way to do this is to use infographics. Natalia Martin's infographics can be shown (Bravo, 2018) in the example given in Section 4 for Statistics in Industrial Design subjects. For most degrees in which mathematics subjects are taught, Belén Trincado's STEM infographics can be used (Sempere, 2018). Although designed for the field of physics, Gibney's infographic (2016) can be used to show the lack of inclusivity of LGBTIQ+ people. A section of the virtual classroom can be dedicated to these types of resources with an explanation of what it is for and why it is there.

It is important to bear in mind that there may be people who doubt the existence of the gender gap. Ferrer (2018) (see also Valian, 1999) offers a number of explanations and studies on gender gap denialism (also denied by many women), and how the best way to eliminate prejudice is to be aware that it exists (Parker *et al.*, 2018). Note that it is precisely among men in STEM that we find the greatest resistance to accepting the gender gap (Handley *et al.*, 2015). Project Implicit (2019) includes an implicit association test for detecting gender bias in the sciences. The article by Barres (2006) is a must-read: as a transgender person, it shows the difference in social recognition due to gender alone, and furthermore, it refutes the hypothesis that women do not advance in the sciences because of some kind of innate disability (see also O'Dea, 2018).

But there are many other biases and possible solutions to examine. For references to studies that have analysed these biases, see <http://genderedinnovations.stanford.edu/institutions/bias.html>, which is a resource that can be added to the virtual classroom so that interested students can access these works. For a collection of different solutions from governments, universities and private sector companies, see <http://genderedinnovations.stanford.edu/institutions/solutions.html>. The website <https://womensleadership.stanford.edu/tools> can also be included as a resource in the virtual classroom, as it provides tools both to detect bias in the world of work (see bias) and to try to prevent it (block bias).

Some biases often encountered in the world of work include: a) leadership qualities being seen as incongruent with the gender roles of women, which means, for example, that women who demonstrate assertiveness may be perceived as competent but unpleasant, and their work may also be scrutinised to a greater degree; b) people dedicated to science being associated with the image of (white) men, which means women scientists who are perceived as more feminine are seen as less likely to excel in science; c) mothers being viewed as less competent than childless women (for men, fatherhood not only is not penalised, but in some cases benefits them) (González *et al.*, 2019); d) stereotype threat undermining the performance of women (negative gender stereotypes creates anxiety that undermines performance); e) extremely competent women suffering from imposter syndrome (they think their success is a fraud); f) men involved in caring for their children being penalised in their careers; g) stereotyped work environments (Spertus, 1991), etc.

Worklife Law (2019) is a fun and engaging resource that illustrates gender biases through bingo games, tests, and videos, and offers strategies to combat them: 1) 'Prove it again!', when women have to work harder to demonstrate their competence; 2) 'Double binds', when women have to choose between being respected or loved; 3) the 'Maternal wall', when mothers are assumed to be less competent and less committed to their job; 4) 'Gender wars', when gender bias pits women against women, for example, in the so-called 'mommy wars' between women who are mothers and those who choose not to have children. To delve deeper into this, Martin (2014) has compiled an extensive annotated bibliography on mathematics and implicit biases.

Langin (2019b) and Mattheis (2019) highlight the challenges for LGBTIQ+ people working in STEM. APS (2016) offers recommendations for LGBTIQ+ inclusive practices at work.

Mathematician and actress Danica McKellar (2019) has also written a number of books (to date, only in English) especially for teenage girls to break down stereotypes and showcase the glamour of mathematics, which are especially applicable to mathematics education. Boston and Cimpian (2018) offer a collection of strategies to tackle stereotypes that can turn girls and women away from science, such as negative stereotypes about their own intellectual abilities and that STEM is for nerds. It is important to bear in mind that among (future) primary and secondary school teachers, stereotypes that, for example, girls are better at reading and boys are better at science are still prevalent (Gallego, 2019).

Hottinger (2016) shows how our culture constructs mathematical knowledge and mathematical people.

In terms of situations of gender violence, this same section of the virtual classroom must include a link to the university's equality unit, and mention that in the workplace, unions can offer guidance, aside from any possible legal action.

Pixar's *Purl* (2019) is a very powerful audiovisual resource. It is a short film that tackles the issue of sexism and discrimination in the workplace and illustrates and underscores the importance of belonging (Langin, 2019a; Langin, 2018b).

