Mathematics education 5-14 and gender

In 2021, the Joint Mathematical Council of the UK commissioned a piece of work on mathematics education and gender 5-14. This is a summary of our longer report in which we review relevant studies from the UK and present a wider systematic review of research.

We present four general findings with associated recommendations for policy and practice aimed at developing gender equity in mathematics education. Each of these is expanded upon in the remainder of the paper with emphases on the role of (i) individual learning, (ii) family, (iii) community, (iv) classroom, (v) teaching, (vi) school/institution, (vii) assessment, (viii) profession, and (ix) regional and national government policies.

Gender and other inequalities are reproduced at every level/locale

Gender inequalities and stereotypes shape children's developing mathematics relationships and aspirations for future participation at every level: individual, family, community, classroom and school, regionally and nationally.

Policy and practice should be devolved to the appropriate level for collective action

Policy and practical actions to tackle these inequalities must be designed and developed locally by appropriate collectives/groups, whether by students and teachers with their communities, or schools and local or regional education officials and professional associations

Emotions and stereotypes related to mathematics emerge very early in the child's life and school career

It is harder to intervene when emotions towards mathematics and gendered stereotypes have already crystallised in adolescence.

Intervening at the right time for the emerging relationships with maths

It is crucial to observe children's developing relationships with mathematics early enough to understand (and potentially side-track) trajectories of disengagement from learning.

Performative practices contribute to inequalities in mathematics participation

The culture of performativity and associated pressures (e.g. transmissionist pedagogies, emphasis on attainment to the detriment of enjoyment and attitudes) disadvantages and causes negative emotions for many. There are clear links to gender differences here.

Connectionism, inclusion, and formative assessment

Policy and practice should focus on connectionist learning/teaching for understanding, social inclusivity, and formative assessment.

Equitable policy and practice can improve engagement

More equitable policy and practice, which does not solely focus on standards and attainment but promotes access and inclusion for all groups, (whether gendered, ethnic, etc.), can improve engagement of all learners and teachers in mathematics.

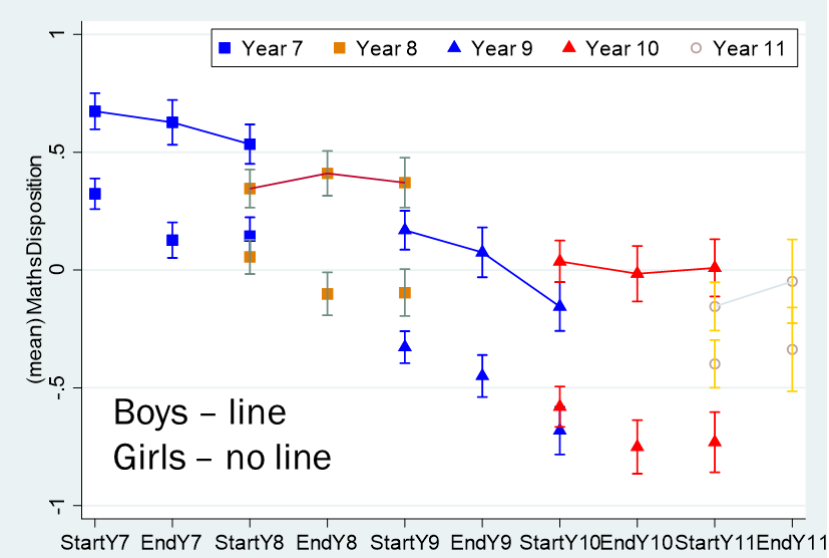
Transforming affective practice

A transformation of the curriculum, pedagogy and assessment is required: one that values engagement, enjoyment, confidence and inclusion as much as attainment.

Key findings: what does the literature say?

The need for understanding the gender 'gap' in mathematics' participation is evident in almost all of the reviewed literature with starting headlines such as, "Despite great efforts, women are underrepresented in computer science, engineering and other STEM disciplines" linking back to a global challenge: "Girls' declining interest in STEM coincides with an increasing demand for STEM-skilled professionals across the globe."

