Sensitizing future teachers to psychological research on gender and STEM

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Abstract

What leads less women to pursue STEM careers? What does research find about differences in girls' and boys' educational trajectories? Students and faculty may have heard about gender bias, the leaky pipeline, gender stereotypes, or gender differences in the brain, but it is often difficult to grasp the underlying complexity of these topics. As social scientists in a technical university, we think that learning more closely about research in this field is helpful in developing a balanced and critical perspective. We have thus developed a course on gender issues in education and STEM for students in the teacher education program at ETH Zurich. In this paper, we first introduce some of the main issues in the context of gender and STEM, around which our course is designed. We then describe the pillars of our course. The course is interactive, with students presenting and critically discussing psychological and educational research. We walk students through the various controversies in the field: the nature-nurture question, gender differences vs. similarities, biases vs. interests, gender stereotypes and potential interventions. In a final assignment, students in small groups integrate several papers into a blog-post. Finally, we describe how students respond to our course, and discuss the challenges we as lecturers experience throughout.

Introduction

Why aren't more women in science? is the title of a 2007-published book (Ceci & Williams 2007), in which distinguished social scientists, primarily psychologists, discussed some major and uneasy questions regarding what has become a burning problem in western societies: the underrepresentation of women in science. *Underrepresentation* denotes that compared with the roughly even male / female ratio in the population, substantially less than 50% of the people entering STEM domains (science, technology, engineering and mathematics) are women (OECD 2018). Although more women are in science today than several decades ago, the increase has been uneven across STEM fields. In the most mathematically intensive fields such as computer science, physics and engineering, the proportion of women still stands far below 50% (Cheryan et al. 2017). Such imbalance in gender distributions is prevalent across education levels (from high-school tracks to doctoral studies), with a further drop in the share of women in academic positions beyond the doctoral level (Ceci et al. 2014). Furthermore, universities across countries seem to face this situation, ETH Zurich being no exception (ETH Zurich 2021).

Considered problematic for several reasons, the low participation of women in some areas of science yielded extensive research into understanding its causes and potential ways for change. Academic institutes have become increasingly interested in finding ways to alter the situation, and are implementing various initiatives. Some examples are efforts in making fields

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like engineering more attractive for girls, or searching for female role models in male-dominant fields (Liben & Coyle 2014, Stout et al. 2011). Some of these activities are informed by or even rely on research findings from the social sciences. Thus, it is not unlikely that students and faculty have heard terms such as *gender bias*, the *leaky pipeline* or *gender stereotypes*. Nonetheless, it might be difficult to grasp the complexity of the gender-science issue without knowing about the scope of scientific work done in this context, or without delving into questions such as: What leads less women to pursue STEM careers in the first place? What does research find regarding differences in girls' and boys' educational trajectories before they decide about higher education? We think that learning more closely about research in this field is helpful in unfolding some of these complexities, gaining a deeper insight about them, and developing both a balanced and a critical perspective.

With this goal in mind, we have developed a course on gender issues in education and STEM, which is offered to students enrolled in the teachers' education program at ETH Zurich, whom we regularly teach in our group. Inspired by Ceci and Williams' book, which spans a wide breadth of empirically studied topics and considerable debate, we constructed the course around key issues regarding gender and STEM education. Although research has expanded and findings have been updated since that publication, the main issues remain highly relevant in contemporary research and theory. While we are not covering every possible aspect in our course, the goal is to provide students with a comprehensive view on these matters rather than overemphasize certain factors as "the main reason" a student continues or not in STEM. Since our students are future secondary school teachers, an emphasis is put on linking these topics to teachers' role in the classroom setting. We believe, however, that learning about these topics is relevant to university faculty as well as to other students. In the next section, we briefly review the key topics around which the course is organized, and then go on to describing the course.

Cognitive performance by gender, or "Are boys better in math and girls better in languages?"

