

Girls in the UK have similar reasons to boys for intending to study mathematics post-16 thanks to the support and encouragement they receive

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This paper focuses on the aspirations of 13- and 15-year-olds to continue with mathematics after the age of 16 and the association with perceptions of their mathematics education during the academic year 2008/9. A quantitative analysis was undertaken on the views of 12,176 UK students, obtained through surveys, with qualitative case studies on two of these students lending support to the quantitative findings. This paper also places a focus on a sub-set of 1,476 London students. The analysis indicates that girls and boys with high mathematics aspirations had similar responses towards their mathematics teachers and lessons, and had comparable extrinsic mathematics motivation. However, girls, regardless of mathematics aspirations, were less likely than boys to be encouraged by their families and others within their social circles to study mathematics post-16. Many of the London findings are similar to those we found across the UK, although girls within London schools with high mathematics aspirations perceived their mathematics education to be more equitable. Low aspiring girls across the UK and in London still reported less support and encouragement, and described their mathematics education less favourably than did boys.

Keywords: gender; psychology; perceptions; mathematics; motivation; aspirations

Introduction

The UK government is committed to increasing the number of STEM (science, technology, engineering, and mathematics) professionals as it perceives this is crucial for the UK to be able to compete in an increasingly competitive global economy; it has therefore expended efforts to review the curriculum for 14- to 16-year-olds in England and Wales (DfE, 2014). In recent years there has also been a shift in students' attitudes towards mathematics. It is increasingly seen as a useful subject for higher education entry and/or future careers (Taylor, 2014). Despite increases in enrolment figures in higher education there is still a problem with the relatively low proportion of students, compared with other countries, who continue with mathematics in post-compulsory education (Royal Society, 2011; Hodgen *et al.*, 2013). The Mayor of London identified mathematics qualifications as being important in enhancing London's workforce and economy (GLA, 2012). That report also highlighted the fact that despite London's schools having improved in attainment, relative to the rest of England, they were still not performing as well in mathematics as those from other major cities across the globe.

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One of the key reasons why the under-representation of females in post-16 mathematics is important is because of the implications this has for their career development and access to specialist higher education courses. Therefore, gender equity is a thread that runs through this paper. It is also our contention that the findings have implications for some other STEM subjects, and we make reference below to physics in particular. The gender gap in attainment in mathematics in the UK at secondary level is now fairly small. For example, in 2015, 5.6 per cent of girls who were entered for the GCSE (General Certificate of Secondary Education) mathematics examination (typically at age 16) achieved A* compared to 6.7 per cent of boys, with the figures for A being 10 per cent for girls and 10.6 per cent for boys, and for B being 16.9 per cent for girls and 17 per cent for boys (JCQ, 2016a). In contrast to this, the odds of girls continuing with mathematics post-16 are still considerably lower than those of boys, even after controlling for entry requirements into A level (DfE, 2010). In 2015, 38.8 per cent of A level mathematics entries were for female candidates compared to 50.9 per cent of GCSE mathematics entries (JCQ, 2016a; JCQ, 2016b).

In order to study mathematics at A level, students in England, Northern Ireland, and Wales are typically required to gain a high grade (A*, A, or B) in GCSE mathematics. However, such grades on their own are clearly not enough, given the large gender difference in A level mathematics uptake. Such gender disparities in A level mathematics entries feed through into the uptake of mathematics at higher education. The concerns with the number of females on STEM courses are also related to the high attrition rates of women at each post-16 stage of education as well as in STEM careers (Blickenstaff, 2005). There has been a number of UK initiatives put in place to increase female participation in mathematics and other STEM subjects, such as Girls into Science and Technology (WISE, 2007), and work by the Institute of Physics (2012) and the Further Mathematics Support Programme (2016); however, despite these initiatives, participation in mathematics and the physical sciences remains substantially gendered. Reasons explaining these gendered patterns of post-16 participation include boys' higher interest in mathematics compared to girls.

We reviewed a wide range of literature to help inform the development of our research tools and the studies cited here contributed to the research agenda. The academic literature now rejects the notion of meaningful innate differences between males and females that are relevant to attainment or participation in mathematics (Hyde and Mertz, 2009). Differences in choice have been attributed by some to the psychological traits of boys and girls. Indeed, Alcock *et al.* (2014) found that gender differences in attainment and behaviour among undergraduate mathematics students disappeared when personality differences were accounted for. Boys have been found to be more goal-oriented, dominant, independent, and competitive; whereas girls are typically more socially responsible, cooperative, and person-oriented (Smithers and Hill, 1987). Students who are cooperative veer towards group harmony, whereas competitive students veer towards individual goals. Some research has related personality differences and the way mathematics is taught as being advantageous to boys and disadvantageous to girls. Isaacson (1988) suggested that girls would benefit from mathematics classes if classes used cooperative approaches to learning, whereas Boaler (1997) found that girls have increased confidence and enjoyment of mathematics when more collaborative approaches are used within lessons. We collected data on students' personality traits in order to assess their relative importance; within this paper we focused on the construct that measured students' competitiveness.

