Written Evidence Submitted by UCL Centre for Education Policy & Equalising Opportunities (CEPEO)

(DIV0112)

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Gender differences in uptake of STEM subjects: the facts

1. At Key Stage 4 (GCSEs and equivalents, taken at age 16), gender gaps have reduced substantially over the last decade: in 2010, girls were 15-20% less likely to take GCSEs in biology, chemistry and physics (triple science) than boys; in 2019, they were only about 2-3% less likely.[1]

2. At Key Stage 5 (A-levels and equivalents, taken at age 18), girls are around 20% more likely than boys to take A-levels at all, and are also more likely to take some STEM subjects. For example, girls were already nearly 30% more likely to take A-level biology than boys in 2010, and have extended their advantage since then, to 70% more likely in 2019. Girls are also now 16% more likely to take chemistry than boys. (They were less likely to take chemistry than boys in 2010). However, girls remain substantially less likely to take maths (35% less likely), further maths (65%), physics (70%) and computer science (85%) than boys. These differences have remained largely unchanged since 2010.[2]

3. It is worth noting that despite these large gender differences in uptake, maths is the third most popular A-level subject amongst girls (behind psychology and biology) and more girls take physics than boys take English literature, for example. It may therefore also be worth considering the question from the perspective of boys as well: why do so many of them take maths and physics – they are the two most popular subjects – in preference to other subjects?

Why are there differences in uptake of STEM subjects by gender?

Context

4. Young people's subject choices are heavily shaped by their context. For example, our own previous work has highlighted that a substantial proportion of the variation in young people's subject choices can be explained by the school in which they find themselves, for example its composition in terms of prior attainment,[3] and other research has shown that these choices can also be affected by early exposure to biases and stereotypes.[4] This evidence undermines any sense that an individual's subject choices are pre-ordained by their gender or other characteristics. In particular, there is a complete lack of basis for sex-based biological differences[5] that would explain differences in preferences or aptitude.

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[1] Authors' calculations using the subject time series tables available at: https://www.gov.uk/government/statistics/key-stage-4-performance-2019-revised.

[2] Authors' calculations based on the data tables from: https://www.gov.uk/government/statistics/provisional-entries-for-gcse-as-and-a-level-summer-2019-exam-series.

[3] Anders, J., Henderson, M., Moulton, V. & Sullivan, A. (2018), The role of schools in explaining individuals' subject choices at age 14, *Oxford Review of Education*, 44:1, 75-93, DOI: 10.1080/03054985.2018.1409973.

[4] Chang, A., Sandhofer, C. M., & Brown, C. S. (2011), Gender Biases in Early Number Exposure to Preschool-Aged Children, *Journal of Language and Social Psychology*, 30:4, 440–450, DOI: 10.1177/0261927X11416207.

[5] Rippon, G. (2021), A window of opportunity: a neuroscience perspective on the gender stereotyping of science in the early years, *Journal of Emergent Science*, 20, 11-18.

Single sex schools

5. One context that has received particular attention in the debate around what drives gender differences in STEM subject uptake is a schools' gender composition – in particular whether girls in single sex schools are more likely to take maths and physics than girls in mixed sex schools.

6. There is little evidence of school level differences in uptake of STEM subjects at Key Stage 4.[6] Our own analysis of the 2018-19 school-level A-level exam entries and results suggests that girls in single sex schools are substantially more likely to take STEM A-levels than girls in mixed sex schools – especially in maths, further maths, physics and chemistry.[7] This is not driven by greater availability of these subjects, as all girls schools/colleges are only slightly more likely to offer most STEM A-levels than mixed sex schools. (They are less likely to offer computing.)

7. International evidence suggests that the majority, if not all, of these differences can be explained by the types of girls that attend single sex schools compared to those that attend mixed sex schools: in other words, the differences are largely driven by the fact that girls who attend single sex schools possess characteristics or traits that make them more likely to opt to study a STEM subject, regardless of school context, rather than by any effect of attending a single sex school on subject choice. In studies in which school choice is essentially random – either because students are randomly allocated to schools (as in one study in Korea[8]) or because there are other reasons why school choice can be argued to be close to random (as in a study in Ireland[9]) – girls in single sex schools are no more likely to study STEM subjects than those in mixed schools.

