ETH zürich

Gender Attainment Gaps

Literature review and empirical evidence from IARU universities

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Contents

Executive Summary

This report reveals a number of factors which are likely to be involved in the emergence of gender attainment gaps in various research universities. The relevant literature discusses *sex specific challenges*, such as a disproportionate development of visuospatial skills in men and women, which might lead to a difference in performance on certain types of tasks, *psychological factors* such as interests and self-confidence levels, as well as *cultural factors* such as national-level gender-science stereotypes. In addition, this report identifies a series of likely causes of gender attainment gaps which universities can directly influence, such as the campus environment and teaching and examination styles.

The report also comprises empirical data from ETH Zurich, the University of Tokyo, the University of Cape Town, the University of Copenhagen and the University of Oxford. Universities in the sample vary greatly with regard to the percentage of female students enrolled, yet also with regard to their relative emphasis on STEM programmes, the area in which gender attainment gaps are most acute. *Prior knowledge* and *academic self-concept* (the belief in one's own ability to succeed in a given subject) emerged as significant predictors of gender attainment gaps. It is also apparent from the data that there are significant differences between female and male students on psychometric variables. Female students report higher levels of perceived *stress*, *threat* and *uncertainty*, are *less competitive* than men and more likely to perceive the workload as excessively heavy.

The report recommends measures to level up students' prior knowledge and skills at the start of study programmes. It also advocates for acceptance of different problem-solving approaches (verbal, visuospatial, collaborative, competitive), while encouraging full-time attendance and interaction with faculty. Acknowledging the context-dependent nature of such measures, the report advises universities to delegate an institutional body responsible for identifying institution-specific gender gap determinants, and for designing and implementing policies tackling them.

1 Introduction

The International Alliance of Research Universities (IARU) launched, in 2017, an investigation of gender attainment gaps, after observing that the phenomenon exists in some of its eleven research-intensive member institutions. An internship position based at ETH Zurich was created for this purpose, and the results of the investigation are presented in the current report.

The report comprises three main components. The first part is a review of the relevant literature. The most methodologically sound scientific articles have been selected and structured into those addressing sex specific challenges, those addressing psychological and those addressing cultural factors which might have an influence on the emergence of gender attainment gaps. Since the aim of this report is to facilitate institutional intervention alleviating gender gaps, the factors which appear to influence performance and which are mostly under the influence of universities, as opposed to families or societies in general, have received particular attention. Furthermore, the report contains empirical data collected from the IARU universities which responded to our call. The respective data is presented and analysed. Lastly, in the final part the report advances some conclusions and a series of recommendations as to how gender attainment gaps could be closed.

2 Starting Point

Research on gender attainment gaps dates back from the beginning of the 20th century. Throughout their development, these studies sparked debates around not only the causes of such a phenomenon, but also about whether gender gaps exist in the first place. Against a background of fierce discussions about which variables would best predict differences between boys' and girls' school performance, Hyde & Linn (2006) and Hyde et al. (2008) claim that, in fact, there is no evidence of significant gender attainment gaps in the case of American children up until high school. They argue that the differences in performance might actually be fabricated by media overstating minor effect sizes found in studies of attainment, psychological and behavioural differences between women and men, which result in the end in the reinforcement of biases. Under these conditions, it is not the subtle differences between women and men that should be emphasised in order to increase women's ability to succeed, but the similarity between women's and men's capacity to achieve high performance.

In line with Hyde & Linn (2006)'s emphasis on the implications of media's approach to gender studies, Halpern et al. (2005) illustrate this media bias using the hyped example of a presumed variation in cognitive abilities over the menstrual cycle. Considered highly controversial and potentially discrimination-generating, the issue of cyclical change in cognitive abilities due to fluctuating hormone levels has only been presented by the media using studies on females' performance levels, although there are observations of similar variations in males. The effect of hormone levels on performance in various tasks is, however, of small magnitude in the case of both sexes.

The remainder of this paper will focus, hence, on instances in which evidence of gender attainment gaps has been found. It will be structured in six main sections. Section 3 reviews literature focusing on sex specific challenges, Section 4 presents the main psychological factors, while Section 5 addresses cultural influences on gender attainment gaps. Section 6 covers those factors which are mostly under the influence of universities. In Section 7 we report on the gender attainment situation in IARU member institutions, presenting empirical evidence provided by the research universities themselves (subsection 7.1) and a series of comparative observations (subsection 7.2). Lastly, Section 8 advances conclusions and a series of recommendations, derived from the literature as well as from the data that has been collected, on how gender attainment gaps could be closed.

This structure should nevertheless be regarded with the caveat that the differentiation between categories of predictors is imperfect and only meant to facilitate readability. As Halpern et al. (2007) note, biological and environmental factors reciprocally influence each other and are thus almost impossible to analyse separately. In terms of the topic of this paper, it is extremely difficult for conclusions to be drawn as to whether high ability in a domain leads to more interest and involvement in additional activities, or a high level of interest and willingness to get involved in additional activities lead to high ability in that specific domain.

3 Sex specific challenges

Assessing variation in academic performance between females and males first makes the assumption that the grouping variable is binary. However, sex and gender are not the same. While males and females can often be distinguished by their sex chromosome karyotype (XY or XX), the phenotypic expression of genetic sex as gender is not binary, but instead is expressed along a continuum of variability. Nonetheless, academic and professional scholarly assessments commonly treat individuals as either male or female. Genetic influences on gender attainment gaps have largely been rejected due to the overwhelming evidence that social and environmental factors that disadvantage females and favor males are the primary contributors to gender inequities within academia. It has been noted that countries differ significantly in the extent to which boys have higher science achievements than girls, with some of them even displaying the reverse pattern. Whereas the male advantage is manifest in countries such as the US, Australia, Belgium, Chile, Hungary, Tunisia, or Israel, girls have higher science grades that boys in Jordan, Macedonia, Moldova, Philippines and Cyprus (Nosek et al., 2009). In addition, evidence from the U.S. shows that, compared to previous generations, boys and girls take high school math and science courses in equal numbers and with equal difficulty levels (Ackerman et al., 2001).

Awareness of academic variation between and within genders does not validate the existence of a ’smarter sex’ (Halpern & LaMay, 2000, p. 229), but of basic human variation in association with opportunities to excel without the encumbrance of social and professional inequities. For example, evidence suggests that women perform better in tasks involving the retrieval of semantic or phonological information from the long-term memory, advanced language or reading skills, or high perception speed. Comparatively, men have been reported to display higher performance rates when the tasks require visual-spatial transformations, aiming-like motor skills or abstract reasoning of the type employed, for example, in mathematics (Halpern, 1997). However, these results are hampered by their applicability to academic and professional achievement as well as the overwhelming evidence of explicit and implicit bias against females within academia. The fact that a set of skills which is associated with either females or males is routinely valued higher is essentially a result of the social structure establishing the hierarchy in abilities and not a consequence of the sex differences themselves (Halpern et al., 2005).

Implications of the fact that performance levels are highly sensitive to characteristics of the tasks are evident in education and particularly in standardised testing. For instance, using evidence from the United States, SAT-Ms have been shown to systematically underpredict female performance in mathematics, presumably due to the mix of items used to assess mathematical reasoning (Spelke, 2005). Despite men obtaining higher SAT-M scores, women's and men's grades in college calculus classes are equal (Bridgeman & Lewis, 1996), women generally have higher undergraduate grade point averages (Sonnert & Fox, 2012), and they have been shown to earn US bachelor's degrees in mathematics in a proportion almost equal to that of men (Chipman, 2005). However, when standardised testing is conducted at higher educational levels, the disparity between women's and men's scores reappears, showing that normed tests and classroom achievement differ in the knowledge and skills that they are tapping into.

A possible explanation for the so-called 'grade-test disparity' (Halpern et al., 2007, p. 4) might lie in the above-mentioned easiness with which men and women approach different types of tasks. Women's superior retrieval capacity and language skills might improve their performance in advanced math classes, whereas men might perform better in nationally or internationally normed tests, which deviate from the course material, due to their superior abilities in visual-spatial transformations (Halpern et al., 2005). Alternatively, Kling et al. (2013) have found that conscientiousness, a personality trait most often displayed by women, mediates the relationship between gender and grade-test disparity. In other words, women are able to exceed the performance that their results in standardised tests would predict because of their tendency to be more careful, deliberate and thorough.