An association between competitiveness and female anxiety towards mathematics has been documented (Paechter, 2001). Students' engagement with mathematics, via mathematics self-concept (belief in oneself as being good in mathematics), has been shown to be important by a number of studies, such as Green *et al.* (2007), though less emphasis has been given to other

personality differences in mathematics education. A number of studies have concluded that the gender gap can be explained by the lower levels of interest girls have in mathematics (Reid, 2003). Leedy *et al.* (2003) found that students' beliefs about mathematics, and about seeing themselves as learners of mathematics, are impacted by the way the subject is taught; and such associations are related to lower participation and performance in mathematics. It is quite possible that such learning environments lead to girls under-evaluating their own performance, which is associated with girls' lower intentions to continue with mathematics post-16 (Sheldrake *et al.*, 2014). This may stem, at least in part, from the classroom environment. Kyriacou and Goulding (2006) found that boys had higher mathematics self-concept than girls, whereas Hannula (2002) found that girls had more mathematics-related anxiety. Girls' low confidence levels have been put forward as an explanation as to why they are less likely to choose mathematics (Armstrong, 1985). It has also been argued that teachers are less likely to put girls in top sets, to shelter them from competitive male environments (Boaler, 2002). It has, furthermore, been suggested that the gender gap is attributable to the way in which girls associate STEM careers with males (Lee, 1998); and it is also evident that both girls and boys internalize these social gender roles and so see STEM-related careers as being more for males (Lindsey *et al.*, 1997).

Research tends to focus on the average or typical differences between boys and girls (e.g. Brown *et al.*, 2008; but see Solomon, 2007), rather than examining within-gender group variation and between-gender group overlap and seeking to establish what is distinctive about girls who choose mathematics. Girls' continued lower levels of interest in mathematics compared to boys is likely to be because of a number of factors, although much of the research conducted to date tries to explain engagement and participation by focusing on one particular factor, or simply on why girls do not want to do mathematics (Brown *et al.*, 2008). Very little research makes comparisons between girls with high mathematics aspirations and girls with low aspirations, or examines how these groups differ from boys. The term 'aspirations' can be understood in a number of ways; our focus is on stated intentions to study mathematics once it is no longer compulsory.

The context of this study

Our work extends previous studies in a number of ways. First, while the majority of existing work focuses on the question of why girls are more likely than boys not to choose mathematics, we are particularly interested in girls who aspire to choose mathematics – are they similar to boys who aspire to choose mathematics, or is there something distinctive about these girls? Much of the literature looks into why girls choose not to do mathematics. Second, while most work in this field is qualitative – and each of us is entirely comfortable with and undertakes qualitative research – we are also interested in work with large sample sizes that allows one to investigate hypotheses statistically. Although this paper places most of its emphasis on quantitative analysis, we use qualitative work to simply support some of the quantitative findings. In this we seek to build on the work of Brandell and Staberg (2008), who used the questionnaire responses of 1,300 Swedish secondary school students to conclude that there was a marked tendency to view mathematics as a gendered domain, with positive aspects associated with boys and negative aspects perceived as more female.

This paper aims to identify which factors relate to students' stated intentions to study mathematics beyond compulsory level, using a mixed methods longitudinal approach. The data are extracted from the 'Understanding Participation Rates in Post-16 Mathematics and Physics' project (Reiss *et al.*, 2011), the fieldwork for which was conducted from 2008 to 2011; the quantitative element of the study, part of which we draw on here, surveyed the responses of

just over 23,000 students across the UK aged 12–13 (year 8) and 14–15 (year 10). We have also included extracts from interviews taken from a boy and a girl to exemplify the quantitative findings. The interviewees were taken from a bank of interviews we conducted with 56 students who had also completed surveys. This paper explores in detail issues around gender, perceptions, motivations, and attitudes in relation to intentions to participate in mathematics post-16. Our analysis therefore explored students' perceptions about a range of issues related to mathematics education in order to help build a profile about girls with high aspirations.

We hypothesize that females with high post-16 mathematics aspirations are a distinctive group (in terms of their relationship with mathematics), compared both to low aspiring females and high aspiring males. Such a hypothesis reflects similar analyses on the physics surveys, where we concluded that girls who had high aspirations to study physics post-16 were a distinct group with motivation levels similar to that of high aspiring boys. High aspiring girls were more motivated by physics and had more positive perceptions of their physics education than both boys and girls with low aspirations to study physics post-16 (Mujtaba and Reiss, 2013a).

