Canadian Journal of Science, Mathematics and Technology Education

ISSN: 1492-6156 (Print) 1942-4051 (Online) Journal homepage: http://www.tandfonline.com/loi/ucjs20

"I Fall Asleep in Class … But Physics Is Fascinating": The Use of Large-Scale Longitudinal Data to Explore the Educational Experiences of Aspiring Girls in Mathematics and Physics

Tamjid Mujtaba & Michael J. Reiss

To cite this article: Tamjid Mujtaba & Michael J. Reiss (2016) "I Fall Asleep in Class … But Physics Is Fascinating": The Use of Large-Scale Longitudinal Data to Explore the Educational Experiences of Aspiring Girls in Mathematics and Physics, Canadian Journal of Science, Mathematics and Technology Education, 16:4, 313-330, DOI: 10.1080/14926156.2016.1235743

To link to this article: http://dx.doi.org/10.1080/14926156.2016.1235743

Accepted author version posted online: 24 Oct 2016.
Published online: 24 Oct 2016.

CANADIAN JOURNAL OF SCIENCE, MATHEMATICS AND TECHNOLOGY EDUCATION
2016, VOL. 16, NO. 4, 313–330
http://dx.doi.org/10.1080/14926156.2016.1235743

"I Fall Asleep in Class … But Physics Is Fascinating": The Use of Large-Scale Longitudinal Data to Explore the Educational Experiences of Aspiring Girls in Mathematics and Physics

Tamjid Mujtaba and Michael J. Reiss

UCL Institute of Education, University College London, London, United Kingdom

ABSTRACT

This article explores how students' aspirations to study mathematics or physics in post-16 education are associated with their perceptions of their education, their motivations, and the support they feel they received. The analysis is based on the responses of around 10,000 students in England in Year 8 (age 12–13) and then in Year 10 (age 14–15). The students were first surveyed during 2008–2009 and then followed up in 2010–2011. *t*-tests revealed a decline in their perceptions of their mathematics and physics education. Factor analyses indicated subject-specific constructs that were associated with gender aspiration groups (i.e., high-aspiring girls, high-aspiring boys, low-aspiring girls, low-aspiring boys). High-aspiring girls were more likely than low-aspiring boys to be positive about mathematics/physics education, motivation in these subjects, and support received. However, high-aspiring girls were less likely than high-aspiring boys to be encouraged by their teachers and families to continue with these subjects post-16 and had lower self-concepts, intrinsic valuations, and perceptions of lessons. Low-aspiring girls reported the least favorable views of their mathematics/physics education of all four gender aspiration groups. Findings were generally similar for mathematics and physics, although students overall responded more favorably to mathematics than to physics. The quantitative findings are illustrated with extracts from longitudinal interviews (ages 15, 16, and 17) of two high-aspiring girls.

RÉSUMÉ

Cet article se penche sur les liens qui existent entre d'une part la volonté d'étudier les mathématiques ou la physique chez les étudiants de 16 ans et plus, et d'autre part la perception qu'ont ces étudiants de leur formation, leurs motivations et le soutien qu'ils estiment avoir reçu. L'analyse se base sur les réponses d'environ 10 000 étudiants de 8e année (12–13 ans), puis de nouveau lorsqu'ils étaient en 10e année (14–15 ans), en Angleterre. Le premier sondage a été effectué en 2008–2009, et le second en 2010–2011. Les tests t montrent qu'il y a eu un déclin dans leur perception de leur formation en mathématiques et en physique. Les analyses factorielles indiquent la présence de construits spécifiques liés à des groupes classés en fonction de leur sexe et de leur niveau d'aspirations (filles hautement motivées, garçons hautement motivés, filles peu motivées, garçons peu motivés). Les filles hautement motivées avaient plus souvent une meilleure opinion de leur formation en mathématiques et en physique, de leur motivation dans ces sujets et du soutien qu'elles avaient reçu, comparativement au groupe des garçons peu motivés. Cependant, les filles plus motivées avaient moins de probabilités d'être encouragées par leurs enseignants et leur famille à poursuivre une formation dans ces sujets que les garçons hautement motivés, et elles avaient également une moins bonne

CONTACT Tamjid Mujtaba t.mujtaba@ucl.ac.uk UCL Institute of Education, University College London, CPA 20 Bedford Way, London, WC1H 0AL, United Kingdom.

image d'elles-mêmes, une évaluation intrinsèque plus basse et une moins bonne perception des leçons. Des quatre groupes, c'est dans le celui des filles peu motivées qu'on trouve la perception la moins favorable de leur formation en mathématiques et en physique. Les résultats se sont généralement avérés comparables pour les mathématiques et la physique, même si, dans l'ensemble, les réponses des étudiants étaient plus positives à l'égard des mathématiques que de la physique. Les résultats quantitatifs sont illustrés au moyen d'extraits provenant d'entrevues longitudinales avec deux répondantes provenant du groupe des filles hautement motivées (soit à 15, 16 et 17 ans).