Sevilla's (2014) comedy monologue on stereotype threat is an excellent resource for introducing biases, myths and stereotypes (Ribera, 2014). Her monologue presents the findings of Moss-Racusin *et al.* (2012) and Spencer *et al.* (1999) from an experiment on stereotype threat in mathematics, and of Niederle *et al.* (2013) on positive actions and some of the undesired effects of quotas in academia (Bagues *et al.*, 2014).

5.4 Resources with ideas for humanising problems

As mentioned above, it is important to humanise problems and relate them to current issues of interest. In statistics, moreover, educators can pose problems related to gender equality. For example, Chapter 13 of Moore *et al.* (2007) evaluates a gender violence programme, Aguayo *et al.* (2014) examine discrimination at work, and Tanur *et al.* (1989) describe cases of sexist and racist behaviour. It is easy to construct gender-sensitive problems using data disaggregated by gender. The problems presented should also be open-ended (Momparle, 2012). But, problems in mathematics can be humanised as well. For example, matrices are often introduced without context, but contexts can be added (Shaw, 2018; Mikolajczyk *et al.*, 2010). Derivatives can be studied by calculating the rate of increase of plastic consumption (Geyer *et al.*, 2017), and logistic functions can be introduced with Nobel Prize bias (Lunnemann *et al.*, 2019). This bias can also be illustrated by presenting economic models of Nobel Prizes in homogeneous functions. Along the same lines, in abstract algebra, the application of semigroups can be presented using genetics as an example (Lidl and Pilz, 1998), and the case of Rosalind Franklin (Angulo, 2014) and the Matilda and Matthew effects can be discussed. The Fourier basis can be introduced and used to approximate climate and pollution data (Ullah and Finch, 2013), as can the B-spline basis. To show the applications of the two-dimensional Fourier transform in image processing, for example, an image of women and girls fetching water could be employed, since they account for 80% of people displaced by climate change (Garcia, 2016). This would contrast with the infamous sexist image of Lena which is still very often used (O'Leary, 1999). In operational research, problems of a humanitarian nature can be presented to contrast with its military origins, such as the allocation of resources to prevent diseases like tuberculosis and malaria, the transmission of AIDS between mother and child in childbirth and breastfeeding, determining the location of health services (Azcárate *et al.*, 2006), or even optimising bus routes, emphasising the importance of using public transport, which is used more frequently by women (Ordaz, 2018). Whipple (2019) gives specific examples of the inclusion of LGBTIQ+ content in mathematics problems.

Sanders *et al.* (1997) complies materials with mathematical problems to work on equality primarily applicable to didactics of mathematics, such as *Add Ventures for Girls: Building Math Confidence* or *She does math! Real-life Problems from Women on the Job*. Unfortunately, many of these resources are out of print.

Most resources on inquiry-based methods (IBL, 2019; PRIMAS, 2019) lack context, but we can add it. A few are worth mentioning, Wawro (2012), for example, uses magic carpets for the subject of linear algebra, and in Monterde (1994), students explore mid-19th century Africa by avoiding a cannibalistic tribe in a topology exercise.

SIAM (2019) offer mathematics education resources about the applications of mathematics in everyday life, such as digital animation, which can be seen in more detail in Khan Academy (2019). Grima's book (2018) is also very interesting in this regard.

Anneberg (2019) provides a good collection of visual resources on mathematical applications in everyday life, especially in the programme *Against All Odds: Inside Statistics*, Chapter 4 of which deals with how statistics were used to solve a wage gap problem, equal pay for equal work. The programme *Digits* (2019) is also recommended.

06. TEACHING HOW TO CONDUCT GENDER-SENSITIVE RESEARCH

When planning bachelor's or master's final projects or theses in mathematics that incorporate the gender perspective across the various phases of research, the Yellow Window (2009, p 14) checklist can serve as a useful reference source. It contains two blocks. The first addresses the subject of equal opportunity for men and women (Yellow Window, 2009, p 12), and I would add that this could apply to any group with a minority representation in mathematics, such as members of the LGBTIQ+ community, or those who have made a transition into research later in their careers, or those with family responsibilities, etc. The second block refers to the content of research (Yellow Window, 2011, p 13).