Methodology

Sample

Although there is considerable literature in mathematics education pertaining to extrinsic factors affecting choices and achievement (see Boaler, 2009), comparatively little has been reported on the relationship between intrinsic factors, such as personality, attitudes to mathematics, and achievement in mathematics, and their relationships to subject choice, achievement, and post-16 participation. Accordingly, we designed student questionnaires to include items derived from established psychological constructs (e.g. for motivation, self-efficacy, and competitiveness) alongside mathematics conceptual tasks so that possible relationships between performance, confidence, and intrinsic and extrinsic factors could be explored. The surveys intentionally included a large number of possible factors that had previously been suggested that might relate to students' decisions to study mathematics at post-compulsory level (Reiss *et al.*, 2011). In total we had 12,176 students (6,083 year 8 and 6,093 year 10) who completed our surveys as learners of mathematics between October 2008 and January 2009. The London sample consisted of 1,476 students (761 year 8 and 715 year 10). We used London as a sub-group, given the focus of London for this special issue in conjunction with the general focus of raising the attainment of London students in science and mathematics. Our school sample was derived from all four nations in the UK. Because the focus of the study is to find factors that influence post-16 participation, it was a deliberate part of the sampling to over-represent in our sample schools, which were above average in either or both of mathematics and physics attainment and post-16 participation. In addition, given our research agenda, we targeted students who were predicted to get grades A*–D in GCSE mathematics and physics/science. This bias was intentional because, although all barriers to participation are important, we are particularly interested in factors that affect the 'choices' of those students who have the opportunity, including fulfilment of attainment criteria, to study mathematics or physics post-16. Such a sample will have a bearing on the types of associations we find and report; in particular, we make no claims that our findings are representative either for London or for the whole of the UK. This paper also draws on qualitative data to help illustrate and enrich the quantitative findings. Within our quantitative sample of schools, we conducted longitudinal interviews with six to nine students from each of twelve schools. We used extracts from six semi-structured interviews with two high aspiring and high attaining students: a girl and a boy, interviewed at ages 15, 16, and 17 (years 10, 11, and 12, respectively). These students

were typical of those with high aspirations to continue with mathematics (with respect to their perceptions of their mathematics education). Each interview was conducted by Tamjid Mujtaba and was around 30 minutes in length.

Procedures prior to main analyses

Student questionnaires were designed following a review of the literature considering factors that may influence post-compulsory participation rates. The mathematics survey, alongside questions related to intentions to continue to study mathematics post-16, also included mathematics-specific items to determine such things as attitudes, perceptions, and mathematical understanding. A factor analysis using principal components affirmed some of the constructs, but also led to minor changes in others. Questionnaires were administered in class during normal school hours. Interviews were audio-taped, transcribed, and analysed thematically. The detailed methodology surrounding the set-up of the survey and how it fits within the wider project is provided in Reiss *et al.* (2011). Cronbach's alphas were used to assess the internal consistency of all constructs, which were found to have fair to high reliability (.6–.9). All of the items within each construct were scored so that a high score represents strong agreement. Most items were measured on a six-point Likert scale, although some had only four points. A brief summary of what each construct measures is provided with its corresponding analysis.

The two interviews used within this paper are taken from one boy and one girl. Pandora is a high attaining white girl from a middle-class background, who attends a high attaining all-girls 11–18 school in the south-east of England. Pandora decides not to continue with mathematics at age 17 (although she had considered this earlier). This is despite having strong family/out-of-school influences in mathematics. Her father, a former mathematics Oxford graduate, is an actuary; her older brother studies mathematics at Oxford; and one of her father's close friends is a 'mad maths professor at Oxford'. In year 10, Pandora was inclined towards studying non-STEM subjects, while still considering mathematics. In her year 11 interview she was toying with the idea of doing engineering at university. Despite having a high intrinsic valuation of mathematics and being aware of future prospects it may bring, she decides not to continue with it at age 17.

Miles, a high attaining white male of middle-class background, attends an 11–18 grammar school in the south-east of England. His mother is an English teacher and his father is an IT manager. In his year 10 interview he mentioned that he would like to continue with the sciences and possibly mathematics, to help him become a rocket engineer – although he also said in the same interview that he would like to become a chemistry teacher. By his second interview (age 16) he was including mathematics in his future plans, primarily to help him become a chemistry teacher. His plans had shifted by the time of his third interview, when he said he was keen to do either marine biology or astrophysics at degree level.

Results

In the survey we asked year 10 students whether they were intending to continue with mathematics post-16 (a high score represents strong aspirations to continue with mathematics post-16). Tables 1.1 and 1.2 show that boys had higher post-16 mathematics aspirations than girls (effect size (ES) UK = .215; London = .285). The difference between girls and boys was higher in London schools, although the mean results demonstrate that London students reported more favourably about continuing with mathematics post-16 than did students across the UK.

Table 1.1: UK year 8 and year 10 students: Survey responses by student gender

Construct/item	Boys		Girls		Difference	
	M	SD	M	SD	Sig. (p)	Effect (d)
Competitiveness personality trait	4.18	.77	4.47	.67	<.001	.406
Mathematics self-concept	4.23	1.01	3.79	1.01	<.001	.431
Home support for achievement in mathematics	4.73	1.00	4.48	1.02	<.001	.253
I intend to continue to study maths after my GCSEs	4.33	1.53	3.99	1.57	<.001	.215
Advice/pressure to study mathematics	4.38	1.27	4.19	1.27	<.001	.149
My teacher thinks that I should continue with maths beyond my GCSEs	4.88	1.30	4.69	1.39	<.001	.147
Intrinsic value of mathematics	4.08	.94	3.89	.85	<.001	.215
Extrinsic material gain – mathematics motivation	4.79	.86	4.66	.80	<.001	.159
Emotional response to mathematics lessons	3.96	1.00	3.83	.96	<.001	.132
Perceptions of mathematics lessons	4.05	.99	3.97	.93	<.001	.090
Students' perception of mathematics teachers	4.57	.98	4.59	.94	.434	.014

Notes: M = mean; SD = standard deviation; comparisons between girls and boys.