Introduction

In line with many nations, the UK government has been focusing its efforts to increase the number of science, technology, engineering, and mathematics (STEM) professionals given that advancement in STEM industries is seen as vital for the success of all nations, including the UK (Department for Business, Innovation and Skills, 2009). However, UK practitioners and policy makers have indicated that despite recent increases in the numbers entering STEM courses in postcompulsory education in recent years, there are still problems with the relatively low proportion of students, compared to certain other countries, who continue with STEM subjects in postcompulsory education (e.g., Royal Society, 2011). The UK, along with the United States, Australia, and other Organization for Economic Cooperation & Development countries, is a postindustrial nation that increasingly requires its citizens to compete in a global economy. Given that most STEM subjects (biology is a notable exception) still attract males more than females, education initiatives have been put in place in an attempt to encourage girls to study STEM subjects. However, issues around inequality between the sexes still exist in several areas in UK STEM education. Inequalities exist with respect to participation (e.g., Smith, 2011) and experiences in education (e.g., Archer, DeWitt, Osborne, Willis, & Wong, 2012, 2013; Brandell & Staberg, 2008). Despite girls doing as well as if not better than boys in the sciences and mathematics in compulsory national assessment examinations at age 16 (Joint Council for Qualifications, 2014b) and postcompulsory examinations (Joint Council for Qualifications, 2014a), relatively low number of girls progress on to these subjects when they are no longer compulsory. In 2014 across the UK, 39% of mathematics A-level results were obtained by girls and for physics the equivalent figures was only 21% (Joint Council for Qualifications, 2014a).

Research indicates that there are few differences between girls' and boys' interest in STEM subjects when they are young (Murphy & Beggs, 2005). However, as students get older, boys generally exhibit more positive attitudes toward science (e.g., Sjoberg & Schreiner 2005) and mathematics (Paechter, 2001) than do girls. Analyses of survey responses of 1,300 Swedish secondary school students concluded that there was a marked tendency among students to view mathematics as a gendered domain, with positive aspects associated with boys and negative aspects perceived as more female (Brandell & Staberg, 2008). Many reasons have been suggested for girls' declining aspirations in STEM subjects as they progress through their schooling. For instance, an association between competitiveness in the classroom in secondary education and female anxiety toward mathematics has been documented (Paechter, 2001). In Noyes (2003), the family environment was found to be an important influence (more so than schools) in the way in which students identify with mathematics.

Recent evidence on elementary school students aged between 10 and 11 indicates that though there was little difference between girls and boys with respect to their liking of science, boys were more "keen" on science than girls were (Archer, DeWitt, Osborne, Willis, & Wong, 2012). This research also found that girls from middle-class and largely White or South Asian backgrounds had high aspirations and positive attitudes toward science. These findings suggest that science is still quite an elitist subject, only open to certain types of girls who have the social skills to manufacture a science identity that fits in with their femininity. Such restricted feminine science identities are usually associated with, and open to, those from middle-class backgrounds. Girls from working-class and certain ethnic minority backgrounds who express femininity in a different way are further alienated from science because they have little way of accessing it.

Teachers clearly have an important influence on students' engagement with subjects and future choices. In a longitudinal study, Reiss (2004) found teacher influence to be highly important for whether or not students liked science. Rather worryingly, Zohar and Bronshtein (2005) found that of the 25 science teachers they interviewed in Israel, around half underestimated the severity of the problems around girls' low participation in physics postcompulsory education. Furthermore, they found that around two thirds of their teacher sample did not report that the issue with girls' low participation in physics was a concern that required any action. In addition, nearly all of the teachers were unaware of what they could do to encourage girls to continue with physics and were similarly unaware of how to make the physics learning environment less biased toward boys and more inclusive for girls. There is also evidence that at least some teachers treat girls differently from boys in physics laboratory lessons (e.g., Randall, 1987; Smail, 2000) and that students are aware of teachers' preference for boys in physics classes (e.g., Guzzetti & Williams, 1996). This reinforces stereotypes of physics being associated with being male. If science classrooms continue to use noninclusive teaching methods, then students who do not traditionally choose physics will continue to be sidelined.

Similar findings around the importance of teachers and how they need overtly to engage with girls to increase girls' liking and engagement in mathematics have been reported (e.g., Brandell & Staberg, 2008). Leedy, LaLonde, and Runk (2003) found that students' beliefs about mathematics and how students identify themselves as learners of mathematics are crucially impacted by the way in which the subject is taught. A study in Wales found that girls are generally less likely to report feelings of anxiety and a lack of confidence in mathematics in smaller classes, where there is less teacher turnover and, perhaps counterintuitively, where teachers of mathematics are male (Cann, 2009).

Of course, teachers are not the only important factor influencing how girls feel about school subjects. The curriculum can be important, with girls being more likely to prefer context-based and real-life approaches to STEM subjects (Bennett, Lubben, & Hogarth, 2006). In addition, certain forms of summative assessment typically favor one sex rather than the other, with girls being more likely to do well on answers that require prose rather than box ticking (Goldberg & Roswell, 2002).

A large body of research explores students' attitudes and perceptions of science and mathematics by relying on quantitative survey methods (e.g., Asante, 2012; Lovelace & Brickman, 2013). Although these methods are extremely helpful in exploring the relative importance of different aspects of attitudes toward mathematics and science, large-scale surveys have, to date, been less successful at revealing why it is that some students go against the grain and choose these subject. There have, though, been useful insights from qualitative studies as to why this is the case (e.g., Boaler, 2009; Osborne & Collins, 2000). For example, Boaler (2009) showed that many students engage much more with mathematics and produce better quality work when they work in groups, are given open-ended tasks, and have time to think through challenging problems.

The context of this study

This article explores issues around gender, perceptions, social influences, motivations, and attitudes in relation to aspirations to continue with mathematics and/or physics post-16. There is a fair amount of work in mathematics and science education that refers to extrinsic factors affecting choices and achievement (e.g., Archer, DeWitt, Osborne, Willis, & Wong, 2012; Boaler, 2009), though there has been little focus on the relationship between intrinsic (and extrinsic) factors, attitudes, social influences, and school influences in subject choice within the same study. We designed student surveys to include items derived from established psychological constructs as well as our own items so that possible relationships between social influences, self-concept, and intrinsic and extrinsic factors could be explored. Research tends to focus on overall differences between boys and girls, rather than examining within-gender group variation and between-gender group overlap; our findings indicate that there are important differences among girls in terms of how they view physics (Mujtaba & Reiss, 2013b) and mathematics (Mujtaba & Reiss, 2016).