Students' enjoyment of the subject

8. Students' enjoyment of a subject has been identified as a key driver of whether they continue studying it. As part of a research project we undertook on why girls were less likely to study maths and physics, we surveyed girls predicted to do well in GCSE maths or physics early in Year 11. While we only surveyed girls – and hence do not have equivalent figures for boys as a comparator – a majority reported enjoying each subject, as well as finding them interesting, suggesting that this may not be the primary reason for the gender differences we see.

9. However, in the case of both maths and physics, they pointed to there being a content-heavy curriculum which meant teachers had to focus on exam content in a fairly dry and repetitive manner and weren't able to go into detail on topics of interest to the students. Most girls also perceived the quality of physics teaching in particular to be low – perhaps because the majority of students are taught physics by a non-specialist (because of a shortage of physics teachers). This suggests that finding ways to make these more maths-based curricula more engaging, or improving the knowledge or pedagogical styles of teachers teaching these subjects may be helpful (although these could also be just as helpful, or even more helpful, for boys).

Beliefs students have about their ability

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[6] Henderson, M., Sullivan, A., Anders, J. & Moulton, V. (2018), Social Class, Gender and Ethnic Differences in Subjects Taken at Age 14, *The Curriculum Journal*, 29:3, 298-318.
[7] Authors' calculations based on the maths and science tables available from: https://www.gov.uk/government/statistics/a-level-and-other-16-to-18-results-2018-to-2019-revised.
[8] Park, H., J. Behrman and J. Choic (2018), Do single-sex schools enhance students' STEM (science, technology, engineering, and mathematics) outcomes?, *Economics of Education Review*, 62, 35–47.
[9] Doris, A., O'Neill, D. and O. Sweetman (2013), Gender, single-sex schooling and maths achievement, *Economics of Education Review*, 35, 104–119.

10. There is evidence that being highly ranked in STEM subjects in primary school has large positive impacts on taking STEM A-levels, even after taking achievement into account.[10] This suggests that individuals' beliefs about their own ability – their perception of their performance relative to peers – is important in what they choose to study, over and above their actual ability.

11. A number of studies have pointed towards differing beliefs about their ability, holding performance constant, as one potential reason for gender differences in the likelihood of taking STEM subjects. In other words, women are less likely to take STEM subjects because they are less confident in their ability than men with similar prior attainment. These gender differences in perceived ability seem to be particularly large in skills or domains seen as male-dominated.[11] Interventions that raise girls' confidence in maths-based subjects could therefore help.

12. Providing feedback on their performance – and their performance relative to their peers – may be one way in which this could be achieved. Recent research shows that providing students with information about their performance relative to their classmates, and in particular to those students taking STEM courses, shrinks the gender gap in who takes STEM subjects – but by reducing the likelihood of low-performing men taking STEM subjects, rather than increasing the proportion of women taking them. This suggests that the gender gap in STEM enrolments is not driven by underconfident women, but rather by overconfident, low-performing men.

Gender stereotypes

13. Existing evidence also points to an important role for gender stereotypes in explaining gender differences in STEM uptake and performance. For example, recent research[12] shows that gender stereotypes – in particular that boys are better at maths than girls – spread across generations through pupils' peers and have a self-reinforcing effect on pupils' actual maths ability. It highlights that a child who is randomly assigned to a class with a higher proportion of peers whose parents believe that boys are better at maths is more likely to adopt the belief themselves. This in turn affects their performance in maths, helping boys and harming girls. There is also complementary evidence that gender differences in maths performance are lower in countries with weaker gender stereotypes.[13]

Peer effects

14. As part of the research project referenced in paragraph 8 above, we asked girls about their motivations for choosing or not choosing to study certain subjects, including physics and maths. One of the things identified as important to the girls was whether the A-level or university class, or the future occupation, was male-dominated, with some girls expressing reticence about taking subjects because of concerns about being in a minority in those environments (or about boys' behaviour in the classroom).