Table 1.2: London year 8 and year 10 students: Survey responses by student gender

Construct/item	Boys		Girls		Difference	
	M	SD	M	SD	Sig. (p)	Effect (d)
Competitiveness personality trait	4.10	.75	4.45	.65	<.001	.519
Mathematics self-concept	4.51	.88	4.00	.98	<.001	.525
Home support for achievement in mathematics	4.88	1.01	4.80	.97	.176	.087
I intend to continue to study maths after my GCSEs	4.65	1.40	4.23	1.53	<.001	.285
Advice/pressure to study mathematics	4.54	1.17	4.39	1.22	.045	.120
My teacher thinks that I should continue with maths beyond my GCSEs	5.05	1.06	4.97	1.25	.381	.064
Intrinsic value of mathematics	4.18	.92	4.04	.86	.009	.166
Extrinsic material gain – mathematics motivation	4.87	.80	4.82	.78	.235	.074
Emotional response to mathematics lessons	4.12	1.01	3.90	1.00	<.001	.221
Perceptions of mathematics lessons	4.19	.93	4.07	.91	.036	.130
Students' perception of mathematics teachers	4.63	.96	4.65	.94	.816	.014

Notes: M = mean; SD = standard deviation; comparisons between girls and boys.

In order to explore issues around gender and post-16 mathematics aspirations, the answers from the question on intentions to continue with mathematics were cross-related with gender. This resulted in four post-16 mathematics aspiration gender groups: boys with high aspirations; girls with high aspirations; boys with low aspirations; and girls with low aspirations (see Tables 2.1 and 2.2). For each of the core measures, an analysis was conducted comparing the responses of males and females; t tests were used to identify gender differences; and ANOVA and Bonferroni-adjusted tests were used to explore differences between the gender aspiration groups. As we show, our particular interest is in one of these four groups: girls with high aspirations. However,

to examine the extent to which such girls represent a distinct grouping, it is necessary for us to undertake analyses across all four groups.

Table 2.1: UK year 8 and year 10 students: Girls' and boys' aspirations in mathematics and the relationship with other factors

Construct/item	High aspiration boys		High aspiration girls		Low aspiration boys		Low aspiration girls		Difference	
	M	SD	M	SD	M	SD	M	SD	Sig. (p)	Effect (η)
Competitiveness personality trait	4.23	.74	4.51	.65	4.02	.82	4.37	.70	<.001	.222
Mathematics self-concept	4.45	.90	4.08	.89	3.58	1.06	3.22	1.01	<.001	.430
Home support for achievement in mathematics	4.92	.85	4.74	.87	4.16	1.18	3.94	1.10	<.001	.369
Advice/pressure to study mathematics	4.79	.95	4.70	.95	3.09	1.28	3.16	1.19	<.001	.576
My teacher thinks that I should continue with maths beyond my GCSEs	5.16	.98	5.08	.99	3.80	1.75	3.72	1.71	<.001	.440
Intrinsic value of mathematics	4.30	.82	4.13	.77	3.37	.94	3.38	.79	<.001	.429
Extrinsic material gain – mathematics motivation	5.03	.66	4.94	.64	4.09	1.02	4.11	.82	<.001	.480
Emotional response to mathematics lessons	4.10	.96	4.04	.92	3.54	.99	3.42	.92	<.001	.282
Perceptions of mathematics lessons	4.30	.85	4.25	.81	3.30	1.00	3.40	.89	<.001	.435
Students' perception of mathematics teachers	4.69	.88	4.71	.87	4.20	1.16	4.31	1.02	<.001	.206

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Construct/item	High aspiration boys		High aspiration girls		Low aspiration boys		Low aspiration girls		Difference	
	M	SD	M	SD	M	SD	M	SD	Sig. (p)	Effect (η)
Competitiveness personality trait	4.15	.68	4.46	.67	3.89	.99	4.43	.58	<.001	.224
Mathematics self-concept	4.59	.83	4.22	.90	4.09	1.00	3.45	.95	<.001	.387
Home support for achievement in mathematics	4.99	.92	4.99	.87	4.40	1.23	4.28	1.02	<.001	.307
Advice/pressure to study mathematics	4.78	.96	4.78	.98	3.36	1.34	3.38	1.21	<.001	.500
My teacher thinks that I should continue with maths beyond my GCSEs	5.17	.93	5.21	.98	4.32	1.47	4.24	1.64	<.001	.319
Intrinsic value of mathematics	4.29	.85	4.24	.81	3.62	1.07	3.52	.79	<.001	.353
Extrinsic material gain – mathematics motivation	5.02	.65	5.03	.67	4.14	1.06	4.28	.77	<.001	.429
Emotional response to mathematics lessons	4.20	.96	4.06	.98	3.78	1.13	3.49	.94	<.001	.251
Perceptions of mathematics lessons	4.31	.86	4.28	.85	3.61	1.03	3.52	.82	<.001	.358
Students' perception of mathematics teachers	4.64	.96	4.71	.93	4.54	1.01	4.43	.93	<.001	.119

Notes: Data presented as mean (number); effect size indicates eta value for the ANOVA between gender aspiration groups (Bonferonni tests indicated statistical significance between groups that are highlighted in the text and not in this table; highest score is 6).