The purpose of this article is to explore issues connected with the low levels of post-16 mathematics/physics aspirations in many girls. The research question we seek to address is therefore, "What factors contribute to the low levels of post-16 mathematics/physics aspirations in many girls?" We have been unable to find previous research that (a) compares girls with high mathematics/physics aspirations with girls who do not have such aspirations and (b) examines how these groups differ from boys. This article will also highlight problems faced by girls regardless of their aspirations and discusses when it is useful to talk about specific issues related to gender as opposed to those related to aspirations irrespective of gender.

Methodology

The data are drawn from the Understanding the Participation Rates in Mathematics and Physics (UPMAP) project, which explored a range of influences on student choice. The quantitative element of the study surveyed the responses of several cohorts of students in England aged 12–15. This article focuses on around 10,000 Year 8 students who were followed through from 2009 when they were in Year 8 through to Year 10 (in 2011). In Year 8, we employed separate mathematics and physics surveys and only around 30% of the students filled out both surveys. We therefore decided in the administration of the Year 10 survey to have just one survey that included questions on both mathematics and physics.

In order to explore issues around gender aspirations, the answers from the questions, "I intend to continue to study maths after my GCSEs [General Certificate of Secondary Examinations]"[1] and "I intend to continue to study physics after my GCSEs" in the Year 8 (2009) survey were each cross-related with gender to create four gender aspiration groups. Our total physics sample contained 4,762 students for whom we had aspiration and gender records: 29.2% (1,392) high-aspiring boys, 31.6% (1,504) high-aspiring girls, 15.5% (736) low-aspiring boys, and 23.7% (1,130) low-aspiring girls. Our total mathematics sample was 5,119 students in 2009, which broke down into the following categories: 36.1% (1,848) high-aspiring boys, 41.8% (2,138) high-aspiring girls, 8.7% (446) low-aspiring boys, and 13.4% (687) low-aspiring girls. High-aspiring students are those who strongly agreed or agreed with the statement, "I intend to study physics (or mathematics) after the age of 16." Low-aspiring students are those who strongly disagreed or disagreed with the statement "I intend to study mathematics (or physics) after the age of 16." Throughout this article we use the phrases high-aspiring and low-aspiring only in relation to mathematics and/or physics. We do not imply that students with low aspirations for these subjects have them for other subjects too.

Our analysis explored how the Year 8 aspirations of students in both subjects related to their perceptions of their Year 8 and Year 10 mathematics/physics education, their motivation in these subjects, and the support they received in these subjects. All explorations of our survey data are through the use of statistical tests; for example, correlation analyses.

Our school samples (from England) were above average in either or both average mathematics/physics attainment and post-16 participation, given that the focus of the study is to find factors that influence post-16 participation. Similarly, our student sample attempted to exclude those who were predicted by their teachers to get less good grades (lower than grade D) in GCSE mathematics and physics/science. Although all barriers to participation are important, this study focuses on factors that affect the choices of those students who have the opportunity, including fulfillment of attainment criteria, to study mathematics or physics post-16. We therefore only wanted to sample students for whom there was a realistic chance of going on to study physics or mathematics post-16. Such participation is most unlikely in students not predicted to get grades A*–D.

The UPMAP surveys included constructs (with their constituent items) that measured the encouragement that students reported for continuing with mathematics/physics post-16; students were asked such questions in 2009 and again in 2011. The surveys included mathematics/physics-specific items to determine attitudes toward each subject, attitudes toward lessons, perceptions of teachers, support for learning, social influences in choice, and intrinsic and extrinsic motivation for learning. We acknowledge that some students, particularly in Year 8, may not have been clear which aspects of science were physics and which were not. This is partly because in some schools science at Year 8 (much less often at Year 10) is taught as an integrated subject—though the fact that the National Curriculum clearly distinguishes between the various disciplines within science means that this is less of an issue than it would have been in some schools 20 years earlier. A related point is that when we refer to *physics teachers*, this should be understood to mean *teachers of physics*. Though such teachers nearly always have a science degree, there is a shortage of specialist physics teachers in schools in England so that it is not unusual, even in Year 10, for a student to be taught physics by a science teacher who does not have a specialism in physics.

The student questionnaires went through several rounds of design and piloting in 2009 and 2011. A factor analysis using principal components affirmed many of the constructs but also led to some modifications. 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. Items/constructs reported in this article utilize a 6-point Likert scale. The final questionnaires can be downloaded from the project website (http://www.ucl.ac.uk/ioe/research/featured-research/upmap); the methodology surrounding the setup of the survey and how it fits within the wider project is provided in Reiss et al. (2011). An explanation of what each construct measures is provided below along with its corresponding analysis. The Appendix details the items for each construct.

To help illustrate the quantitative findings on high-aspiring girls, this article uses qualitative data from a total of six semistructured interviews with two high-aspiring and high-attaining girls (one interview with each girl in Years 10, 11, and 12). Interview data were collected from 52 students in Year 10 and for a third of these we had data at both Year 11 and Year 12. For the purpose of this article, an in-depth thematic analysis has not been conducted and presented; rather, the qualitative data are used to illuminate the quantitative findings and to suggest future lines for research. Each interview lasted approximately 30 min and was audio-taped and transcribed. Rhoda, of dual-heritage Black Caribbean and British White background, chose mathematics and physics as A-levels,[2] mainly because she wanted to get into the Royal Air Force (RAF); a fascination with aeroplanes grew out of day trips with her father that focused on planes. Amber, a second-generation British Pakistani, chose physics at A-level but decided not to do mathematics A-level, despite getting the top grade (an A*) in her GCSE mathematics examination at age 16, because she felt that she was not good enough; at the time of her Year 12 interview she regretted this decision. Both girls were at a mixed-sex, 11–18, inner-city grammar school that was ethnically diverse.