The Study of Mathematically Precocious Youth (SMPY), a longitudinal study following more than 5000 gifted American children over 35 years, proposes a relative approach to individual abilities. Starting from the first years in which the study has been conducted, a difference in the type of abilities at which boys and girls excel has been noted (Benbow & Stanley, 1980). Yet, in comparison to previous studies, the SMPY found that more accurate predictions can be formulated based on the relative score on one of either mathematical, verbal, and spatial reasoning abilities, rather than by examining the three dimensions independently. Individuals having outstanding verbal abilities, compared to their mathematical and spatial skills, were the ones who then chose as favorite courses, college major and occupations from social sciences and humanities. Comparatively, favorite courses, college majors and occupations from math, engineering or computer science have been later selected by those participants which initially displayed superior mathematics and spatial, relative to verbal abilities (Lubinski & Benbow, 2006). Ability profiles might explain the gender difference at university level in that the relatively higher mathematical abilities compared to verbal abilities, which was then associated with careers in mathematics and science, is a more common trait of men, whereas women generally display a math-verbal balance (Halpern et al., 2007).

And it is not only that women obtain systematically lower scores than men in nationally and internationally regulated tests, but the difference grows larger the higher the educational level at which the test is taken. This observation has been argued to be the consequence of males' higher variance in their academic abilities and achievement, resulting in more men being situated at both the high and the low ends of the distribution. Test scores for men in the United States have been found to be more variable than those of women, particularly for measures of science achievement and vocational aptitudes. It is for this reason that differences in means are relatively small when comparing the number of women and men in a nearly representative sample, but in subsamples of the most talented individuals men clearly outnumber women, with sex ratios of 5:1 in the top 3% and 7:1 in the top 1%. At the same time, about twice as many men than women are situated in the bottom 10% of the national distribution for reading comprehension, perceptual speed and associative memory (Hedges & Nowell, 1995). Nevertheless, the ratio of men to women in the upper tail of the SAT-M scores distribution has recently become less extreme. Speculative reasons behind the improvement include the now balanced number of math courses taken by boys and girls, as well as the newly-introduced special programs and mentoring for girls (Halpern et al., 2007).

4 Psychological factors

In the current section, we review those psychosocial factors that may contribute to gender attainment gaps which are predominantly under the influence of families separate from those mostly under the influence of universities. The distinction is, naturally, imperfect, more so given that both categories of influences are also themselves impacted by societal-level factors, yet useful given the purposes of the present report.

The Study of Mathematically Precocious Youth went beyond the analysis of the subjects' abilities and identified further differences in the preferences reported by women and men. Women were three times more likely than men to place social interests (learning about and working with people) among their top two preferred themes, whereas men were four times more likely than women to place realistic interests (learning about and working with things and gadgets) among their top two preferences. 72% of males and 35% of females indicated theoretical values as one of their top two preferences. Later in the life course of the study participants, it has been found that individuals possessing high mathematical abilities and theoretical values, while scoring low on the social dimension, were the ones who have then obtained a college degree in mathematics or science, as opposed to one in humanities (Lubinski & Benbow, 2006). As noted before, these math-related abilities and preferences are shown predominantly by men.

When analysing trait complexes, that is, combinations of variables related to cognitive, personality and interest constructs, Ackerman et al. (2001) found that men score higher on the Science/Math/Technology trait complex, while women score higher on Social Potency/Enterprising, Social Closeness/Femininity, and Traditionalism/Worry/Emotionality. These trait complexes have further been found by Ackerman et al. (2001) to be correlated with knowledge, with those individuals scoring high on the Science/Math/Technology complex having also a more advanced knowledge in the physical science and technology fields. It has thus been argued that a general interest in science and math, a trait mostly shown by men, and the resulting interest-based experiences, might explain the difference in math performance between women and men (Halpern et al., 2005).

Expectations form another psychosocial factor influencing performance. It is considered that positive expectations related to one's ability to successfully fulfill a task would lead the individual to being more persistent and thus, at least in the case of mathematical problem-solving, increase their performance. Higher performance would in turn increase the level of self-confidence, ultimately generating a positive feedback loop (Halpern et al., 2005). Indeed, Vermeer et al. (2000) found a strong correlation between the perceived confidence of sixth-grade boys and girls and their mathematical performance. Boys outperformed girls in applied problem solving, with girls reporting lower confidence levels when starting to work on the same applied problems. The relationship between perceived confidence and persistence, however, did not receive significant empirical support.

A longitudinal study of students in the US revealed that high aspirations for degree attainment and high self-confidence are significant predictors of degree completion in science and engineering. Expectations and self-confidence appear to even mitigate the negative effects of lack of family financial support and low level of parental education (Huang et al., 2000). Yet women systematically report lower self-confidence levels related to math ability and higher levels of perceived discrimination and effort compared to their male counterparts (Vogt et al., 2007), factors which may lead to a higher likelihood of them abandoning science, mathematics and engineering disciplines at early stages (Seymour, 1995). Grunspan et al. (2016) argue that women's low self-confidence levels and resulting low retention rates might be partially due to the systematic underestimation of their knowledge by male peers. In a study conducted with college-level biology students, they have found that, even after controlling for performance and outspokenness, men are more likely to be nominated by colleagues as being knowledgeable about course content. The difference appears to be driven by males disproportionately naming their male peers relative to their actual performance, while females do not display gender bias in their assessment. Similarly, Proudfoot et al. (2015) have shown that males are perceived as more creative than women, regardless of how their competence is evaluated.

Parental impact is traditionally considered to play a major role in shaping boys' and girls' self-confidence levels, yet the direction of the effect is notoriously difficult to identify. Despite strong correlations between parents' beliefs in the abilities of their children and their actual performance, little can be said about which one phenomenon led to the other, or whether there is a reciprocal relation between the two. Under these conditions, studies are even less likely to provide evidence of differential parental treatment by sex. One notable exception is the finding that parents tend to grant boys a play range up to three times larger than that of girls (Halpern et al., 2007). In a longitudinal study of primary school children in the US, Entwisle et al. (1994) found that boys spend more time away from home than girls do and are more often left by themselves. Boys are also playing more often with friends in the street or play organised sports, while girls spend more time with relatives, at home. Entwisle et al. (1994) argue that these specific experiences might help boys develop superior math skills.

In sum, psychological factors such as interests, preferences, expectations, and self-confidence levels are likely not only to guide degree choice, but also to generate gender attainment gaps. Out of all agents, families appear to be in the best position to mitigate possible negative effects. Whether consciously or not, families exert influence on boys' and girls' preferences and interests from young ages through selective exposure to certain types of stimuli. Starting from the choice of toys that the children are handed and continuing with didactic material they get in contact with, the places they visit and people they interact with, families control to a large extent the trait complexes that boys and girls are likely to display later on. As the evidence in the current section supports, these trait complexes tend to reflect in the field in which young adults are then likely to pursue a degree. Similarly, high expectations and self-confidence are traits which families can actively instill in their children. Awareness of the fact that female students tend to display lower self-confidence levels and that low confidence negatively impacts performance might encourage families to counter societally-held stereotypes and act towards ameliorating this effect.

5 Cultural factors

Women's low confidence levels have oftentimes been discussed in relation with a socio-cultural context dominated by pervasive gender-science stereotypes. A national indicator of implicit gender-science stereotyping, measured as the likelihood of both men and women associating men with science and women with liberal arts rather than the opposite, has been shown to be correlated with that nation's gender gaps in math and science performance (Nosek et al., 2009). Yet the role that gender-science stereotypes play remains unclear. Whereas Nosek et al. (2009) advocate for a mutually reinforcing relationship between stereotypes and gender differences in science participation and performance, Miller et al. (2015) found that a high level of female enrollment in tertiary science education in a country predicts weaker implicit and explicit gender-science stereotypes at the national level. Their analysis focuses on a sample of 350.000 individuals from 66 countries. It appears that, even when a country has high overall gender equity, if science fields are male-dominated, then that nation is also likely to display strong gender-science stereotypes.

Miller et al. (2015) also note that women's employment in the researcher workforce in a given country could only predict explicit, and not implicit, gender-science stereotypes. This observation, together with the fact that the relationship between high female enrollment in tertiary science education and weak gender-science stereotypes is most robust in the case of college-educated individuals, suggest that it is only through repeated and varied exposure to counterstereotypic women that these pervasive societal-level gender-science stereotypes could be overcome.

Another indicator which is frequently included in analyses of gender attainment gaps in light of cultural factors is the World Economic Forum's Gender Gap Index, measuring a country's gender equality commitments. In a cross-sectional study, Guiso et al. (2008) have found a correlation between a country's score on the Gender Gap Index and the magnitude of the gender gap in mathematics existing in that country. In more gender equal countries, there is no significant difference between the scores that boys and girls obtained in the mathematics section of the Programme for International Student Assessment (PISA).