Comparing genders on cognitive performance is relevant to many research questions, and is obviously done in the context of gender and STEM. While exploring whether differences exist does not provide us with explanations on their causes or indicate their meaning, it is an important starting point prior to asking any *why* questions. International assessments among school-age children and adolescents find minor or no gender differences in mean performance on mathematics and science assessments, averaged across countries, while a rather consistent advantage for girls emerges on language competencies (Berkowitz et al. 2020, Reilly et al. 2017). The issue of performance assessment is, however, complicated by several factors. For example, the type of assessment matters: there is a tendency for a male advantage on standardized mathematics tests and a female advantage on teacher assigned grades (Miller & Halpern 2014, Voyer & Voyer 2014). The area of cognitive performance matters, with general cognitive abilities hardly showing gender differences, but some gaps emerging on specific abilities, such as a male advantage on certain spatial ability tasks (Halpern et al. 2020). The location of scores within the distribution matters as well, with the weakest differences appearing at the mean level, and more apparent differences at the higher or lower range of scores (Pargulski & Reynolds 2017). Disagreements seem to exist not only regarding the origins of any found differences in performance, but also on what makes a finding practically important or not. A small statistical difference may be viewed as important and highlighted by some, while others find the overlap in scores, and hence the similarity between genders, as the more important result (Hyde 2016, Wai et al. 2018). Thus, a simple answer to whether one gender outperforms the other on some area of cognitive performance is difficult to achieve. While providing an overview of such findings in our course, we point out the importance of these additional factors that come into play. An important message in this regard is that gender differences in cognitive performance, when found, fall short of explaining the actual male-female ratio seen in STEM areas, indicating that other factors must be at play.

Interests and preferences by gender

An often-made argument regarding the underrepresentation of women in science is that it is not about any disadvantaged ability, but rather an expression of preference. Put differently, it is argued that some STEM fields are just not interesting enough for most women. Research on interests indeed finds substantial gender differences across development. In particular, differences emerge on a dimension termed *people vs. objects*, referring to areas involving social interaction (*people*) as opposed to areas involving inanimate systems of some kind (*objects* or *things*) (Su & Rounds 2015). When given inventories of different occupations, women, on average, show a stronger preference for *people* (e.g., social worker), whereas men show a stronger preference for *objects* (e.g., technician) (Su et al. 2009). Research on children's play preferences from about the second year of life, as well as on preferable school subjects and adolescents' plans for their future education shows analogical gender differences (Ceci et al. 2014, Dinella & Weisgram 2018, Kuhn & Wolter 2020). Thus, at the level of expressed preferences, the answer regarding gender differences seems less ambiguous than for cognitive performance.

Should the discussion stop here then? Should interests be similarly distributed among males and females? We pose these questions to our students, which usually generates a lively discussion. Although we do not argue that interests must by all means be equal across genders, we believe that taking these statistics at face value may quickly lead to oversimplified conclusions such as "girls just do not like physics, it is their free choice not to specialize in this field". A first reason for not stopping the discussion is that gender differences in interests also do not fully account for the underrepresentation of women in some STEM areas (Su et al. 2009). Second, we know that interests and choices are strongly influenced by socialization, which includes gender roles and stereotypes regarding what girls and boys should like or do. These may suppress potential interests in gender-atypical domains, lead to fewer experiences in such domains, or to develop narrow perceptions of them (Eccles 2007, Wang 2012). Furthermore, a drop in women's STEM-participation often occurs after they have entered STEM, hence among women who did have enough initial interest. An important message in this regard is that interests should not be seen as fixed traits that are resistant to change. Rather, interests develop and can be encouraged, and many researchers study ways for doing exactly that (Gaspard et al., 2015; Rozek et al., 2015).