Results

Levels of mathematics and physics self-concept at ages 12 and 14

The mathematics/physics self-concept is a construct that consists of five items; for example, "I am good at maths" (see Appendix for the times that make up the constructs). For mathematics, there were statistically significant differences both in Year 8 and in Year 10 between the four gender aspiration groups: Year 8, F (3, 5114) = 9,306.710, $p < .001$, $\eta^2 = 0.390$, and Year 10, F (3, 2381) = 90.748, $p < .001$, $\eta^2 = 0.320$. High-aspiring girls had a lower self-concept than high-aspiring boys but a higher self-concept than low-aspiring boys and girls. However, at Year 10 there were no differences in the self-concepts of high-aspiring girls and low-aspiring boys (though the difference remained between high-aspiring girls and low-aspiring girls). High-aspiring boys had a higher self-concept than high-aspiring girls at both ages (see Table 1). Though there was a decline in the self-concept of most student groups, a *t*-test indicated that there was a statistically significant increase in the self-concept of low-aspiring mathematics boys between the ages of 12 and 14 (from 3.64 to 3.87, $p < .001$). The student interviews demonstrated how girls could doubt their own ability despite being high achievers. We found that the self-concepts of both of our interviewees in mathematics and physics may have been impacted by their perceptions of their academic environments. Rhoda reported in her Year 12 interview:

> I got an A in maths [at GCSE]; I wasn't expecting that at all. … I did well in all my sciences and I got an A in chemistry and A*s in the other two. I found maths and physics quite challenging [at A-level], whereas before I could just turn up for the exams [meaning at GCSE] but now I have to study a lot harder … my maths isn't going well at all, I can't keep up with the class and I don't understand lot of the stuff … it's going a lot better now, we aren't doing two [modules] at once and we have a better teacher.

Table 1. Mathematics Year 8 and Year 10 student survey responses by gender aspiration group.

Measure		High-aspiring boys			High-aspiring girls			Low-aspiring boys			Low-aspiring girls			Bonferroni post hoc difference(s)*			Effect size
		N	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*	HG–HB	HG–LB	HG–LG	
Advice–pressure to study	Year 8	1,830	4.82	0.96	2,122	4.73	0.96	433	3.13	1.35	675	3.31	1.25	*	***	***	0.522
	Year 10	824	4.64	1.08	922	4.36	1.16	167	3.86	1.34	265	3.58	1.34	**	***	***	0.288
Home support for achievement	Year 8	1,740	5.03	0.83	2,058	4.85	0.85	399	4.25	1.18	656	4.14	1.14	***	***	***	0.330
	Year 10	819	4.62	0.78	938	4.33	0.81	157	4.23	0.83	269	4.02	0.93	**		***	0.237
Extrinsic material gain motivation	Year 8	1,847	5.12	0.64	2,138	4.98	0.64	446	4.16	1.03	686	4.17	0.83	***	***	***	0.464
	Year 10	891	5.01	0.78	1,005	4.81	0.75	196	4.64	0.92	293	4.44	0.88	*	***	***	0.226
Extrinsic social gain motivation	Year 8	1,782	3.35	1.14	2,088	3.20	1.04	422	2.43	1.10	668	2.49	0.94	***	***	***	0.300
	Year 10	848	3.13	1.19	976	3.01	1.02	185	2.79	1.26	284	2.74	1.06			*	0.121
Intrinsic value	Year 8	1,829	4.46	0.80	2,127	4.23	0.79	425	3.47	0.97	676	3.44	0.81	***	***	***	0.423
	Year 10	891	4.23	0.89	1,002	3.98	0.86	196	3.71	1.03	292	3.57	0.94	*	***	***	0.239
Self-concept	Year 8	1,848	4.48	0.89	2,138	4.11	0.89	446	3.64	1.06	686	3.32	1.04	***	***	***	0.390
	Year 10	892	4.27	0.88	1,004	3.81	0.95	196	3.87	1.06	293	3.27	1.09	***		***	0.320
Perceptions of lessons	Year 8	1,833	4.41	0.87	2,127	4.29	0.83	440	3.24	1.01	682	3.37	0.92	**	***	***	0.444
	Year 10	876	4.31	0.96	979	4.15	0.89	186	3.78	1.02	288	3.66	1.01	*	***	***	0.229
Emotional response to lessons	Year 8	1,827	4.22	0.94	2,127	4.07	0.93	438	3.55	0.99	681	3.51	0.91	***	***	***	0.272
	Year 10	872	4.03	1.04	975	3.88	0.98	182	3.62	1.08	286	3.53	1.07	*	***	***	0.161
Perceptions of teachers	Year 8	1,829	4.73	0.88	2,124	4.72	0.88	440	4.17	1.14	681	4.28	1.03		***	***	0.216
	Year 10	872	4.61	0.95	976	4.58	0.89	181	4.32	1.07	286	4.38	0.91		**	*	0.105

Note. Post hoc comparisons are high-aspiring girls with high-aspiring boys, low-aspiring boys, and low-aspiring girls; measures use a scale of 1 (*strongly disagree*) to 6 (*strongly agree*). a HG = high-aspiring girls; HB = high-aspiring boys; LG = low-aspiring boys; LB = low-aspiring girls. * $p < .05$. ** $p < .01$. *** $p < .001$.