The first block should be applied in any field of mathematics, both pure and applied. This subject will be addressed again at the end of the section. However, with regard to the second block, a distinction should be drawn between research that involves pure mathematics (entirely theoretical) and that which involves the application of mathematical methods. If only pure mathematics is being considered, then proposals are not susceptible to analysis through the prism of sex and gender (Bernabeu, 2017). However, for applications, which are common in the fields of applied mathematics, and especially in statistics and operations research, the gender perspective can and should be incorporated.

6.1 Block 2: Fields of mathematics application

The Gendered Innovations (2019) project has developed a variety of checklists based on specific fields of application, such as those for engineering (<http://genderedinnovations.stanford.edu/methods/engineering_checklist.html>) and health sciences (<http://genderedinnovations.stanford.edu/methods/health_med_checklist.html>). Other useful reference sources for incorporating the gender perspective into research include Lobo, Bacigalupe and Fernández (2015), whose point 6 presents key aspects regarding how research work should be reviewed (for example, the research-society relationship must be considered in scientific/technological works); CIREM (2012), which presents an analysis of eight methodological tools applicable in medicine, architecture, and computer science; and especially the *Toolkit Gender in EU-funded research* produced by Yellow Window (2009), which discusses case studies in the areas of health; food, agriculture, and biotechnology; nanoscience, materials science, and new production technologies; energies; environment; transport; socioeconomic sciences and humanities; science and society; and international cooperation.

6.2 Block 2: Applied mathematics, statistics, and operations research

This section addresses specific works and ideas as examples of how the gender perspective can be incorporated into the contents of research. The content is taken from a variety of mathematical disciplines and serve as sources of inspiration.

In many fields, research conclusions are based on the statistical analysis of data. In order to achieve gender-sensitive analyses, data must be disaggregated by sex (women, men, other options). However, there are additional questions that need to be asked: What are the interests being considered? Which groups in society are included? Who is being favoured, and who is being ignored? A variety of European gender statistics databases can be found at <https://eige.europa.eu/>.

The gender perspective is also essential when producing official statistics. For example, Ruiz-Cantero *et al.* (2006) revealed gender biases in the language used in Spain's 2003 National Health Survey, while the Radical Statistics Group (RadStats, 2019) has focused on the degree to which official statistics reflect aims that are governmental rather than societal.

Renowned statistician Elizabeth L. Scott used statistics as a way to promote equal opportunity and equal pay for women in academics (Golbeck, 2017). In fact, the Elizabeth L. Scott Award was established in 1992 and named in her honour, to recognise the contributions of those who have helped create opportunities for female statisticians. Another famous statistician, Gertrude Cox, also focused some of her work on ways in which statistics can contribute to reducing inequalities ('Especially in Africa one must plan not only for better official statistics but for better experimental work in agriculture, medicine and industry') (Hunter, 2009). She received the O. Max Gardner Award for her contribution to the welfare of the human race (Powell, 1979). Now, the Cox Scholarships bear her name, which the ASA awards as a way of promoting careers in statistics for women.

In a Spanish-speaking context, the Spanish Biometric Conference and the Ibero-American Biometric Meeting has established its Florence Nightingale Prize for best communication with the gender perspective. It was inspired by the need to improve the visibility of the gender perspective and incorporate it into all research, and especially in research involving any type of data analysis. The most recent edition of this event, held in 2019, included the presentations of several research studies in which this approach had been successfully applied (<https://adeit-estaticos.econgres.es/2019_CEB/LIBROABSTRACTS_2.pdf>).

Other examples of research in field of statistics in which new methodologies have been developed to address non-gender-neutral research subjects include Grané and Romera (2018), who present profiles of people who were at risk of social exclusion at the beginning of the Spain's 2008 economic crisis, and Albarrán *et al.* (2015), who focus on profiles of dependence for Spanish children between 3 and 6 years of age. The *Journal of the Royal Statistical Society, Series A (Statistics in Society)* has published numerous works on the non-gender-neutral problems along with others that expressly address gender gaps, such as Berrington *et al.* (2008). Further examples from other fields of mathematics, such as applied mathematics and operations research, include Delgadillo-Alemán (2019), Leal-Enríquez (2018), Clifton *et al.* (2019), De la Poza *et al.* (2016), Mwiti and Goulding (2018), Al-Yakoob and D. Sherali (2007), Amado *et al.* (2018), and Altay and Green (2006). In the last study cited, the authors review applications of operations research in another non-gender-neutral field: disaster management.