15. This is also borne out by recent evidence focused on economics students (which has a high mathematical content and is also heavily male dominated). In this study, first year economics

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[10] Murphy, R., & Weinhardt, F. (2020), Top of the class: The importance of ordinal rank, *The Review of Economic Studies*, 87:6, 2777-2826.
[11] Bordalo, P., K. Coffman, N. Gennaioli and A. Shleifer (2019), Beliefs about Gender, *American Economic Review*, 109:3, 739–773.
[12] Eble, A., & Hu, F. (2022), Gendered beliefs about mathematics ability transmit across generations through children's peers, *Nature Human Behaviour*, 1-12.
[13] Guiso, L., F. Monte, P. Sapienza & L. Zingales (2008), Culture, Gender and Math, *Science*, 320:5880, 1164–5.

students were randomly assigned to study groups with different gender ratios. Women in minority female groups were almost 10 percentage points more likely to drop out than those in gender balanced groups, with the differences potentially driven by more pessimistic educational expectations and greater risk of social exclusion amongst females in minority groups. The study concludes that introducing gender-balanced study groups could be a simple way to significantly lower the number of women dropping out of the economics pipeline. Similar reasoning could also be applied as a way of trying to reduce the drop-out of women from the STEM pipeline.

Future Careers

16. There is evidence that a lack of female role models working in STEM careers hampers girls' ability to see themselves working in STEM occupations in future. Research suggests that even very low-cost interventions, such as being contacted once, electronically, by a female role model, can improve STEM performance and reduce drop-out amongst women.[14] This suggests that having more women working in STEM occupations – and providing opportunities for female students to interact with these potential role models – may increase the pipeline of talent.

17. There is also some suggestion that increasing girls' knowledge of the careers for which maths and physics could be good preparation, and emphasising the other types of skills that are needed to be successful in STEM careers could be helpful in encouraging more girls to participate. For example, our contribution to the work of the Department for Education's Skills and Productivity Board suggests that many transferable skills – such as critical thinking and problem solving – are just as important in STEM occupations as they are across jobs in the economy as a whole, and studying STEM subjects could provide excellent preparation for these.

18. Thus while we do clearly want greater diversity in STEM occupations as well as in education, there may also be benefits to increasing the number of individuals, including girls, with STEM skills, even if they are applied in other occupations in the economy in future. In other words, while we ideally want to tackle all stages of the 'leaky pipeline' of diverse talent into the STEM workforce, there will clearly also be benefits to reducing gender gaps in STEM education alone.

Possible solutions

19. The evidence in this note shows that subject choices are responsive to a range of interventions, suggesting that gender differences are not driven by preferences, but rather by 'social norms' that females adopt, often to the detriment of their future earnings. The following types of policy interventions could thus be considered to help reduce gender gaps in STEM education uptake:

    - Recruit, train and retain more good maths and physics teachers to increase students' enjoyment and knowledge. (Our own evidence shows that financial incentives could be an effective way to attract and retain staff in shortage subjects, including in disadvantaged schools or areas, but does not link this to student outcomes.)
    - Offer enhanced training in physics for science teachers with a specialty in biology or chemistry to increase confidence amongst teachers in the teaching of physics.
    - Consider ways to reduce the content in the curriculum or focus on ways to make it more engaging and related to students' lives.

[14] S. Herrman, R. Adelman, J. Bodford, O. Graudejus, M. Okun and V. Kwan (2016), The Effects of a Female Role Model on Academic Performance and Persistence of Women in STEM Courses, *Basic and Applied Social Psychology*, 38:5, 258–268, DOI: 10.1080/01973533.2016.1209757.

- Try to boost girls' confidence (relative to boys) in their abilities in maths-based subjects.
- Ensure that teachers do not perpetuate gender-based stereotypes, and that parents, especially mothers, are aware of and supportive of girls' interests in STEM subjects/careers.
- Use role models to showcase that there are 'people like them' working in STEM careers, to try to break down barriers in perceptions about STEM
- Consider what workplace interventions might be necessary to ensure that the experiences of females in male-dominated work environments (and vice versa) can be improved to retain more women (and hence do not put off potential female entrants).

(June 2022)