It appears that Rhoda's perceptions of her teacher had a knock-on effect on her mathematics self-concept.

In line with the findings for mathematics, 12-year-old high-aspiring boys had higher physics self-concepts than high-aspiring girls (the patterns remained the same 2 years later; Table 2); high-aspiring girls reported statistically significantly higher self-concepts than low-aspiring boys and girls. However (unlike with mathematics), 2 years later, high-aspiring girls had lower physics self-concepts than low-aspiring boys (see Table 2). Together these data suggest that despite girls' high aspirations and high self-concepts at Year 8 there is a substantial decrease by Year 10 in both subjects, particularly for physics.

In Amber's Year 12 interview she said:

> I got an A* at GCSE [in mathematics] but I think I would've struggled at A-level … decided not to do it in the end as I didn't think I needed it. I got an A* in physics, I don't know how I did that, though everyone kept saying 'you are good', I didn't think so. … I think I'm going to fail this year [in physics], I haven't learnt anything, I fall asleep in class, the lessons are boring and the teacher is dry.

It was evident from Amber's interview that she felt that her physics teacher failed to engage her. This seems to have been associated with Amber's decreased self-concept, despite her high ability level. She accepted a place at university to study a biology-related course but said, "But physics is fascinating … it's sad to leave it behind." She had evidently not dropped her relationship with physics. As a first-year undergraduate she began privately to teach A-level physics and was mentored by her brother (a well-established science tutor).

Levels of mathematics and physics extrinsic material gain motivation at ages 12 and 14

Mathematics and physics extrinsic material gain motivation measures students' perceptions that continuing with mathematics after the age of 16 would be useful for some tangible reward; for example, for access into higher education or employment prospects. An example of such an item is, "I think maths will help me in the job I want to do in the future." For mathematics (Table 1) and physics (Table 2), high-aspiring girls reported lower levels of extrinsic material gain motivation than high-aspiring boys at Year 8 (and this continued 2 years later); these girls reported higher levels of motivation than low-aspiring boys and girls. The Year 10 results indicated that there was no difference in the physics extrinsic material gain motivation of high-aspiring girls and low-aspiring boys but that for mathematics the Year 8 difference remained at Year 10.

The qualitative work highlights how extrinsic material gain motivation relates to the choices of high-aspiring girls. In Amber's case she was very well aware of the extrinsic material gain of having a STEM qualification, and such knowledge played a crucial part in her degree choice, as such, she reported deciding for intrinsic reasons: "a decision based on enjoyment." In Rhoda's case her choice of mathematics A-level was for extrinsic reasons; she did not express a real liking for mathematics. Just as Amber spoke about subjects being related to future careers, Rhoda said in her Year 10 interview, "I need it [subject choice] for what I want to do in the RAF: maths and physics. But I like physics." In her Year 11 interview she pretty much said the same thing: "I chose the A-levels because I think I'll need maths because whatever I want to do, you'll need maths and I'm interested in physics."

Levels of mathematics and physics social gain motivation at ages 12 and 14

Mathematics and physics extrinsic social gain motivation measures students' perceptions that studying mathematics or physics is useful for some tangible social reward; for example, to help increase their popularity; an example of an item from this construct is, "Being good at maths makes you popular." For mathematics, high-aspiring 12-year-old girls reported lower levels of extrinsic social gain motivation than high-aspiring boys (see Table 1); 2 years later at the age of 14 the difference had disappeared. However, girls with high mathematics aspirations at the age of 12 reported higher levels of extrinsic social gain motivation than low-aspiring boys and girls, and these trends continued through to Year 10.

Table 2. Physics Year 8 and Year 10 student survey responses by gender aspiration group.

Measure		High-aspiring boys			High-aspiring girls			Low-aspiring boys			Low-aspiring girls			Bonferroni post hoc difference(s)*			
		N	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*	HB–HG	HG–LB	HG–LG	Effect size
Advice–pressure to study	Year 8	1,361	4.23	1.23	1,477	4.17	1.19	717	2.68	1.25	1113	2.80	1.20		***	***	0.502
	Year 10	560	4.36	1.07	604	3.78	1.22	260	3.71	1.31	435	3.23	1.22	***		***	0.330
Home support for achievement	Year 8	1,213	4.71	1.08	1,358	4.50	1.05	590	3.79	1.36	983	3.73	1.22	***	***	***	0.345
	Year 10	581	4.41	0.88	632	4.06	0.88	271	4.05	0.94	463	3.83	0.93	**		***	0.233
Extrinsic material gain motivation	Year 8	1,392	4.48	0.81	1,502	4.38	0.75	734	3.33	1.03	1,130	3.40	0.85	*	***	***	0.526
	Year 10	627	4.56	0.81	670	4.26	0.86	304	4.18	0.92	501	3.91	0.89	***		***	0.266
Extrinsic social gain motivation	Year 8	1,300	3.15	1.19	1,422	3.03	1.05	670	2.34	1.08	1,068	2.41	1.03		***	***	0.303
	Year 10	596	3.01	1.11	645	2.93	0.99	289	2.74	1.05	481	2.79	0.99				0.100
Intrinsic value	Year 8	1,370	4.56	0.86	1,485	4.32	0.79	715	3.76	1.08	1,115	3.70	0.91	***	***	***	0.378
	Year 10	626	4.45	0.88	666	4.01	0.88	304	4.09	0.94	501	3.73	0.85	***		***	0.291
Self-concept	Year 8	1,389	4.33	0.90	1,498	3.91	0.86	734	3.50	1.11	1,127	3.24	0.96	***	***	***	0.408
	Year 10	628	4.21	0.90	668	3.47	0.93	303	3.78	0.99	502	3.09	1.01	***	*	***	0.410
Perceptions of lessons	Year 8	1,364	4.40	0.93	1,479	4.25	0.91	718	3.42	1.12	1,112	3.42	0.98	***	***	***	0.416
	Year 10	616	4.32	0.97	655	3.88	0.95	296	3.95	1.00	489	3.51	0.94	***		***	0.297
Emotional response to lessons	Year 8	1,349	4.11	1.02	1,465	4.04	0.93	708	3.78	0.99	1,105	3.55	0.94		***	***	0.226
	Year 10	614	4.14	0.98	614	4.14	0.98	295	3.87	0.97	487	3.42	0.97	***		***	0.268
Perceptions of teachers	Year 8	1,359	4.61	0.99	1,469	4.62	0.95	710	4.08	1.23	1,106	4.24	1.06		***	***	0.206
	Year 10	615	4.52	0.94	653	4.42	0.85	293	4.39	0.94	484	4.27	0.90			**	0.104