However, in a more recent publication, Stoet & Geary (2018) found that countries having the highest levels of gender equality (as reported in the same Gender Gap Index), such as Finland, Norway or Sweden, at the same time have some of the largest gaps in secondary and tertiary STEM education. Despite high levels of overall gender equality in these countries, less that 25% of STEM graduates are female. As opposed to Guiso et al. (2008), Stoet & Geary (2018) focus on female and male students' performance in each of the three subjects covered by PISA examinations (science, mathematics and reading), relative to the remaining two. This measurement change allowed for the observation that, even in the cases in which girls perform equally well as boys in the science assessment, they often perform even better in reading. This might in turn lead to girls being encouraged to pursue an academic path reflecting these superior reading skills as an intra-individual academic strength, and not a path acknowledging their nevertheless high mathematics and science skills that would be required for a STEM career.

Stoet & Geary (2018)'s results showed that the percentage of girls having science or mathematics as their best subject (as opposed to reading) is, in all countries in their sample, higher than the percentage of female STEM graduates, and this difference grows larger in more gender equal countries. That is to say, countries having high levels of overall gender equality are more likely than less gender equal countries to lose from the academic STEM track girls which would otherwise be likely to choose this path based on their relative academic strengths.

The reason behind the larger gender differences in STEM graduation and relative science literacy in countries with higher overall gender equality, Stoet & Geary (2018) claim, might lie in popular beliefs about the value of pursuing STEM occupations in more gender equal versus less gender equal countries. More gender equal countries are generally welfare states, offering extensive social security for all citizens. Comparatively, less gender equal countries are at the same time countries where citizens have more difficult living conditions, less security and in general lower levels of life satisfaction. It is thus in these latter countries that STEM occupations would be particularly attractive, to men as well as to women, in light of their relatively higher remuneration packages and resulting economic security. Overall life satisfaction's role as a mediator between gender equality and the gender gap in STEM graduation received moderate statistical support.

National-level indicators reflecting cultural factors appear to have profound implications for the observable gender gap in STEM fields. Most importantly, it should be noted that these predictors can take either subtle forms, such as implicit gender-science stereotypes, influencing behaviour at the subconscious level, or that of hard observations of the fact that girls perform relatively better in reading despite often having similarly high skills in mathematics and science as boys do. Lastly, aspects related to a state's capacity to guarantee the social security of its citizens might have an impact on their decision to pursue a STEM career, having thus the potential to alter gender distributions in these fields.

6 Factors under the influence of universities

The negative stereotype that women have lower math abilities, usually referred to as stereotype threat, has been repeatedly shown to damage women's performance in difficult math tests (Spencer et al., 1999; Schmader et al., 2004; Tomasetto et al., 2011). In an experiment involving highly mathematically skilled subjects, Spencer et al. (1999) have demonstrated that, by describing a difficult math test as not producing gender differences, the difference in performance that is usually found between women and men can be eliminated. Comparatively, describing the test as one which generates gender differences determines women to perform significantly worse than equally qualified men. Since Spencer et al. (1999)'s study, about a hundred more research papers have been published on the topic (Flore & Wicherts, 2015). There is also evidence, albeit scarce, of stereotype threat not having a noteworthy impact on performance. Stricker & Ward (1998) found that reminding examinees of their gender before taking a test, covering algebra, arithmetic, reading comprehension and sentence skills, does not influence their performance.

In a study including interaction effects, Kiefer & Sekaquaptewa (2007) have found that, for women to perform better in math exams, both implicit stereotypes and gender identification need to have low values, but for them to have the desire to pursue a mathematical career just one of the two factors having low values is enough. It seems that a stereotypical threat is more likely to manifest under the stressful conditions of an exam, than when women are consciously deliberating on career choices. An important consequence of this observation would be that increased attention should be paid to women which do want to pursue a career in math but fall short of achieving it because of stereotype-affected examination results.

Gayles & Ampaw (2014) analyse both background characteristics of students and institutional factors such as the campus climate and advance the enhancement of college experience for women as a mean to retain them in STEM fields. They found that the effects of student background (ethnicity, financial situation, high school track record, parents' educational attainment) on degree completion are relatively uniform for both genders, yet the same cannot be said about characteristics of male and female college experiences. Women appear to benefit more than men from faculty interaction outside of the classroom, an observation which is proposed as a possible way of combating the 'chilly climate' (Vogt et al., 2007), characterised by impersonal interactions, which women in STEM, male-dominated fields report to perceive. Women are also more likely to meet with their advisors and attend study groups, yet this behaviour appears to hinder degree completion. It has thus been proposed that high attendance of advising appointments and group study sessions by women might reveal their attempt at establishing a connection with the faculty in order to offset the perceived chilly climate. Lastly, attending college full-time was found to be a necessary condition for degree completion, particularly in the case of women (Gayles & Ampaw, 2014).

As far as teaching is concerned, it has been found, in a study of Israeli advanced placement physics classes, that girls are more attracted to female rather than male teachers, perform better in examinations implying interaction with a teacher, and are deeply distressed by an excessively competitive, fast-paced environment (Zohar & Sela, 2010). Studies have shown the existence of a gender gap in the willingness to compete, with women being more reluctant to compete than men (Niederle & Vesterlund, 2011). Willingness to compete then appears to be correlated with the choice of a math-intensive study field (Buser et al., 2017). In addition, girls in the Israeli study have reported frustration and alienation from a teaching style which emphasises mechanical problem-solving through meaningless manipulation of formulas. Instead, they would prefer a teaching for understanding approach, also referred to as connected knowledge, in which the curriculum would be studied in a more meaningful way (Zohar & Sela, 2010). This observation ties up with the issue of test problem contextualisation, mentioned in a previous section. Experiments involving changes to the context of test questions from male-oriented to female-oriented formulations have been conducted and revealed an impact on test performance, yet the direction of the effect, and thus it's capacity to reduce the gender gap, is still unclear (McCullough, 2004).

Even though the relationship between teachers' behaviour and the campus environment, on the one side, and the gender attainment gap, on the other side, has not yet been understood in all of its particularities, mounting evidence supports the idea that educators should be aware of the potential of their actions to generate performance imbalances. During examinations, special attention should be paid to problem formulation, which can be either female- or male-oriented, and to the extent to which the test design reminds examinees of their gender or discloses information on whether the examination is likely or not to produce gender differences. As far as teaching is concerned, performance of female and male students might be affected by the educator's choice of a cooperative learning environment as opposed to a competitive one, as well as by her prioritisation of a mechanical approach, as opposed to teaching for understanding. Lastly, universities should be aware of the extent to which they create opportunities for full-time attendance and for interaction with peers and faculty members, both inside and outside of the classroom.

Teachers undoubtedly play a key role in improving students' attitude towards and achievements in science through use of specific teaching strategies and materials or through their ability to explain the information. However, the question remains whether their efforts are able to counterbalance the strong, empirically supported effect of parental attitudes and expectations of child's ability (Labudde et al., 2010).

7 Empirical Evidence from IARU Universities

In November 2017, representatives of each IARU member university have been contacted with a request for information on and related to gender attainment gaps in their institution. Inquiries have been made into female and male students' performance, levels of prior knowledge, skills, positioning along psychometric dimensions, into previous university-level studies which revealed gender differences of any kind and into numerical differences between female and male students in each department (for the full questionnaire that has been sent to IARU members, see Appendix).

In the current section, university-level data will be presented in the order of receipt, as follows: ETH Zurich, University of Tokyo, University of Cape Town, University of Copenhagen, University of Oxford. The section includes, lastly, a subsection covering a series of cross-sectional observations.

7.1 University-level data

7.1.1 ETH Zurich

At *ETH Zurich*, women are a minority at all career levels. In 2016, 31% of doctoral students, 15% of senior scientists and 11% of full professors were women. With respect to students, the total number of enrollments has been continuously increasing, from almost 10000 in 2003 to almost 15000 in 2016. However, the proportion of female students has remained constant at roughly 30%. Figures vary greatly across departments, with 63.5% female students reported by the Health Sciences and Technology department, while in the Mechanical and Process Engineering department only 10% of the enrolled students were women (Schubert & Kaczykowski-Patermann, 2017). See Table 1 for detailed departmental data.