Views of mathematics lessons

The survey measured views of mathematics lessons in two ways: 'perceptions of lessons' and 'emotional responses towards lessons'. Tables 1.1 and 1.2 indicate that males reported more positive perceptions of mathematics lessons (UK, $p < .001$, $ES = .090$; London, $p < .01$, $ES = .130$), and more positive emotional responses towards mathematics lessons (UK, $p < .001$, $ES = .132$; London, $p < .01$, $ES = .221$), with similar trends across the UK and London. High aspiring girls reported more positive perceptions of mathematics lessons than did low aspiring girls and boys, but less positive perceptions than did high aspiring boys (UK, $ES = .435$). Similar results were found with emotional responses to mathematics lessons (UK, $ES = .282$). Girls with low aspirations had the least positive responses compared to all groups of students. The picture in London was somewhat different; as expected (in line with the UK findings), both girls and boys with high aspirations responded more favourably regarding their perceptions of lessons (London, $ES = .130$) and emotional responses to lessons (London, $ES = .221$) than did students with low aspirations. However, there was no statistically significant difference between girls and boys with high aspirations – they had similar views of their mathematics lessons and emotional responses to them. In addition, there were no gender differences between London girls and boys with low aspirations – they too responded similarly.

These statistical findings are complemented by the qualitative data. In his year 11 interview, Miles indicated that he had problems in accessing mathematics because of the poor lessons:

I mean I am struggling a little bit but I am working a lot at home ... I was at the back [seated at the back of the classroom], so I have recently moved to the front, because I find it hard to concentrate at the back, and while I am now at the front I can concentrate more, I find it a lot easier.

In his year 12 interview Miles reported that:

maths is one of those things that you don't have passion for, you enjoy it when you get it, understand it, comprehend it, may lead to people who want to do maths, which is perfectly valid, if they enjoy it sure ... it seems so emotionless it's very cold for me, half the time when I get it I don't enjoy it and when I do get it I still don't enjoy it.

It is clear from this extract that Miles associates enjoyment of mathematics with being more possible if he was able to understand it, although this was still not certain and he had problems accessing mathematics in the classroom.

Pandora indicated in her year 10 interview that there were problems with disruptive students:

It often takes ten minutes for the class to settle down, and then we normally get given work but then if people don't understand – like, normally, quite a lot of people don't understand it – so it takes a lot of time for the teacher to go round to explain it to everyone ... in our class there are people who focus a lot and then some people who are less well behaved which make it quite difficult ... so we don't get as much work done as we should.

Students' perceptions of mathematics teachers

Within both the UK and London samples, simply looking at the responses of boys and girls in isolation from their aspiration group indicated that they had similar perceptions of their teachers; however, exploring perceptions by aspiration groups did indicate some gender differences, but the trends were different in London compared to the UK. In the UK, high aspiring boys and girls held similar positive perceptions of their teachers; high aspiring girls and boys also held more

positive views of their teachers than did both low aspiring boys and girls (UK, $ES = .206$). Girls in the UK with low aspirations held the least positive views of their mathematics teachers of all groups of students. In the London sample there were no statistically significant differences in perceptions between high aspiring girls and boys.

The survey asked students whether they felt their teachers encouraged them to continue with mathematics after the age of 16. The analysis (Table 1.1) indicates that, without looking at the aspiration group, there was a statistically significant gender effect in the UK (boys felt more encouraged than girls) (UK, $p < .001$, $ES = .147$); but there was no difference between girls and boys within the London sample (Tables 1.1 and 1.2). When taking their aspirations into account, high aspiring boys and girls reported receiving more encouragement than did low aspiring students (UK, $ES = .440$; London, $ES = .319$), with no significant gender difference between high aspiring boys and girls or between low aspiring boys and girls. We note the effect size for this individual item was larger than that of the construct 'perception of teachers'.

Miles reported in his year 12 interview that:

maybe the teachers, the teacher I had before, wasn't a very good teacher so it didn't benefit me, but really don't know what happened. I used to like maths I can't really say I enjoyed it, it was all right but then it didn't really fit into what I thought was a good subject.

Similarly, Pandora reported in her year 10 interview that the way her mathematics teacher handled the class possibly impacted the way mathematics appealed to her:

I think it depends a lot on whether the teacher's good, to make you want to be involved in the class. Like, my English teacher is really, really good so it's part of the reason I really enjoy English. And then the science teachers are really good at making it interesting if it's not something you enjoy, with practical activities and stuff. My maths teachers have been good, but sometimes they're a bit – not very and we don't get much work done. I think if I had a, not a better maths teacher, but someone who was better with the class, then it might make it more interesting. Like, just doing it, cos I find the maths quite interesting but then if the class isn't focused and stuff, it can be quite difficult to do.

Mathematics self-concept

The mathematics-specific self-concept construct measured students' perceptions of their own abilities. Males had higher self-concepts across both samples (UK, $p < .001$, $ES = .431$; London, $p < .001$, $ES = .525$). When looking at student gender and aspirations, in the UK sample high aspiring girls had lower 'mathematics self-concept' than did high aspiring boys (UK self-concept, $p < .001$, $ES = .430$). When compared to low aspiring boys and girls, high aspiring girls had a higher self-concept. The picture in London is somewhat different. As with the UK sample, high aspiring girls had a lower self-concept than high aspiring boys although, interestingly, similar to that of low aspiring boys (London self-concept, $p < .001$, $ES = .387$). Low aspiring girls were the group with the lowest mathematics self-concept.