The gender perspective can also be incorporated in cases where mathematics is applied to non-gender-neutral technological problems, such as pollution or supply systems for electricity and water (Lobo, Bacigalupe and Fernández, 2015). This is in addition to more obvious applicability in fields such as medicine (Martínez-Costa *et al.*, 2013) and social research (Grané, 2020).

Moreover, special attention must be paid to the serious consequences that can arise if the gender perspective is overlooked, especially if a study is based on a biased sample. The Gendered Innovations project <http://genderedinnovations.stanford.edu/casestudies/machinelearning.html> presents examples of the types of sexist and racist situations that can arise from the use of biased datasets. Another example can be found in O'Neil (2016), in which the author demonstrates how a reliance on big data can exacerbate inequality through its influence in a broad range of areas including education, advertising, the justice system, employment, financial lending, and insurance. O'Neil refers to these effects as 'weapons of math destruction'. One important conclusion she draws is that one can never forget that mathematical models are not neutral, and that ethical issues need to be taken into consideration. In her conclusions, she presents a sample of best practices when making use of big data, for example, the detection of slavery in large corporations that assemble their products in countries with lax legislation. Another work by the same author (O'Neil, 2018) includes a highly recommended discussion of teacher evaluations. An additional example of best practices in the use of big data is data visualisation and statistical analysis of tweets associated with the #Cuéntalo (in the same line as #MeToo) movement (BSC, 2018).

6.3 Block 2: geometry, algebra, and mathematical analysis

The gender perspective can also be integrated in applications of pure mathematics. In geometry, for example, Gual-Arnau *et al.* (2015) applied a geometry-based approach to analysing human sickle cells, which are caused by a disease that primarily affects Black people and which can lead to problems during pregnancy. In algebra, groups can be applied in the field of image understanding, such as optical flow (Lidl and Pilz, 1998), which can be used to detect falls captured on video recordings to monitor the homes of elderly residents (Paul *et al.*, 2013). This is also a non-gender-neutral subject because of the greater longevity of women. In addition, functional data analysis is a field that combines statistics, applied mathematics, and mathematical analysis, and which has applications in numerous other fields such as temporal analysis of melanoma data (Ramsay and Silverman, 2005). This is also a non-gender-neutral subject because, in this case, men seem to have a lower survival rate than women.

6.4 Block 1: Equal opportunities

With regard to the subject of equal opportunities from Block 1, it is important to first discuss the various types of relationships that can exist in relation to supervising projects or theses. According to Chamberlein (2016), there are 10 types of relationships. The most ideal is the one known as ‘colleague in training’, where the supervisor guides the student in a respectful way and is sensitive to the process. All of the other relationships should be avoided, especially those that can reflect sexist situations or disparaging attitudes towards the students.

Another aspect of equal opportunities that should be emphasised is that networking also has an influence in science. In addition to what was described in Section 2 regarding the ways in which the higher research categories are dominated by men, men also tend to show more confidence in promising young men than in promising young women, and this contributes to a reality in which men end up with better jobs (Sciama, 2009). Because mathematics is a masculinised field, situations tend to occur in which a research group contains only one woman, who must then face the difficult situation of feeling like an outsider (Langin, 2018b). It is therefore essential to encourage feelings of belonging to the group. Also, because of issues related to self-confidence, female students seem more quickly destabilised when difficulties arise and, in these cases, having a person who can provide adequate mentoring and guidance becomes even more important (Sciama, 2009).

One tool for supporting gender equality in research and academia (GEAR, 2017) is known as FESTA (2019), which is a guide for providing gender-sensitive supervision. This approach includes recommendations at all phases of a research project, and it also covers situations for which the recommendations have been originated, like hostility towards female students at conferences by means of questions that are posed. In relation to this, the ASA has a code of conduct that applies to activities organised by that association (ASA, 2018).

6.5 Conferences and other activities for women in mathematics

Recently, conferences solely for female mathematicians have begun to proliferate in various areas of mathematics, partly for the purpose of increasing the visibility of women and promoting equality, some examples include: <http://www.crm.cat/en/Activities/Curs_2019-2020/Pages/Women-in-Geometry-and-Topology.aspx>, <https://ww2.amstat.org/meetings/wsds/2019/> and <https://awmadvance.org/workshops-and-symposia/> (in many fields of the maths). Also, the first Women in Science event was recently held at the EURO2018 conference (<http://euro2018valencia.com/women_in_science/>), and the women's OR group in INFORMS (<https://connect.informs.org/worms/home>) organises specific sessions. The women's sections in mathematics associations also organise activities aimed at women mathematicians, such as the Women's Committee of the Royal Spanish Mathematical Society (RSME). Notably, on 12 May 2019 the first Women in Maths day was held as an initiative to celebrate the successes of women in this field around the world (<https://may12.womeninmaths.org/>).