The origins of gender differences in cognitive performance and preferences

Perhaps the most challenging endeavor is to provide scientific explanations for any appearing gender differences in either performance or preferences. The old nature-nurture distinction is often present in this context, namely the degree to which innate, biologically determined factors (nature) influence gender differences, comparing to the shaping power of social, environmental and situational factors (nurture). While nature and nurture are no longer viewed as mutually exclusive, but more often as forces in a reciprocal relation (Miller & Halpern 2014), researchers are still debated over their relative importance. On nature's side, sex differences in the brain (e.g., brain structure, function and development) and sex hormones are sometimes linked with the gender-STEM question. For example, a male advantage on certain forms of spatial ability—which is regarded essential in several STEM areas—has been linked with prenatal hormonal exposure to androgens (Beltz et al. 2020). Some researchers suggest that the higher between-hemispheric connectivity commonly found among females and a higher within-hemispheric connectivity among males (Ingalhalikar et al. 2014), partly explain gender differences on the aforementioned *people vs. objects* preference (Baron-Cohen et al. 2005). Evolutionary psychologists argue that factors such as male competition, tool construction and

Man the Hunter shaped brain development in a way that yielded these sex differences (Geary 2010). However, the suggested links between brain, hormones and evolution on one hand, and the underrepresentation of women in science on the other hand, are far from being precise, clear, robust, or consensual. Rather, some of the arguments are highly controversial. Some counter-arguments are, for example, that *Woman the Gatherer* also needed spatial skills for her activities, thus these should have had an evolutionary advantage in females as well (Newcombe 2007). Developmental psychologists conducting infant research find no evidence that either sex is born better equipped for learning in any domain (Spelke 2005). Many researchers acknowledge that there is no simple path from observed biological differences to learning and education. Yet, it is not uncommon to hear in public discussions and the media about a “male” and a “female” brain, or about innate differences that determine gendered preferences. Often, such statements are overgeneralized and oversimplified. In other contexts, speaking about biological sources of cognitive or social gender differences may be viewed very negatively, because it implies that some gender differences (especially if disadvantaging women) are innate and therefore immutable. However, here too there is a misconception, since biological is neither necessarily innate nor immutable (Miller & Halpern 2014, Newcombe 2007).

What about nurture? The extent of research and theory regarding social influences on gendered choices or performance differences is vast. In our course, we first briefly introduce students to the development of gender identity in childhood, as well as to non-conforming gender identities (e.g., transgenderism). We then dedicate more attention to studies on gender norms and stereotypes across development that are relevant to STEM. For example, although female scientists appear more often in children’s drawings today compared to a few decades ago, early adolescent girls switch from drawing more female scientists to drawing more male scientists (Miller et al. 2018). Whereas preschool children perceive members of their own gender as similarly smart, starting from age 6, girls are less likely than boys to associate brilliance with their own gender (Bian et al. 2017). These early beliefs are associated with children’s interests, and are perceived as precursors for later educational choices. Among adults, stereotypes regarding gender and science are prevalent as well, and have been respectively linked with interests and choices in STEM fields (Nosek et al. 2009). Relatedly, students’ academic self-concept—the degree to which one feels competent in a specific academic domain—also shows gender differences and has implications for later educational and career choices (Marsh et al. 2019, Stout et al. 2011). A lower self-concept in mathematics is consistently found among girls, even when controlling for actual performance level. In this context, motivational theories such as the Expectancy Value Theory (see Eccles & Wigfield 2002) provide a comprehensive framework for understanding differential educational choices by gender. Of course, research on social influences is not without limitations either. For example, measuring stereotypes or assessing teacher’s bias is highly challenging. Consequently, there is an ongoing debate around some findings’ validity, generalizability and replicability.

Having introduced some core issues regarding gender and STEM, we now turn to describe the setup of our course in detail. Afterwards, we discuss how students experience the course, as well as our perspective as instructors.

A Course on Gender Issues and STEM

To incorporate the aforementioned perspectives and debate into a coherent course for students, we designed a two ECTS-points elective course entitled “Gender Issues in STEM and Education”. Our group at ETH Zurich, headed by professor Elsbeth Stern, is responsible for teaching all students enrolled in the teaching diploma program. These are mostly advanced students (master’s and doctoral level) who plan to become secondary school teachers in STEM subjects, either at the Gymnasium or Sekundarschule. Our course is usually given each semester and enrolls up to 25 students. Occasionally, interested students not in the teaching diploma program join us as well.