As far as attainment gaps are concerned, investigations have revealed that in some of the traditionally male-dominated departments of ETH, that is, mathematics, physics, engineering and computer science, female students obtain lower grades and are more likely to fail the compulsory exam

Table 1: ETH Zurich. Proportion of female students by department in 2016

Department	% of female students
Architecture	42.6
Civil, Environmental and Geomatics Engineering	30.3
Mechanical and Process Engineering	10.2
Information Technology and Electrical Engineering	16.2
Computer Science	12.2
Materials	29.2
Biosystems Science and Engineering	37.7
Mathematics	21.7
Physics	17.1
Chemistry and Applied Biosciences	43.1
Biology	51.9
Earth Sciences	37.5
Environmental Systems Science	54.4
Health Sciences and Technology	63.5
Management, Technology and Economics	27.7
Humanities, Social and Political Sciences	36.3

Source: Schubert & Kaczykowski-Patermann (2017) which ETH students have to sit at the end of the first year of their studies. In addition, the Student Satisfaction Survey carried out in 2015 revealed that women perceive more time pressure and a generally more threatening atmosphere, while men are more likely to indicate feelings of belonging to ETH. 92% of male respondents and 87% of female respondents declared that they experience respectful treatment on campus, without discrimination, while 96% of men and 91% of women agreed with the statement that women are treated with respect at ETH.

Following these initial findings, ETH Zurich is currently conducting the EQUATES project, aimed at further analysing the factors contributing to performance in the first year of study. Special emphasis is laid on psychosocial predictors which might explain the difference in success rates between men and women. Preliminary results indicate that, for the 2016 cohort, depending on the indicator employed, differences in prior knowledge between female and male first year students benefit one or the other group, providing support for the grade-test disparity hypothesis (Halpern et al., 2007). While men performed better in tests of their conceptual knowledge of mathematics and physics, administered during their first week at ETH, and had superior programming knowledge, women had overall higher high school grades, as well as better grades in the mathematics and first language high school courses. The study also confirmed findings from the Student Satisfaction Survey in 2015, in that female students appeared to report, once again, insufficient time for exam preparation and expressed higher belonging uncertainty than their male counterparts. Conversely, there were no significant differences between women and men regarding their levels of study engagement, they reported a similarly low number of alternative and thus potentially distracting plans they had alongside their studies, as well as similarly high levels of general wellbeing at ETH. However, it appears that prior knowledge (measured with conceptual knowledge tests) fully mediates the effect of gender in models predicting whether students perceive time pressure or belonging uncertainty.

As part of the same EQUATES project, first year students were also assessed at the end of their first semester of studies. Significant differences between women and men identified at this stage include higher levels of perceived stress on female students' side, as well as more uncertainty regarding the extent to which their efforts will lead to desirable results and higher perceived threat of unfavourable outcomes such as bad grades. Female students were also more likely to make detrimental attributions, that is attribute their success to luck and their failure to lack of talent. Performance in the exam taken after one year of studies was found to be, as it was the case in previous studies, lower for women than for men. The effect of gender on grades is, once again, fully mediated by prior knowledge, yet gender does explain additional variance beyond prior knowledge when examining perceived stress, outcome expectations, perceived threat and detrimental attributions.

Another study carried out at ETH Zurich focused on students' cognitive abilities' impact on academic performance, particularly performance in mathematics. Focusing on a sample of 317 first-year bachelor's students (273 men and 44 women) from the mathematics, physics and mechanical engineering departments, Berkowitz (2017) investigated students' spatial visualisation abilities, numerical and verbal reasoning, working memory tasks and prior mathematical knowledge. Significant gender differences emerged only on a few of these cognitive measures: medium effects in favour of men were found in the mental rotations and on one numerical reasoning test (signs assessments), while small effects in favour of women emerged in the paper folding test and figural matrices. However, no gender gap in performance in math-intensive courses has been found, while achievement in the mental rotations test appeared to be unrelated to math performance across groups. Nevertheless, the results should be considered in light of the limitations due to sample size, especially the small number of female students, as well as the fact that students in the sample are all situated towards the higher end of the ability scale (Berkowitz, 2017).

Measures for the advancement of women at ETH Zurich date back to 1991 and the establishment of the ETH point of contact for women, renamed the Office of Equal Opportunities for Women and Men in 1993. Starting from 2007, the Office of Equal Opportunities has been affiliated to the ETH President's office. Events such as trial study weeks for female upper secondary school students, meant to introduce prospective female students to traditionally male-dominated fields of study, are being organised annually. The Office of Equal Opportunities has conducted studies of perceived degree to which family and research responsibilities can be reconciled, a study of Swiss upper secondary school graduates' perception of ETH Zurich, as well as an Implicit Association Test (IAT). The latter, carried out over the course of an exhibition on the topic of gender stereotypes organised by Equal! in 2013, revealed a moderate association of 'male' with 'career' and 'female' with 'family' by both female and male ETH participants, the majority of which were students. The results of the gender science association test also emphasised that, on average, both women and men display a moderate implicit association of 'male' with 'natural sciences' and 'female' with 'humanities'. The Office of Equal Opportunities also provides counseling services in case of sexual harassment or discrimination.

The situation of gender equality at ETH Zurich is addressed in the Gender Monitoring report, published yearly. In addition, binding key measures for attaining gender balance in the institution are specified in the Gender Action Plan, covering four main areas of action: career development, gender aspects in research and teaching, work/life balance, and sexual harassment and discrimination. Most recently, in the 2017/18 academic year ETH launched the Respect campaign, aimed at countering behaviour through which one might overstep another one's personal boundaries. ETH thus puts forward discrimination, sexual harassment, bullying, threats and violence as types of behaviour which will not be tolerated on its premises.

7.1.2 University of Tokyo

The *University of Tokyo* reported a total of about 27500 students in 2017. Half of them are undergraduate students, while the other half comprises an

Table 2: University of Tokyo. Proportion of female students by study level and place of origin

	Undergraduate	MA	PhD
Domestic	19%	19%	28%
International	54%	41%	39%

Source: http://www.u-tokyo.ac.jp/en/about/enrollment.html

almost equal number of master and PhD students. The proportion of female students varies greatly according to whether the domestic or international students group is examined. Thus, while women account for just 19% of domestic undergraduate students, they are in the majority in the international undergraduate students segment. Another noteworthy difference between the two groups is that evidence of a ’leaky pipeline’ is only visible in the case of international students, whereas the proportion of women among domestic students increases by almost 10% from the undergraduate to the PhD level (see Table 2).

Table 3 presents faculty-level data on the proportion of female undergraduate students. Regardless of whether humanities or STEM fields are concerned, female students are a minority at the University of Tokyo. They account for 35% of students at the Faculty of Education, and for just 11% of engineering undergraduates.

The situation among MA and PhD students is presented in Table 4. The majority of education graduates and the majority of medicine master students are women, although the latter field is marked by a stark decrease in the proportion of women among PhD candidates. Female graduate students also come close to holding majority of PhD positions in interdisciplinary information studies. At the other extreme, only 4% of MA and PhD students in mathematical sciences are women, and just 5% of those in the field of

Table 3: University of Tokyo. Proportion of female undergraduate students by faculty

Faculty	Proportion of female undergraduate students
Law	24%
Medicine	19%
Engineering	11%
Letters	29%
Science	12%
Agriculture	24%
Economics	17%
Arts and Sciences	34%
Education	35%
Pharmaceutical Sciences	23%

Source: http://www.u-tokyo.ac.jp/en/about/enrollment.html

information science and technology.

Although the gender attainment gap is not per se a topic actively debated at the University of Tokyo, discussions regarding the university's efforts to enhance the diversity of its members, including students, are currently being carried out. For this purpose, the University of Tokyo proactively promotes gender equality and universal access.

7.1.3 University of Cape Town

The total number of students and the percentage of female students enrolled at the *University of Cape Town* are reported in Table 5. Women form the majority of students, yet their proportion varies greatly across faculties. Whereas females represent 70.6% of students in humanities and 65.3% of students in health sciences, only 28.4% of students in engineering and the built environment are women.

Table 4: University of Tokyo. Proportion of female graduate students by faculty

Faculty	Proportion of female MA students	Proportion of female PhD students
Humanities and Sociology	38%	43%
Education	52%	58%
Law and Politics	30%	29%
Economics	41%	16%
Arts and Sciences	37%	44%
Science	18%	16%
Engineering	13%	18%
Agricultural and Life Sciences	35%	38%
Medicine	59%	36%
Pharmaceutical Sciences	21%	22%
Mathematical Sciences	4%	4%
Frontier Sciences	24%	26%
Information Science and Technology	5%	5%
Interdisciplinary Information Studies	34%	49%
Public Policy	-	14%

Source: http://www.u-tokyo.ac.jp/en/about/enrollment.html

As far as performance is concerned, female and male students at the University of Cape Town do not appear to differ significantly. As shown in Table 6, men at the faculty of law have marginally higher grades than women, yet in all of the other faculties there is evidence of a slight female advantage.