6.6 Gender biases in research

Gender biases in research are manifested in a variety of ways. For example, women may be perceived as less capable, which can even lead to suggestions that a team of female researchers should add a male author to improve their work, as in the case of Megan Head and Fiona C. Ingleby (Pinto, 2015). The bar may also be placed higher for women in terms of having their articles accepted for publication (Card *et al.*, 2019). In fact, Budden *et al.* (2008) found that changing the review process from single-blind to double-blind increased the acceptance of articles with women as their lead author. Research work by men may be thought to be of higher quality simply because of their condition of being men (Knobloch-Westerwick *et al.*, 2013), and Wennerås and Wold (1997) determined that women need to display 2.4 times as much merit as men in order to receive a postdoctoral fellowship. It has also been reported that where conditions are otherwise equal, male researchers are 2.5 times more likely to receive a promotion than female researchers (Libro Blanco, 2011). There can also be biases in relation to awards and prizes. Women are underrepresented as winners of mathematics research awards, and overrepresented in receiving awards for teaching and service (Popoejoy and Leboy, 2012). Academic journals also invite fewer women to serve as referees (Lerback and Hanson, 2017). Other times it is not just that women are perceived as less competent, but sexist beliefs even imply that female scientists cause trouble, such as in the case involving Nobel laureate Tim Hunt (Ribera, 2015).

Unfortunately, the concept of 'publish or perish' remains very much alive these days (Codina, 2018), and this can give rise to unethical practices, such as clientelism (Escudero *et al.*, 2014), or the emergence of prolific scientists who are 'miraculously' able to publish an article every five days (Salomone, 2019). In pure mathematics, authorship order tends to be alphabetical, but this is less common in more applied areas of mathematics, where criteria are based more on meritocracy, in a manner similar to other areas of applied science. Fine and Shen (2018) analysed the distribution of female authors in neuroscience and found them to be underrepresented. Moreover, despite women representing a majority in terms of directing experimental work, their names tended to appear in intermediate positions when authors are listed (West *et al.*, 2013). Fine and Shen (2018) suggested that journals should compile data on gender and ethnicity (and I would add nationality) for articles submitted and accepted, and make this data available to the public. This would help female researchers avoid (or even boycott) journals with a problematic history. They also promote the idea that referees should be given more specific review criteria and that journals should be required to adopt a double-blind review process.

However, gender biases do not only exist in research, but in teaching as well. Numerous studies have demonstrated that simply by the fact of being a woman, female professors receive lower student evaluation scores. MacNell *et al.* (2015) conducted an experiment with online classes, in which the instructors taught different courses using two different identities. When the instructors used masculine identities, they received better evaluation scores regardless of their actual sex. Furthermore, it seems as though effects like these may be even more pronounced among younger female mathematics lecturers (Mengel *et al.*, 2017), suggesting the likelihood of an associated impact on the careers of these young researchers.

Motherhood is also penalised. We still have a long way to go before reaching effective equality between men and women (Ventura and García, 2018), and maternity discrimination and issues regarding the work life balance at universities (Selva Penalva, 2019) affect female teaching staff (assessments, salary bonuses, mobility opportunities, etc.) as well as female students (classroom hours, grading based on attendance without alternatives offered, etc.).

All of these gender inequalities ultimately translate into a wage gap between male and female members of the teaching staff, as demonstrated by Jabbaz *et al.* (2019) in their study at the University of Valencia.

Epifanio (2019) reviewed the barriers and obstacles that hinder real equality between male and female university lecturers, as well as the legal tools in Spain for overcoming those obstacles. Vettese (2019) presents an exhaustive review of sexism in universities, while Cipriani and Senovilla (2020) analyse the various phenomena that can contribute to either perpetuating or changing situations of discrimination against women in the fields of mathematics and physics.

07. TEACHING RESOURCES

7.1 Printed or electronic books, reports, theses

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8. DELVING DEEPER

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