The paradoxical nature of the problem is noted first in the UK where, in the lead up to GCSEs, girls outperform (even though slightly) boys in teacher assessments and standardised mathematics tests, but are more likely to develop negative emotional relationships with mathematics or less interest in the subject (as shown with the figure of declining students mathematics dispositions during secondary school). Some explanations for this are set out below, and are detailed further in the full report.



Mathematics anxiety is perhaps the most common emotional concern and is associated with large gender differences. Within this literature 'state' and 'trait' mathematics anxiety are distinguished. 'State' anxiety refers to an emotional response that occurs when doing particular mathematical tasks and impacts students' performance generally. On the other hand, 'trait' mathematics anxiety refers to the more general experience of anxiety in relation to many forms of mathematical tasks, to the point where students internalise a fear of mathematics as something to be avoided.

In regards to **gender differences in confidence** (and/or attainment) in various mathematical and closely related fields, research has mainly focused on spatial performance and cognitive reflection. For instance, higher levels of maths anxiety in female students are associated with lower performance on spatial tasks. Some recent evidence proposes that this difference is not, as previously suggested, connected with inherent 'natural abilities' but relates instead to engagement in relevant practices. It is young girls' lack of such engagement that develops these 'abilities' that is concerning.

In addition, studies of **'stereotype threat'** demonstrate that stereotypes regarding girls' and boys' mathematics performance feed a self-fulfilling prophecy supporting perceptions that "women are bad at maths", encouraging inequalities in classroom engagement with mathematics and associated negative emotions, such as mathematics anxiety.

Students' and teachers' emotional relationships with mathematics are key to explaining gender differences in interest in the subject and in participation; evidence further suggests that such emotional relationships are shaped by classroom activities, forms of assessment and also cultural expectations regarding future aspirations, all of which reproduce gendered stereotypes associated with mathematics. This takes place very early in a child's education and the decline of students' dispositions towards mathematics over time is becoming a global trend.

Differences in classroom activities and teaching styles due to different 'pedagogies' are important for the emotional climate of a classroom. Mathematics teaching that is more traditional/transmissionist is generally seen as less effective for developing understanding. It also correlates with the most negative emotions, e.g. anxiety, and there is good reason to see this relationship as causal. There are gender differences with these perceptions (e.g. girls report more

transmissionist perceptions) leading to gendered disengagement. There is also evidence of further interactions of gender with other individual (e.g. socio-economic status, ethnicity) and also teachers' characteristics (e.g. gender) which affect these relationships.

Mathematics anxiety also exists in the adult population with parents and teachers as key influencers for children in the 5-14 year-old age group. Teachers' mathematics anxiety, especially primary school teachers, and those in initial training and the early stages of their career, has been identified as a major problem. This is presumably because many teachers have anxious personal histories with mathematics and might also be anxious not to become "bad" maths teachers who pass this on this 'contagion'.

There is widespread evidence in the literature that links mathematics (dis)engagement, including performance outcomes, with **expectations** within schools, and in the social circles of the learner (family, peers, friends), but also the extended environment and its gendered culture. Comparative international studies provide additional explanations also suggesting that **cultural expectations** and **perceptions of gender equality** may be influential. The widely acknowledged national perception of "mathematics as hard", and therefore a "minority sport" in the UK, can be contrasted to some other countries (e.g. China), where the general expectation is that everyone can/should do maths, despite it being hard, or with countries where gender equality perceptions are more common (e.g. Scandinavia). As mathematics is associated with high status jobs (medicine, finance, business, engineering, etc.) globally, it would appear that setting high expectations for maths should increase engagement. However, since many of these high status roles have been viewed as male-dominated for many generations, this career/education trajectory is often differently gendered: there is extensive evidence for adolescents' participation in post compulsory mathematics and career decision making, but also studies are emerging for younger ages.