The lack of evident gender attainment gaps is particularly impressive in light of the fact that differences between female and male students' levels of prior knowledge are at times larger than ten percentage points (Table 7). In line with findings in the literature, women perform better in language, compared to quantitative reasoning tests. In addition, data from the University of Cape Town provides evidence in support of the grade-test disparity hypoth-

Table 5: University of Cape Town. Number of students and proportion of female students, by faculty

Faculty	Number of students	Proportion of female students
Commerce	7751	44.3%
Graduate School of Business	790	37.7%
Engineering and the Built Environment	4673	28.4%
Health Sciences	4572	65.3%
Humanities	7158	70.6%
Law	1462	62.7%
Science	2826	47.2%
TOTAL	29232	52.5%

Table 6: University of Cape Town. Grade point average at the end of first year studies, by faculty

Faculty	Females	Males
Commerce	63.94%	62.68%
Engineering and the Built Environment	62.21%	60.12%
Health Sciences	68.32%	65.57%
Humanities	58.04%	55.35%
Law	57.6%	58.1%
Science	59.21%	58.97%

Table 7: University of Cape Town. Prior knowledge: average score of national benchmarking tests (NBT) and Grade 12 final results

	Females	Males
NBT Academic Literacy	69.97%	69.78%
NBT Quantitative Literacy	59.55%	68.78%
NBT Math Score	46.52%	59.80%
Math Grade 12 final results	74.31%	79.79%
English Grade 12 final results	78.57%	76.51%
Physical Science Grade 12 final results	74.75%	77.90%

esis (Halpern et al., 2007). In the case of the National Benchmarking Test in mathematics, aimed at measuring readiness for tertiary education, the difference in average score between female and male students is a staggering 13%, whereas examining the math grade 12 final results only reveals a difference of 5.5%. Thus standardised tests and classroom achievement appear to be tapping into different types of knowledge and sets of skills.

The topic of gender attainment gaps is generally embedded in a much broader set of actions regarding equity at the University of Cape Town. Given the local context, measures are necessarily informed also by intersectionality, cultural capital and economic disadvantage.

7.1.4 University of Copenhagen

At the *University of Copenhagen*, women form the majority of students in all but one of the Faculties, that is the Faculty of Science, where there are nevertheless 49% female students. Over all departments, women represent 61% of all students enrolled (see Table 8). In addition, women also appear to have higher grades than men do. The average grade of female students having sat the entry exams in September 2017 was 9.6, whereas male students' average grade was 9.1. Similarly, the average grade for the exams

Table 8: University of Copenhagen. Number of students and proportion of female students, by faculty

Faculty	Number of students	Proportion of female students
Faculty of Humanities	9466	67%
Faculty of Law	4380	62%
Faculty of Science	9485	49%
Faculty of Social Sciences	6740	56%
Faculty of Health	7854	71%
Faculty of Theology	556	59%
TOTAL	38481	61%

conducted between September 2016 and August 2017 was 7.3 for women versus 7.1 for men.

Every three years, the University of Copenhagen conducts an Educational Environment Assessment. It covers issues related to the physical, aesthetic and social study environment and it allows students to actively influence the university's prioritising and action plans. The 2016 Educational Environment Assessment reveals that female students reported significantly more physical stress symptoms than men did. 81% of female students admitted to experience stress either during the semester, in connection with exams, or both, compared to only 60% of males. Conversely, 40% of male students claim not to experience any physical stress symptoms, whereas only 19% of female students report to be in such a situation.

Bullying and harassment from employees or students at the University of Copenhagen does not appear to be a widespread phenomenon. 4% of the female respondents claiming they have experienced bullying or harassment in the past 12 months, compared to 2% of the male respondents.

In terms of satisfaction with the study programme, both women and men have reported high levels of satisfaction, with 84% of the students in each gender group claiming they are happy with their chosen programme. Similarly, 69% of the students in each gender group reported to be part of a good study community among the students in their programme, while 75% of male students and 73% of female students are happy with the range of extracurricular activities provided.

Regarding participation and integration in the study environment, female and male students reported active participation in the study environment in almost equal proportions (46% and 47%, respectively). Women appear to have a slightly harder time getting academic help or input from their colleagues in the study programme. 59% of them agree with the fact that getting help is easy, compared to 65% of men. In addition, 61% of men and 58% of women responded that they can find a study group or study partner when they intend to.

Only 57% of female students perceive that they have the necessary knowledge and tools to plan their studies at the University of Copenhagen, while the proportion rises to 67% in the case of males. This gap exists even though an almost equal percentage of female (49%) and male students (52%) report to have clear information about what it is expected of them academically. It thus appears that the different perceptions regarding the availability of means for study planning might not be caused by factors related to communication of this type of information by faculty members, but rather by student-level variables. Tentative explanations could be a difference in the level of prior knowledge between men and women, or different standards between gender groups when it comes to what planning one's studies actually implies.

Lastly, the 2016 Educational Environment Assessment also touched upon students' interaction with faculty members. 67% of men and 63% of women reported that they find it easy to get a hold of their teachers.

Gender gaps receive extensive attention at the University of Copenhagen, especially in study programmes where the gender gap in enrollment is significant, such as Computer Science.

Table 9: University of Oxford. Number of students and proportion of female students, by division

Division	Number of students	Proportion of female students
Medical Sciences	3334	54%
Social Sciences	6306	49%
Mathematical, Physical and Life Sciences	6632	28%
Humanities	5819	56%
Continuing Education	1343	54%
University of Oxford	541	61%
TOTAL	23975	46%

Source: https://www1.admin.ox.ac.uk/aad/studentregistry/sdma/statistics/student/

7.1.5 University of Oxford

At the *University of Oxford*, the proportion of female students across divisions was 46% in 2017. As noted in Table 9, women are in the majority in the Medical Sciences, Humanities, Continuing Education and University of Oxford divisions. Comparatively, they make up for 49% of the students in the Social Sciences division and for only 28% of the students in Mathematical, Physical and Life Sciences.

Figure 1 is an excerpt from the University of Oxford Gazette Supplement, presenting the number and proportion of students achieving each degree class at the end of their undergraduate studies, by division and sex, in 2017. A significant gender attainment gap is apparent in the Mathematical, Physical and Life Sciences division, where 44% of male students, compared to only 28% of female students, have graduated with a First class degree. Surprisingly, a gender gap is also noticeable in the results of the Humanities division, where 41% of men and only 32% of women have obtained a First class degree. In the Medical Sciences and Social Sciences divisions, on the other hand, the results of male and female student are comparable.

Figure 1: University of Oxford. 2017 undergraduate student outcomes, by division and sex

Division	Sex	1	2.1	2.2	3	Pass/ Unclassified	Fail	Grand total
Humanities	Female	218	451	7				676
		32%	*67%*	*1%*				*100%*
	Male	204	280	14				498
		41%	*56%*	*3%*				*100%*
Total		422	731	21				1,174
Percentage total		36%	62%	2%				100%
Mathematical, Physical and Life Sciences	Female	75	147	40	2	1		265
		28%	*55%*	*15%*	*1%*	*0%*		*100%*
	Male	256	243	58	18	7		582
		44%	*42%*	*10%*	*3%*	*1%*		*100%*
Total		331	390	98	20	8		847
Percentage total		39%	46%	12%	2%	1%		100%
Medical Sciences	Female	61	135	8				204
		30%	*66%*	*4%*				*100%*
	Male	38	83	7				128
		30%	*65%*	*5%*				*100%*
Total		99	218	15				332
Percentage total		30%	66%	5%				100%
Social Sciences	Female	75	219	10	1			305
		25%	*72%*	*3%*	*0%*			*100%*
	Male	100	253	17	1		1	372
		27%	*68%*	*5%*	*0%*		*0%*	*100%*
Total		175	472	27	2		1	677
Percentage total		26%	70%	4%	0%		0%	100%
Grand total		1,027	1,811	161	22	8	1	3,030
Percentage grand total		34%	60%	5%	1%	0%	0%	100%

Note: 1 = First Class Degree; 2.1 = Upper Second Class Degree; 2.2 = Lower Second Class Degree; 3 = Third Class Degree.