The overarching learning goal of our course is to familiarize students with gender issues within STEM domains and with ongoing debate in this field. We also want students to develop critical thinking regarding existing perspectives, and to be able to integrate this critical thinking into their work as teachers. However, we also emphasize that we are not providing a "toolkit" for the classroom. Rather, we focus on conveying an appreciation of the width and complexity of this scientific topic, and supporting students in continually educating themselves throughout their career.

The course comprises 12 weekly sessions and two to three additional writing time sessions dedicated to the final assignment, which we explain below. After an introduction and an instructor-led session, eight of the total of 12 sessions are divided into 1) an instructional part, provided by us in the form of direct instruction, and 2) a student-led part consisting of two student presentations of mandated literature in each session, followed by a discussion. We divide the class into a (deliberately chosen) stereotypical *pink* and *blue* group. Each group reads one of two articles and a member of the group presents it in class. This division limits the workload for students by splitting the mandated literature between the groups. Students are asked to additionally read the abstract of the paper presented by the opposing group, or the entire paper if they wish to. We selected the articles based on the quality of the peer-reviewed journals in which they were published, the established record of their authors, or whether papers influenced the field of publication. The resulting literature provides mostly high-quality empirical research to students, but sometimes also emphasizes influential but methodologically criticized papers. Figure 1 shows the content of each session alongside with the selected articles that are read and presented by the blue and pink group respectively.

Figure 1: Topics and discussed research per session.[4]

Instruction-led part of each session

In this part of the session, we provide an overview of theory and empirical findings regarding the key topics displayed in Figure 1 and described in the introduction. We critically discuss study quality, present unanswered research questions and inform students on ongoing debate. We update and improve this part each semester, by including recent publications or expanding on criticism of existing studies. We also occasionally provide additional information outside of preplanned topics if students request this or as a result of a specific classroom discussion. This allows us to play into new developments, students' interests, and of course satisfy everyone's curiosity when needed.

In addition to reviewing key aspects of gender issues in STEM, we emphasize intervention studies focused specifically on means for reducing STEM gender gaps. Given that our target group are (future) teachers, we think it is very important to get some understanding of possible interventions, something also echoed by students themselves. However, we also want to make students aware as to what might be expected from interventions. The reality of gender and STEM is often complex, as many individual factors interact (Halpern 2014), meaning that there is no such thing as a "simple fix" for teachers. In addition, the immense increase of using positive words – words such as *innovative*, *novel*, or *groundbreaking* – in research papers over the last 40 years (Vinkers et al. 2015) makes it even more difficult to accurately judge the quality of an empirical study or to know which intervention is useful in a classroom. After all, if everything is groundbreaking, essentially nothing is.

So although this is not a methodological course, we do pay additional attention to the methodology and design of research we bring forward. As often the case in social sciences in general, studies differ considerably in sample size, appropriate statistical analysis, control of variables and overall design. With these differences between studies, the overall replication 'crisis' found in psychology (Open Science Collaboration 2012), and the complexity of human behavior under investigation, we consider it important to be aware of those methodological shortcomings. Doing so should prepare teachers for the intricacies of gender issues in STEM in both content and methodology.

Student presentations

In accordance with our course goals, we designed the student presentations as opportunities for students to learn about the perspectives debated in the field, as well as to bring their own critical view on empirical research. In some sessions, these perspectives are more complimentary, such as stereotypes and achievement on an international scale (e.g. Nosek et al. 2009) and recently discovered stereotypes, such as *field-specific ability beliefs* (e.g. Leslie et al. 2015). In other sessions, studies are chosen to help contrast and debate, such as when discussing sex differences in neonatal social perception (e.g. Connellan et al. 2000, Escudero et al. 2013). As we show in the student experience section below, students often struggle to see the relevance of studies with neonates for their classrooms. Yet, we find that discussing

[4] The links lead to the journal's page with the article. Newcombe (2007) and Geary (2007) refer to book chapters (see reference list).

the contrasting views and results of these papers can be incredibly useful to understand the arguments brought up in discussions regarding innate sex preferences for *people* vs. *objects*.