Pandora stated in her year 11 interview that although she was considering doing mathematics after her GCSEs, she probably would not, at least partly because of her low self-concept in it:

Well I've been considering doing maths ... there's a lot of things you get further in life if you do maths like a lot of people say that ... I feel slightly bad that I'm not doing [mathematics] but I can't do it, I'm going to struggle with it.

In her year 12 interview, she briefly considered the possibility that she did not choose to do mathematics as it would always have been difficult to do well in it, or to have been seen to do so, when compared with her brother, who was studying mathematics at Oxford, and her father,

an actuary who had also studied at Oxford. She admitted that having two strong males in the family who are good at maths impacts her self-confidence. Pandora obtained an A at GCSE and, despite her ability, intrinsic valuation of mathematics, and knowledge of its extrinsic benefits, it was her lack of confidence that underpinned her non-continuation with mathematics. She also stated in her year 10 interview that 'when it comes to the test part in physics, it's the maths part that I don't really like because I always find the equations quite difficult; I think I tend to enjoy the classes in physics'. Miles also attained an A at GCSE and, although (unlike Pandora) he chose mathematics at A level, he says of it:

I am not doing too well, I am getting better but the main thing is I don't enjoy it, so half the time I am trying, but I need to push past that emotional barrier so that I can begin to work even though I don't enjoy it.

In the year 12 interviews, the students were asked why girls were less likely to continue with mathematics in post-compulsory education. Miles stated:

Maybe it's just different ideas, I couldn't really tell you to be honest, maybe it's just one of those freak social things or maybe certain genders enjoy a topic more than others ... I don't think anyone can be intelligent or unintelligent just as any other person [in response to whether girls are less capable], some just require more practice.

Although Pandora agreed there were no differences in the mathematical abilities of boys and girls, she did think there was a difference in students' intrinsic preference of subjects:

I think it's great [for girls to do mathematics at A level]; I have a friend doing it and she's finding it quite hard but I think she's quite proud ... yeah I think so [that girls are as good as boys in mathematics] but I think it just appeals less to girls ... I think it's because girls are more creative and enjoy English more, so I think they are more likely to enjoy other subjects.

Motivation and value of learning

We distinguish between extrinsic and intrinsic motivation and valuation of mathematics; students who hold that mathematics has 'intrinsic value' do so because they find the subject enjoyable or interesting, or mention some form of positive emotion when doing mathematics. 'Extrinsic material gain motivation' measures how useful mathematics is seen to be for things like access to higher education or desired employment. The t-test analyses indicate that within the UK sample, males have higher levels of extrinsic material gain motivation (UK, $p < .001$, $ES = .159$) – although no such difference was found in London. Given that our work has indicated that extrinsic material gain motivation is a key factor related to mathematics participation and/or having aspirations to participate (Mujtaba *et al.*, 2015), and that girls are less likely to continue with mathematics post-16, it is noteworthy that there is a gender difference across the UK but not in London. Again, there were no statistically significant gender differences in intrinsic motivation within the London sample; but across the UK, girls showed lower intrinsic valuation of mathematics (UK, $p < .001$, $ES = .215$), although gender differences did arise in the London (and UK) samples when exploring motivation by aspiration level, as we now discuss.

Extrinsic material gain

Tables 2.1 and 2.2 demonstrate that high aspiring girls had lower levels of extrinsic material gain than high aspiring boys (UK, $p < .001$, $ES = .480$). Across the UK, high aspiring girls had higher measures of extrinsic material gain motivation compared to low aspiring boys and girls. No

significant differences were found between the extrinsic motivation levels of low aspiring girls and boys. The findings in London were somewhat different: high aspiring girls and boys had similar levels of extrinsic material gain motivation and, as expected, higher motivation levels than low aspiring groups (London, $p < .001$, $ES = .429$). Similar to the UK findings, no significant differences were found between the extrinsic motivation levels of low aspiring girls and boys.

The interviews with year 10, 11, and 12 students demonstrated that extrinsic material gain motivation was strongly associated with mathematics choice. As Miles stated in his year 11 interview:

Maths isn't a career path I want to follow but to do the job I want, I want to go onto be a chemistry lecturer or a chemist ... I need maths because maths is a big part of chemistry, so I need that at A level, to become what I want to be.

In his year 12 interview, at which point he was studying mathematics by virtue of his taking the International Baccalaureate (IB), Miles said:

I wouldn't say there was no motivation at all [to do well in mathematics] since all components add into one big grade, so I can't afford to mess up in maths so I am trying so that's motivating, the motivation is that I want to get a good IB grade so I guess it's indirect, but there is motivation there, I find it hard to act upon it.

Students were also asked in year 12 whether mathematics was relevant to their future lives. Miles stated:

I think it will play a huge role in the future, maths will be a commonplace I think ... you won't be able to get through life without maths, especially in hundreds of years in the future ... technology would be based of mathematical equations, lots of computers would be using maths so I think maths would play a huge part in the future.

When asked how he would be involved, Miles replied, 'I would have to be ... I would have to get involved in it whether I like it or not ... I will have to understand how something works to use it properly and that brings math equations with it.'