Source: University of Oxford (2018)

At the same time, University representatives confirm a significant reduction of the gender attainment gaps in certain subject areas such as Biological Sciences, Engineering, Geography, Law, and Modern Languages. Within the Chemistry course, outcomes have also been analysed in relation with students' level of prior knowledge. It appears that A* grades, the highest achievement in A-level examinations, do correlate with undergraduate performance, yet there is no gender difference in the number of A* results.

The gender attainment gap is a topic which receives substantial attention at the University of Oxford. Activity in this area has been coordinated between 2007-2011 by the Gender Panel, followed by the Student Attainment Gap Working Group from 2015 onwards. The latter body's role is precisely to identify possible causes of the difference between the proportions of women and men attaining a First class degree. Attainment by gender, ethnicity and disability is reviewed on a yearly basis at institutional, departmental and divisional levels.

The University of Oxford has conducted extensive investigations into the causes of gender attainment gaps. Despite not being able to conclusively identify one or more such causes, their research made possible the rejection of a series of hypotheses. The gender attainment gap at Finals could not be explained by:

- Differential intelligence;
- Lowered efficiency of female selection at admissions;
- Disadvantage for state school students relative to those attending independent schools;
- Women's lower self-efficacy and confidence;
- Women's higher levels of anxiety and depression;
- Differences in physical strength;
- Pre-menstrual syndrome.

In addition, research at the University of Oxford also resulted in the identification of a series of hypotheses which could not be proven, either because they have not been sufficiently tested, or because it is still not clear how the causal mechanism, linking the predictor with women's lower performance levels, works in practice. Plausible, yet unproven predictors are:

- Stereotype threat;
- Assessment environment;
- Differential approach to learning;
- Teaching styles;
- Differential understanding of assessment criteria;
- Differential approach to examinations;
- Different responses to 'sudden death' examinations;
- Examination anxiety;
- The possibility of examiner bias;
- Declining female academic self-concept;
- Perfectionism;
- Psychosocial factors.

The Student Attainment Gap Working Group has also conducted a university-wide longitudinal analysis of the first year students' academic self-concept, a predictor of academic performance defined as the belief in one's own ability to succeed in a specific subject area. It has been found that women have a significantly lower academic self-concept than men and that this level is mainly predicted by sex, performance in A-levels and competitiveness, with school performance being a statistically significant predictor in just one of the two survey waves. Socioeconomic status, on the other hand, did not appear to have a significant impact on students' beliefs in their ability to succeed academically. In addition, the academic self-concept levels remained constant for both men and women throughout the first year.

Taking the analysis one step further and inquiring into factors influencing performance, the study found that academic self-concept and competitiveness, measured half way through the first year of studies, and A-level grades predict achievement during the first public examination, taken at the end of the first year. Sex itself was not found to be a significant predictor, thus indicating academic self-concept's mediating role in the association between gender and attainment. Since the lower academic self-concept is a trait which female students possess before arriving on campus, the question of how to raise their perceived academic competence remains an open one at the University of Oxford.

Given the nature of this investigation, the academic self-concept survey also revealed a series of significant differences between women and men with regard to competitiveness, aspirations and responses to personal problems and to workload. It has been found that men are more competitive than women, reporting higher motivation levels when in competition with other people. Female students, on the other hand, were more likely to report aspiring to get an experience that would help their career plans, to participate in non-academic activities and to make a contribution to public life. As far as response to personal problems is concerned, women claimed to throw themselves into work and to keep talking the problem over with other people to a larger extent than men did. Lastly, female and male students' response to workload was found to be significantly different, with women reporting being assigned an excessively heavy workload in a larger proportion than men did. Questions related to one's disposition to understand, tapping into levels of effort and independent attempts at sense-making, finding examples and reaching own conclusions, did not reveal any significant gender differences.

7.2 Comparative observations

Drawing cross-sectional conclusions from the university-level data above is a challenging undertaking for two main reasons. First, the quantitative data is hardly comparable and thus impossible to analyse using conventional statistical instruments beyond those having a descriptive function. This lack of comparability derives from the fact that each university has its original institutional structure. Aside from being a differentiation factor in itself, this specific structure will dictate the levels at which the data is aggregated. In addition, each university has developed its own methodology for assessing variables related to gender attainment gaps. So long as no one single instrument has been used for data collection, one cannot conduct a comparative analysis in the traditional sense.

Secondly, our report includes at this point five IARU member universities from three different continents. Even if the quantitative data itself would be comparable, it is unlikely that a statistical analysis performed on such a small sample of institutions which differ greatly with regard to the social, political and economic conditions in which they function would produce meaningful conclusions on which recommendations could be based.

We thus resort to reporting on descriptive statistics, where relatively comparable data from all of the universities in our sample exists, and to formulating several comparative observations in those cases where two or more institutions have collected data in relation with the same phenomenon.

Universities in the sample vary greatly with regard to their percentage of female students (Figure 2), from 23% at the University of Tokyo, up to 61% at the University of Copenhagen. Yet these institutions also vary greatly in their focus on STEM versus non-STEM fields. For a better understanding of the situation of female students particularly in technical fields, in Figure 3 each of the universities in the sample is positioned according to both its percentage of female students and STEM focus, measured as the share of STEM students out of the total number of students.

The Oxford, Cape Town and Copenhagen Universities have a larger per-

Figure 2: Percentage of female students, by university

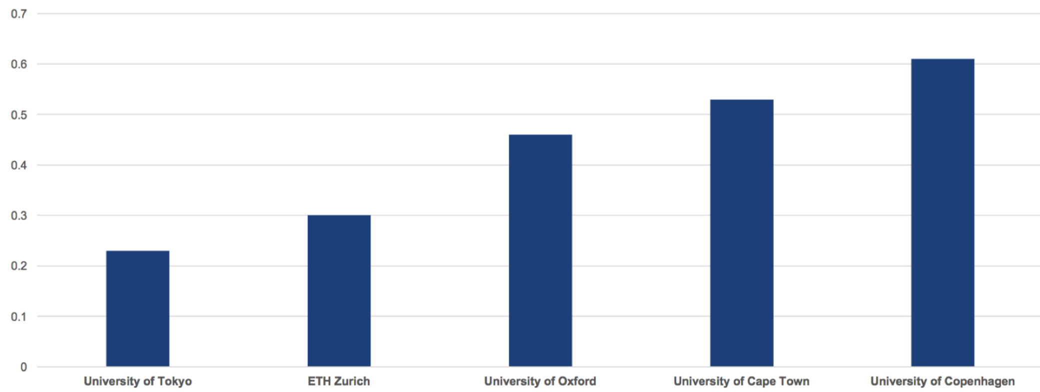
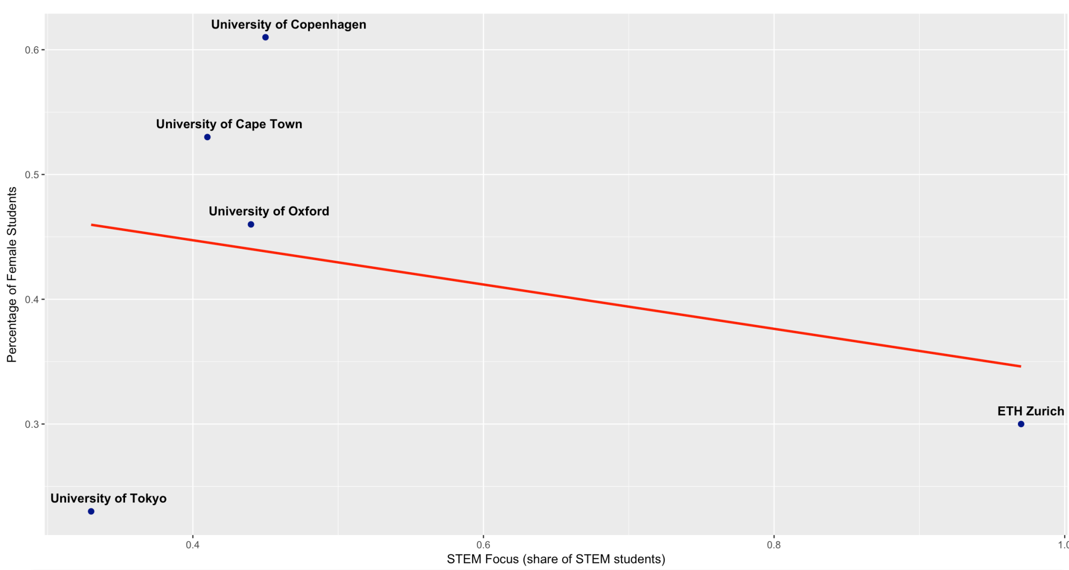


Figure 3: Percentage of female students and share of STEM students, by university



Note: health sciences students have also been included in the STEM category.

centage of female students enrolled than their focus on STEM fields would predict. Although more than 40% of their students are pursuing a STEM degree, overall the percentage of female students enrolled at these universities is higher than 45%. Comparatively, ETH Zurich falls right under the predicted percentage of female students, yet it is also the university with the by far strongest emphasis on STEM subjects. The University of Tokyo appears here as a relative outlier, with low values in both share of female students and STEM focus.