The study by Connellan et al. (2000), for example, has proven very influential, being cited over 600 times since its publication. Their results were in line with the hypothesis of innate sex differences in preferences, with girls assumed to be innately attracted to people and boys to objects. These results could then be taken as indication that trying to motivate girls for STEM subjects could be of little value. However, as these results appeared hard to replicate, and more experimentally controlled studies found no such differences (e.g. Escudero et al. 2013), it provided us with a good opportunity to discuss methodology within this complex topic, and how this might influence the debate. The methodology implemented by Connellan et al. (2000), for instance, could not exclude experimenter effects (see Doyen et al. 2012). The overall small sample showed very little difference for the majority of the neonates investigated. Moreover, as mentioned in the introduction, biological differences are not immutable, even if sometimes presented as an all-encapsulating answer. Contrasting both papers effectively introduces the debate on innate or socially acquired differences that is the basis for a lot of empirical research. It also provides a good platform for students to discuss their ideas, practice critical thinking and get an understanding of how early interests of neonates might be relevant to their practice as teachers.

Blogpost assignment

As a final assignment, we require students to write a blogpost about two empirical intervention studies that have previously been discussed in class as student presentations (see Figure 1). Blogposts are a popular method of introducing and discussing specific topics in an approachable way. As such, we figured that writing a blogpost is a good way of giving students practice with relevant interventions, critical reading, and ways of communicating academic literature in an understandable way. This goal ties in with an overarching aim towards teachers being able to educate themselves and others, continuously throughout their career.
The blogposts are written in groups of two to four students. Figure 2 gives an impression of the blog with posts written by the students. We ask students to provide a first draft, followed by a peer-review phase in which each student reviews one to two other posts. We emphasize the use of positive and constructive feedback, and specifically highlight the importance of argumentation. Students who review a post and are suggesting changes should argue their reasons for these changes, whereas students who receive feedback should argue their reasons for not accepting these suggestions.

We ask students to describe both studies to a fictive audience of parents and colleagues at their school, in the form of a coherent story on two relevant interventions. This means that students should find a common theme, provide readers with the most important information from the studies, integrate findings and conclusions, and link the topic to their work as teachers. We provide students with two categorization schemes of interventions. The first is the scheme by Liben and Coyle (2014), which emphasizes goal types for reducing STEM gender gaps. The second theme is developed by us, and consists of categorizing interventions by their focus (i.e. student-focused, teacher-focused, or environment-focused) and their type (i.e. interventions on social and individual factors, interventions on learning and instruction, or comprehensive interventions). These schemes help students to organize intervention studies, often differing in methodology and target populations, around meaningful themes.