Note. Post hoc comparisons are high-aspiring girls with high-aspiring boys, low-aspiring boys, and low-aspiring girls; measures use a scale of 1 (*strongly disagree*) to 6 (*strongly agree*). a HG = high-aspiring girls; HB = high-aspiring boys; LG = low-aspiring boys; LB = low-aspiring girls. * $p < .05$. ** $p < .01$. *** $p < .001$.

The trends were a little different for physics (see Table 2). At Years 8 and 10, high-aspiring girls had similar levels of extrinsic social gain motivation to high-aspiring boys. At Year 8, high-aspiring girls had higher levels of extrinsic social gain motivation than low-aspiring boys and girls, although by Year 10 this difference had disappeared. Of all groups, boys with high aspirations had the highest social gain motivation.

Levels of mathematics and physics intrinsic value at ages 12 and 14

Students who demonstrate an intrinsic value for mathematics/physics find the subject enjoyable or interesting and agree with items such as, "I think maths is an interesting subject." There were seven items within this construct. High-aspiring girls had higher levels of mathematics intrinsic value than low-aspiring boys and girls at the age of 12 and then again at the age of 14. At Year 8 and 2 years later at Year 10, high-aspiring boys had significantly higher levels of mathematics intrinsic value than high-aspiring girls.

For physics (Table 2), at Year 8 high-aspiring girls had significantly higher levels of physics intrinsic value than low-aspiring boys; however, by Year 10 there was no statistically significant difference. High-aspiring girls reported lower levels of physics intrinsic value than high-aspiring boys at both Year 8 and Year 10.

Rhoda did not value mathematics intrinsically but did choose physics. In her Year 11 interview she said, "I'm good at physics and I like it [a statement which also mirrored those in her Year 10 and Year 12 interviews], and I was always going to take that for A-level because I read some of the A-level textbooks last year." In interviews, we asked students about their earliest memory of both subjects and the responses appeared to connect with their current choices. Rhoda's Year 12 account continued the story she related in Year 10 about her father and her fascination with planes:

> … in Year two … I wanted to be a pilot … because I liked Concorde, my mum told me I had to do maths because you need maths to be a pilot so I started to work on it, just reading at the back of the class. … I used to go to Heathrow Airport Visitors Centre a lot back before it closed. There was a lot of flight display on how planes fly so maybe from five until nine or ten, there are memories of that nearly every other week [she would watch them whilst her father was working].

Amber also expressed passionately her love of physics in Year 11 though there was no clear indication of where this came from: "I find physics fascinating, it's here and now and it's tomorrow … the only problem with doing physics at university is having to do maths." In her Year 12 interview she said:

> I'm not sure why physics and not chemistry … chemistry was all around me when I was about six or seven. My brother would come back from uni in the holidays and do experiments, explode things in the garden, my other brother was a school chemistry assistant … my sister's birthday presents [i.e., to Amber] would consist of a mismatch of girly things with boys stuff. One birthday she gave me a fancy Victorian-looking doll with a chemistry set and a football, the football was the best. … I can't remember anything about physics.

Perceptions of mathematics and physics lessons at ages 12 and 14

Students were asked seven survey questions about their perceptions of their mathematics and physics lessons. The items explored whether they saw the relevance of their lessons and what opportunities they had for learning; for example, "In my maths lessons, I have the opportunity to discuss my ideas about maths." Girls with high aspirations for mathematics reported less positive perceptions of their Year 8 mathematics lessons than did high-aspiring boys but significantly more positive perceptions than did low-aspiring boys and girls; the findings were also similar for physics (see Table 1). Two years later, at Year 10, these trends remained for mathematics. For physics, though, the difference between high-aspiring girls and low-aspiring boys had disappeared, although high-aspiring girls continued to have more positive perceptions of their Year 10 physics lessons than did low-aspiring boys and girls.

Rhoda attributed the problems she was having with her GCSE mathematics to her own shortcomings:

> To be honest I think it's me. … I think I could do more time in places, it seems like we are going to do two modules in two weeks of the course and that's too fast so you have to go back and study on your own and not studying for what's coming up so it's like you are always playing catch with yourself.

Rhoda's self-blame was despite the fact that there may have been an issue to do with the structure of the GCSE course that impacted her:

> I had two teachers and there was a split and we did statistics with one and core with the other so we would be doing two sets of homework in one week so I would get confused with the stuff we were doing.