Gender attainment gaps are manifest at ETH Zurich, yet fully mediated by differences in prior knowledge. The opposite scenario can be observed at the University of Cape Town, where, despite differences in the level of prior knowledge between female and male students, there is no evidence of gender attainment gaps. It should be noted, however, that in both cases the differences in prior knowledge appear when measured at the level of standardised tests, while in the case of both universities there is evidence of a grade-test disparity. At the University of Copenhagen women outperform men in both entry exams and course exams. Lastly, at the University of Oxford there is evidence of gender attainment gaps in, surprisingly, both the Humanities and the Mathematical, Physical and Life Sciences divisions.

Psychometric variables have been systematically analysed in three of the universities in the sample: ETH Zurich, University of Copenhagen and University of Oxford. Female students at ETH report higher levels of perceived stress than men do and are more uncertain about whether their efforts will lead to success. They also show a higher perceived threat of unfavourable outcomes, such as bad grades, and are more likely than men to make detrimental attributions: attribute their success to luck and their failure to lack of talent.

At the University of Copenhagen, female students also report higher levels of perceived stress than men do, have a slightly harder time than men in getting academic help from their colleagues, and are report having the necessary tools to plan their studies to a lesser extent than their male counterparts. Investigations of psychosocial variables at the University of Oxford have shown that female students have a significantly lower level of academic self-concept, meaning their belief in their own ability to succeed, and that academic self-concept is a significant performance predictor. Female students are also less competitive than males and are more likely than men to tackle personal problems by throwing themselves into work or by talking the problem over with other people. Female students at the University of Oxford are more likely to report having been assigned an excessively heavy workload, while no gender difference has been found in students' perception of the amount of effort they have invested in their studies.

8 Conclusion and recommendations

This report brings together findings in the relevant literature and empirical evidence from IARU universities, in an attempt to identify the main factors leading to the emergence of gender attainment gaps, and to grasp the magnitude of the phenomenon. We found that the causes of gender gaps in performance lie at the intersection between sex specific, psychological and cultural factors, yet also that universities nevertheless have the power to alleviate them to a certain extent. It is for this reason that we will now turn to suggesting a series of measures which could lead to a gradual closing of gender attainment gaps, structured in four main areas of intervention.

Accepting different problem-solving approaches

Following the observation that the level of visuospatial abilities is one of the main factors leading to differences in mathematical performance between women and men, Halpern et al. (2007) propose intervening in the problem-solving strategies that are being taught. Students should be taught both verbal and visuospatial solution strategies and be allowed to employ either one of them, thus creating a more flexible problem-solving process in which both women and men can make use of their best abilities.

Leveling up students' skills

In addition to creating opportunities for women and men to employ their preferred approach to problem-solving, it has been shown that visuospatial abilities can also be trained. After meta-analysing 217 studies of the effects of training on spatial skills development, Uttal et al. (2013) have concluded that training indeed generates long-lasting improvements to individual spatial abilities and that these abilities also transfer to other spatial tasks which have not been specifically practiced. Both women's and men's spatial skills appear to improve equally well with training. A direct test of the visuospatial abilities improvement through training has been performed by Sorby & Baartmans (2000). They developed a real-life course meant to enhance the skills of first year engineering students who, after testing, have been found to be weak in 3-D spatial visualisation. The course significantly improved attendees' visuospatial skills and the results held for all of the six consecutive cohorts investigated. In addition, not only have the students taking the course improved their performance on the test which had served as criterion for their admission, but they also obtained higher grades in subsequent engineering graphics courses. The visualisation course also seems to have had a positive impact on women's retention rate.

Following the case of visuospatial skills, we would recommend, based on the empirical findings in this report, a thorough evaluation of incoming students' prior knowledge, followed by swift action aimed at leveling skills up, before attainment gaps start manifesting.

Promoting interaction and understanding

In light of their findings about the role of women's academic and social experiences during the college years on degree completion, Gayles & Ampaw (2014) recommend universities to lay great emphasis on interaction with the faculty outside of the classroom and facilitate full-time attendance. Inside of the classroom, teachers might consider slowing down the pace in order to promote students' understanding of the topic, a teaching strategy which is generally considered to be beneficial to both women and men. In addition, a mixed strategy, integrating both competitive and collaborative work, would ensure equal opportunities for all students (Zohar & Sela, 2010).

Employing interactive engagement courses, as opposed to the traditional lecture format, would also improve female students' performance while not affecting that of males. Lorenzo et al. (2006) argue that the reduction and even elimination of the gender attainment gap could be achieved through the introduction of peer instruction, tutorials, and cooperative problem-solving activities. These instructional methods differ from traditional ones in that they foster a less competitive interaction between students and create opportunities for them to explain their ideas, in an alternation of structured teaching and group discussions. This allows women to employ their preferred verbal articulation of ideas and men to benefit from the structured learning experience which has been shown to improve their performance.

Considering the context and creating accountability

Lastly, we would advise IARU member universities to each delegate an institutional body responsible for identifying those gender gap determinants specific to the socio-cultural environment in which the institution is functioning and even specific to the university itself. Given the context-dependent nature of any measure aimed at closing gender attainment gaps, the establishment of such a body becomes a necessary condition for efficient policy design and implementation.

Appendix

Questionnaire for Member Institutions of the International Alliance of Research Universities

1. What is the average performance of students at your university, by gender?

> Do you observe gender attainment gaps, and, if so, what do you believe could be causing them?
>
> By performance we mean grades obtained at the level of entry exams, course assessments, or standardized tests.

2. Are there differences between female and male students' levels of prior knowledge (for instance in mathematics or languages)?

> What is the magnitude of these differences, in each of these domains, and what is the differences' direction?

3. Do female and male students interact differently with faculty members?

> We would be interested in either quantitative or anecdotal evidence regarding frequency of question asking during class, frequency of faculty contact, talking with faculty outside class, requesting or attending advisory meetings, attending study groups outside class, etc.

4. Do female and male students differ with respect to their self-confidence, positive expectations levels, willingness to compete, or other psychometric dimensions?

> What is the magnitude of these differences, on each dimension, and what is their direction?

5. Are there differences between female and male students' skill levels (verbal, visuospatial, etc.)?

> What are the magnitude and direction of these differences, for each type of skill?

6. Has an implicit association test ever been conducted at your university?

> If yes, did it lead to university-wide discussions about gender stereotypes or to the (re-)formulation of gender policies at your university?

7. Have the students at your institution ever been subject to in-class experiments in which the treatment has been found to differentially influence women's and men's behaviour?

> Such experiments might include, but are not restricted to, changes in problem formulation or use of personal response devices (clickers) during lectures.
> Please describe some examples of such experiments, their results, as well as some after-experiment reactions or changes.

8. Is gender attainment gap a topic discussed at your university?

> If yes, which next steps are planned?
> If no, why do you think the topic is not on the agenda?

9. What is the number of students at your university (total and by department)?

10. What is the percentage of female students at your university (across departments and by department)?

References

Ackerman, P. L., Bowen, K. R., Beier, M. E., & Kanfer, R. (2001). Determinants of Individual Differences and Gender Differences in Knowledge. *Journal of Educational Psychology*, *93*(4), 797–825.

Benbow, C. P., & Stanley, J. C. (1980). Sex Differences in Mathematical Ability: Fact or Artifact? *Science*, *210*(4475), 1262–1264.

Berkowitz, M. (2017). *In the minds of STEM beginners: On cognitive abilities, working memory, and first year mathematics*. Doctoral thesis.

Bridgeman, B., & Lewis, C. (1996). Gender Differences in College Mathematics Grades and SAT-M Scores: A Reanalysis of Wainer and Steinberg. *Journal of Educational Measurement*, *33*(3), 257–270.

Buser, T., Peter, N., & Wolter, S. C. (2017). Gender, Competitiveness, and Study Choices in High School: Evidence from Switzerland. *American Economic Review: Papers and Proceedings*, *107*(5), 125–130.

Chipman, S. F. (2005). Research on the Women in Mathematics Issue. A Personal Case History. In A. M. Gallagher, & J. C. Kaufman (Eds.) *Gender Differences in Mathematics. An Integrative Psychological Approach*, (pp. 1–24). Cambridge: Cambridge University Press.