Intrinsic value of mathematics

High aspiring boys scored higher on the intrinsic value of mathematics than did high aspiring girls (UK, $p < .001$, $ES = .429$; London, $p < .001$, $ES = .353$), although within the London sample these two aspiration groups were similar. In both the UK and London, high aspiring girls scored higher on the intrinsic value of mathematics than did low aspiring girls and boys; no significant differences were found between low aspiring girls and boys.

Although Pandora expressed only limited aspirations to continue with mathematics post-16, she had a more positive and consistent (across her three interviews) intrinsic valuation of the subject than did Miles, despite his genuine deliberations about continuing with mathematics (to get access to a scientific teaching career). For Pandora, mathematics was straightforward and was relevant to other aspects of everyday life: 'I enjoy maths ... everything in maths is very set ... I get quite excited when someone's talking about something and you think "Oh, that's kind of like this in maths" ... you can link it to other subjects.'

However, Miles's intrinsic valuation of mathematics changed and became less favourable as he progressed through secondary school. At age 15 (year 10) he said, 'Maths, yes, it's quite interesting, once again I don't dislike it ... our teacher related [mathematics] to the real world, and it was quite interesting.' Yet in his year 12 interview he stated, 'I find it hard to think anyone has a passion for it ... it seems so emotionless.'

Extra support, advice, and learning in mathematics

The 'advice and pressure to study mathematics' construct contained items about the encouragement students received from family, teachers, friends, and acquaintances. The 'home support for mathematics achievement' construct contained items that focused on learning support within the home.

The analysis indicated that males reported greater advice and pressure to study the subject (UK, $p < .001$, $ES = .149$; London, $p < .001$, $ES = .120$), but only the UK had more home support for mathematics achievement (UK, $p < .001$, $ES = .253$). When looking at the gender through aspiration group, the UK findings demonstrate that high aspiring girls and boys had more advice and pressure to study mathematics than did low aspiring boys and girls – although high aspiring boys received more advice and pressure to study mathematics than high aspiring girls (UK, $p < .001$, $ES = .576$). There were no significant differences between low aspiring boys and girls in advice and pressure to study mathematics. The London findings suggested that the advice and pressure to study mathematics were more equitable across the gender groups regardless of aspirations; high aspiring girls and boys reported similarly as did low aspiring girls and boys. The only difference was that high aspiring girls and boys were more likely to report receiving advice/pressure to study mathematics than low aspiring girls and boys.

The UK sample indicated that low aspiring girls were the least likely group to say they received home support for achievement in mathematics ($p < .001$, $ES = .369$). High aspiring girls reported higher levels of such support than did low aspiring girls and boys, but less home support for achievement in mathematics than did high aspiring boys. Again in London, the data perceptions of support were more equitable and there were no differences in perceptions of support between high aspiring girls and boys. As with the UK findings, high aspiring girls reported higher levels of such support than did low aspiring girls and boys. In both the UK and London samples, high aspiring boys reported the highest levels of support.

Advice/pressure to continue studying with a given subject has important implications for students' choices. Our research on students as learners of physics found that advice/pressure to study physics had an independent and statistically significant association with aspirations to continue with physics post-16 (Mujtaba and Reiss, 2013a).

Although Pandora did consider studying mathematics post-16, the advice she received from her mother in year 11 was to not continue with it:

But my mum said if [maths is] not something that I've found particularly easy or enjoy as much, I probably shouldn't do it just because I think it would benefit me in life, because I am all right in maths but it's not one of my favourite subjects ... there's no point in me doing it [at A Level] if I'm not going to enjoy it or find it hard.

Competitiveness

We explored whether competitiveness was related to high mathematics aspirations; a score above 3 indicates that students are competitive, with a tendency to veer towards self-enhancement as opposed to group enhancement; scores below 3 indicate more cooperation. Within our analysis we found that girls were more competitive than boys across both samples (UK, $p < .001$, $ES = .406$; London, $p < .001$, $ES = .519$). When looking by aspiration group, we found that high aspiring girls were the most competitive group in both samples (UK, $p < .001$, $ES = .222$; London, $p < .001$, $ES = .224$).

Discussion

The findings from this study indicate the importance and pervasiveness of gender issues, and lend support to feminist-informed work (e.g. Mendick, 2006), which has sought to explain girls' low participation in mathematics once it is no longer compulsory. However, our results also indicate considerable variation among the girls and important overlaps between the boys and the girls. In particular, for some of the constructs, no statistically significant differences appeared between those males and females who had similar aspiration levels (Tables 2.1 and 2.2), which was particularly evident within our London sample. This means that for some measures, high aspiring girls gave similar responses as did high aspiring boys, and these girls as a group had more positive perceptions, attitudes, and motivations – particularly towards mathematics-related constructs – than did low aspiring boys and girls. In addition, high aspiring girls rated some aspects of their mathematics experiences more positively than did low aspiring boys. All of this highlights that analyses based on gender alone do not sufficiently explain differences in student responses. Our work extends the research to date, as our quantitative analysis suggests that positive associations with mathematics can be found among girls, and that high aspiring girls hold more positive mathematical attributes than certain boy groups. This group of high aspiring girls is distinctive in the sense that its members share characteristics that (statistically) enable them to be distinguished from other groups, including low aspiring girls. It is not, of course, our belief that high aspiring girls form a closed group. Indeed, our hope is that this group can be enlarged through changes in the practices of teachers, of schools, and of mathematics itself.