Evidence in the literature is not conclusive regarding the impact of **parents and peers** in the age range of interest (i.e. 5-14 years). A body of emerging literature supports the hypothesis that early experiences of mathematics, both at home and in childcare settings, may be important in explaining how gender influences students' attitudes and dispositions towards mathematics later in their educational career. There is also limited evidence regarding the distinctive impact of friends and peers on students' relationships and attitudes towards school subjects and decision making for future career/study at different phases of development (e.g. between children and adolescents, and emerging young adults). More research is needed in this area.

Finally, there is evidence that international and **regional/local differences** in students' historical and cultural background correlate with gender inequality in mathematics. Recent studies have shown that gender differences in mathematics vary between regions (within the same country) sometimes even more than between countries.

What can be done? Recommendations for action at different levels

As a starting point, there is an urgent need to abandon the framing of this problem as a 'gap', as in a 'gender gap' or an 'attainment gap'. This implies a deficit perspective whereby one group (e.g. girls) is positioned as at a deficit against the other (e.g. boys). This is at best simplistic; it ignores the intersections and distribution overlaps and overemphasises the means/central tendencies. At worst, it ideologically reinforces the inequalities it purports to highlight for intervention. The review has pointed to the need to consider the complex pathways and gendered relationships around experience and engagement with mathematics for different age groups, and within different cultures.

Empirical evidence also supports more locally-based devolution of not only educational policymaking but also sharing good teaching and/or professional practice to address gender inequalities in relation to mathematics. This should be considered along with the particular recommendations presented below, and the research recommendations in the main report.

Recommendations for mathematics teachers and mathematics teaching pedagogy

Teachers and schools should consider reducing traditional/transmissionist teaching practices in order to lessen learners' negative emotions and attitudes. Teaching practice should emphasise reduction of the negative emotions (e.g. anxiety) in maths by activities which are fun, relevant to the learners (e.g. their daily life), and include an element of learner-teacher joint activity, e.g. joint

collaborative project work, personalised learning, or tuition. Teachers (or mathematics), according to the literature, could/should:

- Find ways to make mathematics meaningful to learners lives and interests
- Engage students and ensure they have an active role, e.g. in problem-solving and collaborative learning
- Use formative rather than summative assessment
- Connect teaching to current student understanding and their reflections on that understanding
- Create space for social and collaborative learning, based on dialogue between learners, and between learners and teachers
- Develop relationships and respond to student emotion
- Offer more opportunities for learners to control their learning environment (e.g. 'pace', tools and models made available for problem solving) should be encouraged in learning contexts, as well as lighter lesson content demands.

At the same time, initial teacher training and professional development should consider and attempt to ameliorate potential mathematics anxiety that may exist within the trainee or even practicing teachers (mainly of primary education). Similar efforts may be considered for reducing the impact of negative emotions of parents and the wider community.

Finally, we note that although role models are crucial, it may be more effective when resources, programmes and support are stereotype-free or gender-neutral.

Recommendations for policy

It is evident that policy emphasises performance on tests and attainment scores over affective outcomes. The National Pupil Database, for example, has no measures of affect. This emphasis marginalises the importance of enjoyment, or the social and emotional well-being, of children and teacher engaged in mathematics education. Within this educational culture, it is not surprising that teachers struggle to prioritise what might be important for some learners, but rather feel compelled to focus on what is measured. Cultivating children's enjoyment of mathematics can easily take a poor second place in comparison with maximising their capacity to perform on tests.

Supporting the changes in teaching and learning indicated above should involve:

- Developing pedagogy, evaluations and assessments that pay more attention to engagement in, and enjoyment of, mathematics. This in turn can promote wellbeing and positive affects of learners and teachers in relation to inequalities, including gendered and other culturally affected relations;
- Recognising the importance of the early introduction of children to such programmes (including programming and engineering) before gender stereotypes develop.
- Greater attention in research, policy and practice to gendered processes and climates in classrooms and institutions, and to other aspects of the learners' and teachers' institutional and cultural environment.

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