Entwisle, D. R., Alexander, K. L., & Olson, L. S. (1994). The Gender Gap in Math: Its Possible Origins in Neighborhood Effects. *American Sociological Review*, *59*(6), 822–838.

Flore, P. C., & Wicherts, J. M. (2015). Does stereotype threat influence performance of girls in stereotype domains? A meta-analysis. *Journal of School Psychology*, *53*(1), 25–44.

Gayles, J. G., & Ampaw, F. (2014). The Impact of College Experiences on Degree Completion in STEM Fields at Four-Year Institutions: Does Gender Matter? *The Journal of Higher Education*, *85*(4), 439–468.

Grunspan, D. Z., Eddy, S. L., Brownell, S. E., Wiggins, B. L., Crowe, A. J., & Goodreau, S. M. (2016). Males Under-Estimate Academic Performance of Their Female Peers in Undergraduate Biology Classrooms. *PLoS ONE*, *11*(2), 1–16.

Guiso, L., Monte, F., Sapienza, P., & Zingales, L. (2008). Culture, Gender, and Math. *Science*, *320*(5880), 1164–1165.

Halpern, D. F. (1997). Sex differences in intelligence: Implications for education. *American Psychologist*, *52*(10), 1091–1102.

Halpern, D. F., Benbow, C. P., Geary, D. C., Gur, R. C., Hyde, J. S., & Grensbacher, M. A. (2007). The Science of Sex Differences in Science and Mathematics. *Psychological Science in the Public Interest*, *8*(1), 1–51.

Halpern, D. F., & LaMay, M. L. (2000). The Smarter Sex: A Critical Review of Sex Differences in Intelligence. *Educational Psychology Review*, *12*(2), 229–246.

Halpern, D. F., Wai, J., & Saw, A. (2005). A Psychobiosocial Model. Why Females Are Sometimes Greater Than and Sometimes Less Than Males in Math Achievement. In A. M. Gallagher, & J. C. Kaufman (Eds.) *Gender Differences in Mathematics. An Integrative Psychological Approach*, (pp. 48–72). Cambridge: Cambridge University Press.

Hedges, L. V., & Nowell, A. (1995). Sex Differences in Mental Test Scores, Variability, and Numbers of High-Scoring Individuals. *Science*, *269*(5220), 41–45.

Huang, G., Taddese, N., & Walter, E. (2000). *Entry and persistence of women and minorities in college science and engineering education. NCES 2000-601*. Washington, DC: National Center for Educational Statistics.

Hyde, J. S., Lindberg, S. M., Linn, M. C., Ellis, A. B., & Williams, C. C. (2008). Gender Similarities Characterize Math Performance. *Science*, *321*(5888), 494–495.

Hyde, J. S., & Linn, M. C. (2006). Gender Similarities in Mathematics and Science. *Science*, *314*(5799), 599–600.

Kiefer, A. K., & Sekaquaptewa, D. (2007). Implicit Stereotypes, Gender Identification, and Math-Related Outcomes. *Psychological Science*, *18*(1), 13–18.

Kling, K. C., Noftle, E. E., & Robins, R. W. (2013). Why do standardized tests underpredict women's academic performance? The role of conscientiousness. *Social Psychological and Personality Science*, *4*(5), 600–606.

Labudde, P., Herzog, W., Neuenschwander, M. P., Violi, E., & Gerber, C. (2010). Girls and physics: teaching and learning strategies tested by classroom interventions in grade 11. *International Journal of Science Education*, *22*(2), 143–157.

Lorenzo, M., Crouch, C. H., & Mazur, E. (2006). Reducing the gender gap in the physics classroom. *American Journal of Physics*, *74*(2), 118–122.

Lubinski, D., & Benbow, C. P. (2006). Study of Mathematically Precocious Youth After 35 Years: Uncovering the Antecedents of the Development of Math-Science Expertise. *Perspectives on Psychological Science*, *1*(4), 316–345.

McCullough, L. (2004). Gender, Context, and Physics Assessment. *Journal of International Women's Studies*, *5*(4), 20–30.

Miller, D. I., Eagly, A. H., & Linn, M. C. (2015). Women's Representation in Science Predicts National Gender-Science Stereotypes: Evidence from 66 Nations. *Journal of Educational Psychology*, *107*(3), 631–644.

Niederle, M., & Vesterlund, L. (2011). Gender and Competition. *American Review of Economics*, *3*, 601–630.

Nosek, B. A., Smyth, F. L., Sriram, N., Lindner, N. M., Devos, T., Ayala, A., & Bar-Anan, Y. e. a. (2009). National differences in gender-science stereotypes predict national sex differences in science and math achievement. *Proceedings of the National Academy of Sciences*, *106*(26), 10593–10597.

Proudfoot, D., Kay, A. C., & Koval, C. Z. (2015). A Gender Bias in the Attribution of Creativity: Archival and Experimental Evidence for the Perceived Association Between Masculinity and Creative Thinking. *Psychological Science*, *26*(11), 1751–1761.

Schmader, T., Johns, M., & Barquissau, M. (2004). The Costs of Accepting Gender Differences: The Role of Stereotype Endorsement in Women's Experience in the Math Domain. *Sex Roles*, *50*(11), 835–850.

Schubert, R., & Kaczykowski-Patermann, H. (2017). Gender Monitoring 2016/17. *ETH Zurich. Equal! Office of Equal Opportunities for Women and Men*.

Seymour, E. (1995). The Loss of Women from Science, Mathematics, and Engineering Undergraduate Majors: An Explanatory Account. *Science Education*, *79*(4), 437–473.

Sonnert, G., & Fox, M. F. (2012). Women, Men, and Academic Performance in Science and Engineering: The Gender Difference in Undergraduate Grade Point Averages. *The Journal of Higher Education*, *83*(1), 73–101.

Sorby, S. A., & Baartmans, B. J. (2000). The Development and Assessment of a Course for Enhancing the 3-D Spatial Visualization Skills of First Year Engineering Students. *Journal of Engineering Education*, *89*(3), 301–307.

Spelke, E. S. (2005). Sex Differences in Intrinsic Aptitude for Mathematics and Science? A Critical Review. *Americal Psychologist*, *60*(9), 950–958.

Spencer, S. J., Steele, C. M., & Quinn, D. M. (1999). Stereotype Threat and Women's Math Performance. *Journal of Experimental Social Psychology*, *35*(1), 4–28.

Stoet, G., & Geary, D. C. (2018). The Gender-Equality Paradox in Science, Technology, Engineering, and Mathematics Education. *Psychological Science*.

Stricker, L. J., & Ward, W. C. (1998). Inquiring about Examinees' Ethnicity and Sex: Effects on Computerized Placement Tests Performance. Report No. 98-2. ETS RR No. 98-9. *College Entrance Examination Board, New York*.

Tomasetto, C., Alparone, F. R., & Cadinu, M. (2011). Girls' Math Performance under Stereotype Threat: The Moderating Role of Mothers' Gender Stereotypes. *Developmental Psychology*, *47*(4), 943–949.

University of Oxford (2017). Enrollment data.
URL https://www1.admin.ox.ac.uk/aad/studentregistry/sdma/statistics/student/

University of Oxford (2018). Final Honours Schools, Bachelor of Fine Art and Bachelor of Theology, 2017. *University of Oxford Gazette*, *Supplement (1) to No 5192, Vol 148*, 235–245.

University of Tokyo (2017). Enrollment data. Last accessed: November 23rd, 2017.
URL http://www.u-tokyo.ac.jp/en/about/enrollment.html

Uttal, D. H., Meadow, N. G., Tipton, E., Hand, L. L., Alden, A. R., Warren, C., & Newcombe, N. S. (2013). The Malleability of Spatial Skills: A Meta-Analysis of Training Studies. *Psychological Bulletin*, *139*(2), 352–402.

Vermeer, H. J., Boekaerts, M., & Seegers, G. (2000). Motivational and Gender Differences: Sixth-Grade Students' Mathematical Problem-Solving Behavior. *Journal of Educational Psychology*, *92*(2), 308–315.

Vogt, C. M., Hocevar, D., & Hagedorn, L. S. (2007). A Social Cognitive Construct Validation: Determining Women's and Men's Success in Engineering Programs. *Journal of Higher Education*, *78*(3), 337–364.

Zohar, A., & Sela, D. (2010). Her physics, his physics: Gender issues in Israeli advanced placement physics classes. *International Journal of Science Education*, *25*(2), 245–268.