Exploring the perceptions of high-aspiring girls in more detail, our Year 12 interview with Amber demonstrated that despite enjoying physics, she felt that her teacher and the way the curriculum was delivered were not helping to engage her:

> I really enjoy physics, physics is fascinating but this year I am finding it difficult to concentrate, I fall asleep in class … the boys shout out answers or talk about non-physics things and I get put off. There are only a few of us [girls] and Sir puts all the girls at the front but it's not the boys, his teaching is boring, I'd rather watch paint dry. … I wanted to do physics [at A-level] for the astronomy but we haven't even covered that. … I thought I wanted to do veterinary science at uni though I realised this year I think I want to carry on with physics at uni but I didn't carry on with maths so I can't now.

Emotional response to mathematics and physics lessons at ages 12 and 14

Students were asked four survey questions about their emotional response to their mathematics and physics lessons; for example, "When I am doing mathematics, I get upset." Girls who had high aspirations for mathematics in Year 8 reported less positive emotional responses to their Year 10 mathematics lessons than did high-aspiring boys and had significantly more positive perceptions than did low-aspiring boys and girls; Year 8 aspirations continued to have a similar association with Year 10 emotional response to mathematics lessons (see Table 1).

The trends for emotional responses to physics lessons were somewhat different than those for mathematics. It was evident that girls with low aspirations at Year 8 appeared to be disadvantaged in their physics lessons compared to all other student groups. At Year 8, boys and girls with high aspirations for physics had similar emotional responses to their physics lessons but by Year 10 differences had set in, with boys being more positive (Table 2). In addition, although at Year 8 high-aspiring girls reported more positive emotional responses to physics lessons than did boys and girls with low aspirations, by Year 10 these differences had disappeared. In addition, at Year 10 girls with high aspirations experienced the classroom similarly to boys with low aspirations (high-aspiring boys continued to report more positive responses at Year 10).

Perceptions of mathematics and physics teachers at ages 12 and 14

Perceptions of teachers were found to be an important issue linked to students' aspirations. Amber described a complex set of feeling she had about science:

> In Year 8 I got into trouble as I was late for an extra science class I didn't know at first I had to go to. You only went to those if you were labeled a concern; if you weren't a concern you could do other interesting things; I did football. When I tried to explain to my teacher she shouted at me and called me a "demented butterfly" and everyone laughed; she also told me to drop football to do extra science classes; she said I was not doing well, I thought I was doing fine. … When I got home I told my sister, she asked to see my reports and homework book. … The next day she spoke to the Head of Science about my science teacher and the damage to my self-esteem. … To this day the only grade I can remember from any time at school is that B+. … I got to keep football practice after the meeting … with no need for extra science classes. … I never had a problem with being labeled as bad in science again … though this was the first and only time I was worried about grades … not being good enough … and thought about the problems of not being in the top set.

Amber's interview extract highlights the importance, at least for some students, of their subject teachers for their confidence and perceptions of science. It seems clear from Amber's interview that she did not have a strong science self-concept and, though it is difficult to determine with confidence any causal links, the extract suggests how teachers can unknowingly create anxieties for students.

The Year 8 data indicated that girls with high aspirations in mathematics reported similarly to boys with high aspirations about their perceptions of their mathematics teacher. High-aspiring girls did report more positive perceptions of their mathematics teacher than did girls and boys with low aspirations (see Table 1), and these trends continued in Year 10, F (3, 2,311) = 8.506, $p < .001$, $\eta^2 = 0.105$.

The findings for the physics survey were somewhat different. At Year 8 girls and boys with high aspirations responded similarly about their perceptions of physics teachers, and these trends continued through to Year 10. Although high-aspiring girls responded more positively about their physics teachers than did low-aspiring boys (and girls) at Year 8, F (3, 4,640) = 68.683, $p < .001$, $\eta^2 = 0.206$, by Year 10 there was no difference between high-aspiring girls and low-aspiring boys, suggesting that the classroom environment disadvantaged high-aspiring girls. However, high-aspiring girls had more positive perceptions of their teachers than did low-aspiring girls both at Year 8 and at Year 10.

Advice/pressure to study mathematics and physics at ages 12 and 14

The constructs advice/pressure to study mathematics (or physics) consisted of five items that measured students' reported perceptions about who encouraged them to study mathematics (or physics) after the age of 16. The items measured the influence of teachers, friends, and family; an example of such items is, "My teacher thinks that I should continue with maths beyond my GCSEs." At Year 8, high-aspiring girls reported receiving more advice/pressure to study mathematics than did low-aspiring students, highlighting that there is a difference between some girl groups and some boy groups (see Table 1). However, high-aspiring girls reported receiving less advice/pressure to study mathematics than did high-aspiring boys, and this was also the case 2 years later at Year 10. At Year 10 low-aspiring students reported an increase in the advice/pressure to study mathematics; for low-aspiring girls this increased by 0.25 points, whereas for low-aspiring boys it increased by 0.74 points. Despite these increases (and the slight decrease reported by both high-aspiring girls and boys), high-aspiring girls still reported higher levels of advice/pressure to study mathematics at Year 10 than did low-aspiring boys. There were differences reported at both Year 8 and Year 10 between high-aspiring boys and girls in favor of boys.