There is a gender gap in favour of boys wanting to study mathematics in post-compulsory education across both the UK and London samples (Tables 1.1 and 1.2), although there is still a substantial number of girls wanting to continue with mathematics post-16. Indeed, there has been a fairly steady increase over the last 25 years in the percentage of students taking A level mathematics who are females, from about 30 per cent in the 1980s to about 40 per cent in 2015 (JCQ, 2016b). Perhaps this has something to do with mathematics now having a more prominent exchange value, portrayed as a door opener to many possibilities in life (Taylor, 2014).

Low aspiring girls experience their mathematics classroom environment differently from other groups (i.e. low aspiring boys, high aspiring girls, and high aspiring boys), while high aspiring girls and high aspiring boys experience aspects of their classroom environment in a similar way, as indicated by the observation that both groups were equally positive in their perceptions of teachers. However, the results also indicate that there were statistically significant differences between high aspiring boys and girls in a number of core mathematics-specific areas. In particular, high aspiring girls had lower confidence in their mathematics self-concept than high aspiring boys, in line with existing research (e.g. Boaler, 1997).

Although our findings would benefit from further related studies by others, certain conclusions can be drawn. It seems likely that low aspiring girls are switched off mathematics both by their school environment and by factors outside of school, as girls as a group report receiving less encouragement than boys to study mathematics post-16. This idea is given support by the finding that high aspiring girls are significantly less likely than high aspiring boys to receive home support for achievement in mathematics, have a lower intrinsic valuation of mathematics and, in addition, are less likely to receive advice and pressure to study mathematics post-16. The differences between our four gender aspiration groups are largest when high aspiring boys and low aspiring girls are compared (see Tables 2.1 and 2.2).

These findings imply that a core group of girls who do not intend to study mathematics any further experience the classroom environment in a very different way from high aspiring boys, high aspiring girls, and low aspiring boys. Lack of a supportive environment outside of school may, in some way, curtail such girls' belief in themselves as being capable of doing well in

mathematics; or it may discourage them (as in Pandora's case when she talks about her mother's advice) from seeking a more positive relationship with mathematics. This seems likely to impact their emotional responses to mathematics lessons, which resonates with research that indicates how family science capital is important in helping students identify with STEM subjects (Archer *et al.*, 2015). However, high aspiring girls do manage to overcome issues around lack of support/encouragement in mathematics, given that their extrinsic mathematics motivation levels are on a par with those of high aspiring boys.

Core individual differences between girls who intend to participate in mathematics after the age of 16 and girls who do not – aside from their perceptions of their mathematics environment – are that high aspiring girls have motivation levels similar to those of high aspiring boys; are competitive; and have absorbed the point that studying mathematics post-16 can have material benefits. This contrasts with the finding that the intrinsic valuation of mathematics by all girls, even high aspiring girls, is lower than that of boys who intend to participate in post-16 mathematics. It therefore seems likely that the emphasis given at school, or received elsewhere, about the extrinsic value of mathematics has been taken on board by a core group of girls. Support for this comes from an examination of effect sizes: 'advice and pressure to study mathematics', 'extrinsic material gain motivation', and mathematics 'self-concept' were the three constructs that showed the largest effect sizes in explaining differences between the four gender aspiration groups. We have reported similar conclusions with respect to physics aspirations (Mujtaba and Reiss, 2013b; Mujtaba and Reiss, 2013c). Adding weight to this suggestion are the results that emanate from the personality constructs. Although previous studies (e.g. Smithers and Hill, 1987) have indicated that girls are less competitive than boys, our findings indicate otherwise. Girls who express an intention to participate in mathematics post-16 are more competitive than any other group, including boys who express an intention to participate, mirroring findings we found in our analyses of students as learners of physics (Mujtaba and Reiss, 2013a). The reasons for this remain to be uncovered, but are likely to reflect societal changes including, possibly, today's generation of 15-year-old girls in the UK being part of a more competitive educational market and classroom environment.

Although the analysis on the London data was based on a relatively small sample of students compared to the analysis of UK-wide students, the findings from London nevertheless point towards important conclusions. First, the London findings suggest that having more equitable conditions for learning (i.e. advice/pressure to study mathematics and home support for achievement in mathematics) quite possibly enables high aspiring girls to experience their mathematics education in a similar and positive way to high aspiring boys (e.g. perceptions of lessons and emotional response to lessons and, of course, having high aspirations). Second, we note that there have been various initiatives that have been put in place within London as elsewhere in England (Hoyles *et al.*, 2011) to raise the profile of science and mathematics subjects; such initiatives have had a positive influence in making girls less likely to feel alienated in classrooms where traditionally male subjects are taught (Ofsted, 2010). It may also be the case that there have been changes in the way teachers in London relate to girls in mathematics and physics teaching. Finally, there have been general initiatives unrelated to mathematics and science education that may also have had an influence – for example, the London Challenge (*ibid.*), which was more geared towards increasing the prospects of economically disadvantaged communities.

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