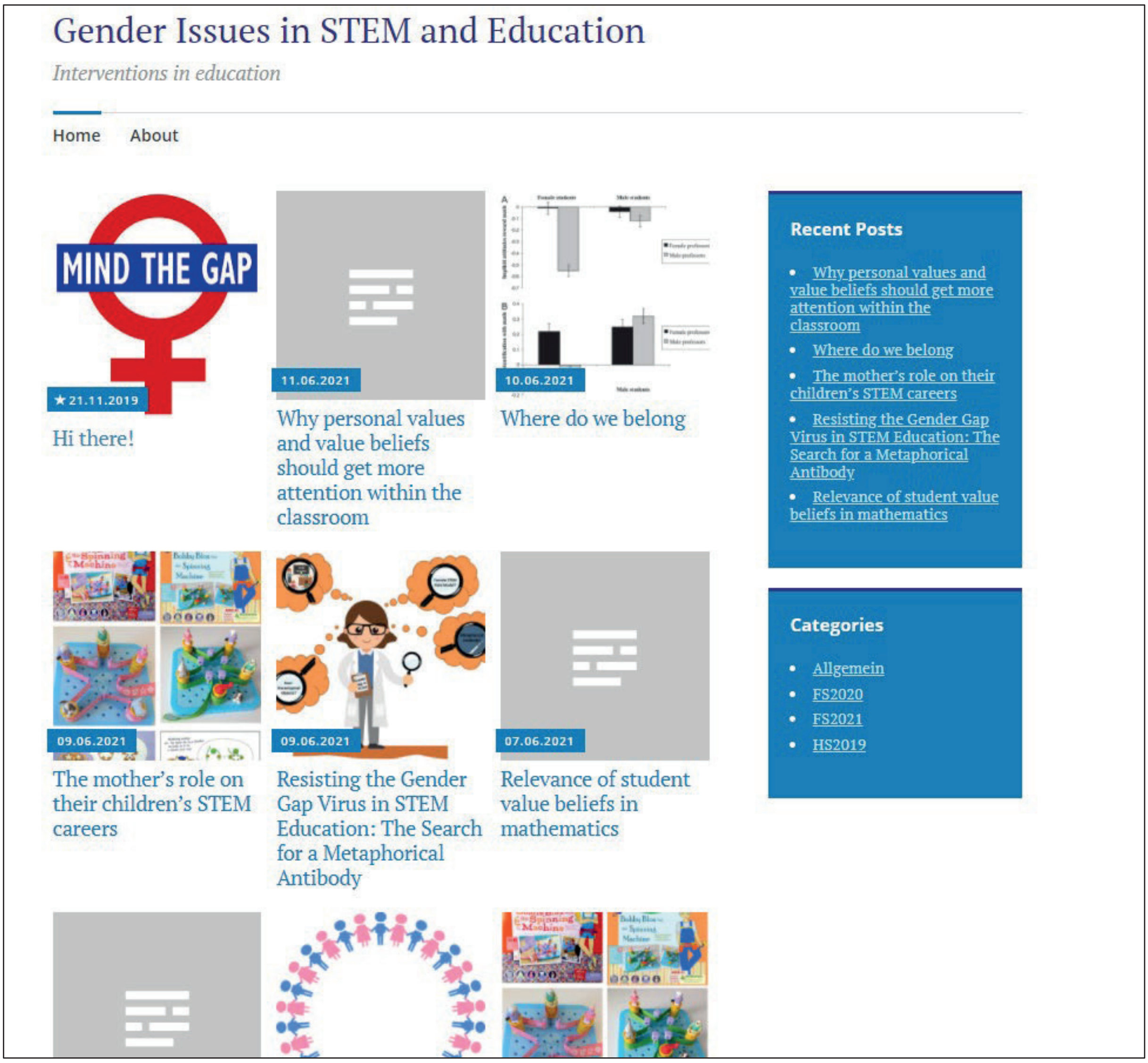

Figure 2: Homepage of the blog with posts written by the students.

Reflecting on the Course

Students' Responses

Towards the end of the semester, we ask students for feedback on the course. In general, students react very positively to our course. They also give constructive suggestions, which we implement in further iterations of the course. In spring semester 2021, we collected feedback from 19 students, in response to several open-answer questions. We extracted a few noteworthy answers and grouped them below into overarching themes.

Our students especially liked the format of the course, having presentations and discussions on research articles and the blogpost assignment. Some students mentioned that they would have liked further discussions on gender identities and non-binary gender, which we could only marginally discuss in the current setting.

Surprising insights

Many students mentioned that the topic turned out more complex than they initially assumed. On being asked what was new to them, one student answered:

"*A lot! Especially that there are so many reasons for gender issues in STEM, and that it is very hard to connect everything and make causalities.*"

Many of the students had prior experience with debate and discussions about gender issues. Yet, they realized that the scientific approach to the topic and the intervention studies were new to them.

While discussing these studies, students also showed critical thinking, which was one of our course goals. For example, one student commented:

"*It surprised me how many of the studies employ questionable statistics, and still get published in big journals. Of course, the gathered data is still valuable and I am still taking their findings seriously, but this reminded me not to trust any headline without looking into what was actually found in the science.*"

Importantly, students also became aware of the similarities between genders as shown by this comment:

"*I take with me the input, that similarities are way stronger than the differences.*"

Students also remarked that they learned how important it is to reflect about the topic in general:

"*I feel like it is very important to be conscious about those topics. I thought it might just be enough to assume everyone to be equal.*"

Changing perspectives

When asked whether they started thinking differently about some aspects, one student mentioned:

"*It has definitely sharpened my awareness for gender differences. (…) I also reflect more on my own behavior and how to fight implicit stereotypes I might have, even outside of the gender dichotomy.*"

Students also mentioned having developed a more nuanced view on the matter. Regarding their experiences at ETH, while some praised ETH for doing a good job, others remarked that some stereotypes are deeply inclined:

"*I think ETH does a good job in a lot of things. It's also hard to blame ETH for certain things as the reasons for certain situations might rather emerge during school.*"

"*I realized how deep some stereotypes at ETH remain. Like how in different departments, it is a huge thing being a woman, and how peers and others react (sometimes negatively) to that.*"

Open questions

Questions that remained open to the students revolved mainly around the topic of actions:

"*What can we do to change the pressures exerted on boys and girls by socialization? Yes, we can try to actively combat them in the classroom, but it seems to me that much of it is upbringing in the end. While we can offer information to parents, it is unclear how readily parents will do the work to confront their own gender stereotypes and want to give this on to their kids.*"

This statement showed a rather disenchanted view on the teacher's role. Students often wanted to know more about what they could do in their future classrooms. Although easy answers are hard to provide, in our course students familiarized with possible interventions that have been empirically tested. When writing the blogpost, students had a chance to analyze intervention studies in more detail and to gain some experience in explaining them to an audience of colleagues and parents.

Another topic that we only marginally discussed in the course was the underrepresentation of men in social fields. Students mentioned they would have found this topic interesting as well, in the sense of equal opportunities.

Finally, an interesting experience that one of our female students described was an awkward feeling towards attempts to 'support' female students as a minority group. For someone who has personally not experienced difficulties for being a female student, it felt out of place. This was a good opportunity to discuss variation in individuals' experiences, and to ask whether assuming that female students in a male-dominant environment are necessarily disadvantaged is justified.

Our experiences: Balancing a challenging issue

When we first designed the course, our aim was to provide a rich overview of gender and STEM issues by getting to know the research behind it. In hindsight, this proved to be a very ambitious aim, because finding a balance between the scope of important research topics and in-depth critical analyses of specific studies was not easy. On the one hand, we wanted to cover important aspects of the field, although there is a huge amount of research and there exists no unitary approach. On the other hand, we wanted to convey the complexity and peculiarity of empirical research with a close look, yet without inducing confusion. Therefore, we decided to let the students read and discuss a selection of articles in depth, while we as instructors provided further content on each topic. After iteratively adapting the form and content of the course, we achieved a good balance between broadness and depth.

One aspect we often reflect upon is our dichotomized use of 'gender'. Although we dedicate time in class to the perplexities of the terms 'gender', 'sex', and the prevalence of alternative gender identities, most of the time we do refer to two categories. On one hand, this aligns with the fact that most people identify themselves as either male or female, and with the fact that most research uses this dichotomy. However, we wonder whether this might induce, at least sometimes, stronger perceived gender differences than necessary. So far, we thought it was beyond the scope of our course content to elaborate on this issue, but we may dedicate more time to it in future iterations.

One question that remains open to us is how much impact our course has in the long run in terms of potential change. We are convinced that informing students about the current issues and sensitizing them to the complex topic designates an important step. Especially for teachers (either in schools or universities), who exert a large influence on their students, being knowledgeable about gender issues is important in understanding the network of intermingled causes. Overall, while preparing and giving this course was demanding, it turned out to be a great opportunity to increase future teachers' awareness and knowledge about this topic. By this extensive description, we have hopefully provided ideas and incitation for other higher education teachers.

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