The findings for physics were somewhat different (see Table 2). At the age of 12, girls with high aspirations to study physics reported similar levels of advice/pressure to study physics as boys with high aspirations. However, by the age of 14, girls with high aspirations to study physics reported lower levels of advice/pressure to study physics than did boys with high aspirations, F (3, 1,855) = 75.647, $p < .001$, $\eta^2 = 0.330$. The decline in high-aspiring girls' advice/pressure to study physics was also apparent when compared to the levels of advice/pressure to study physics reported by low-aspiring boys. At the age of 12, low-aspiring boys reported lower levels of advice/pressure to study physics than did high-aspiring girls, but by the age of 14 there was no statistically significant difference between the two groups. The most disadvantaged group was low-aspiring girls; they continued to have lower levels of advice/pressure to study physics than did high-aspiring girls (as well as the boy groups).

The qualitative data suggest that for some students, talking to teachers about choices was really important; for others it was not so or perceived not to be so because they received advice from elsewhere. In Rhoda's Year 10 interview she reported that she did not speak about post-16 subject choices to her teachers, though she did to friends (as she reiterated in her Year 12 interview). Her family were reported as influencing her choices through activities rather than by talking about choices. She said in Year 10 about her father's influence on her subject choice: "A little bit, my dad's very interested in planes and stuff, so I went to a lot of the air shows and things, so that probably influenced me a bit." Her childhood experiences were seen as influencing her intended choices at Year 10, and the effects of these were still evident in Year 12 where she chose mathematics and physics to help her with her ambition of joining the RAF. In Amber's Year 12 interview she said of her family:

> … there wasn't a month, sometimes weeks, where I would be asked how I was doing at school [in sciences and mathematics] and how that relates to my future. There were points when I felt I couldn't do well. … I compared myself to my brothers who did well without revision; they are naturals, whereas I have to work. … My sister would say, "Some boys like to pretend they are naturally good at things but you are as good if not better, girls are just less confident." … Everyone [family] always talk about what career I could have with the sciences … everyone says I am good at everything so it became a decision based on enjoyment. … Was told I should continue with it [maths] but didn't see a purpose till now. I did consider for some weeks doing theology but I was told to do it as a hobby as it wouldn't lead to a sound career. … I've chosen veterinary science [degree choice] but a part of me wishes I'd done maths so I could think about carrying on with physics instead.

Amber's interview spells out how she may have been bound for a science career from the start; she was in many respects molded to continue on the science trajectory and was consistently told about the extrinsic value of having a STEM qualification.

Findings from the interviews indicated that the advice students received about whether or not to continue on with mathematics or physics was sometimes felt to be an important element in helping them decide, though the role played by teachers and career staff varied. For example, Rhoda said:

> I talked about it [subject choices] with my friends … but we didn't talk much to the staff; they said take it but no official stuff. … I got one interview [with a careers advisor] but it was more I told them what I wanted to do and they said, "OK, carry on"; they didn't give me much advice.

Amber reported similar experiences:

> You'd get the same from all teachers—"Take my subject"—but nothing in depth, no real encouragement or feeling they believed in you. … I had lots of chats with people in my family about choices though that was difficult, too; my brother was insisting on how important maths was for future careers, which was opposite to other advice I got.

Home support for mathematics/physics achievement at ages 12 and 14

The construct home support for mathematics/physics achievement consisted of five items that measured the reported support students received from their families in learning mathematics (or physics); an example of an item from this construct is, "Someone in my family wants me to be successful at school in maths." At the age of 12, high-aspiring girls reported receiving more home support for mathematics achievement than did low-aspiring students. Girls with high aspirations to study mathematics reported lower levels of advice/pressure to study mathematics than did boys with high aspirations both at the age of 12 (see Table 1) and 2 years later at the age of 14. By the age of 14, low-aspiring boys reported similar levels of home support for mathematics achievement as high-aspiring girls.

The findings within the physics survey indicated that 12-year-old girls with high aspirations to study physics reported lower levels of home support for physics achievement than did boys with high aspirations; these trends continued 2 years later at the age of 14. At the age of 12, and again at age 14, high-aspiring girls reported receiving more home support for physics achievement than did low-aspiring students at age 12, although by age 14 there was no difference between high-aspiring girls and low-aspiring boys because both groups reported receiving an equivalent amount of support.

Overall changes in attitudes between years 8 and 10

The descriptive statistics in Tables 3 and 4 present the overall mean in mathematics and physics constructs at both Year 8 (age 12) and Year 10 (age 14) alongside how the Year 8 and Year 10 constructs correlate with one another within the respective surveys. Overall, the means and *t*-test analysis indicate that although students were positive about their attitudes toward and perceptions of their mathematics and physics education at Year 10, when compared to their reported responses at Year 8, both their attitudes and perceptions decreased. The correlations between the two time points also suggest a moderate relationship. Therefore, for example, at Year 8 students reported an average of 3.90 for the construct emotional response to physics lessons; this had declined to 3.76 at Year 10. A series of paired sample *t*-tests was conducted for the students for whom we had both Year 8 and Year 10 survey data in order to explore

Table 3. Changes and relationship between mathematics constructs at Year 8 and Year 10 for the entire cohort.

	Year group	Mean	*N*	*SD*	*t*-value	Correlation
Advice–pressure to study mathematics	Year 8	4.47	3,250	1.17	5.870***	0.355***
	Year 10	4.33		1.22		
Extrinsic material gain motivation	Year 8	4.83	3,505	0.75	4.368***	0.393***
	Year 10	4.77		0.84		
Intrinsic perceived value of mathematics	Year 8	4.10	3,472	0.87	3.584***	0.408***
	Year 10	4.04		0.93		
Self-concept	Year 8	4.14	3,506	0.98	13.239***	0.533***
	Year 10	3.93		1.01		
Perceptions of mathematics lessons	Year 8	4.15	3,381	0.90	0.330 n/s	0.385***
	Year 10	4.14		0.99		
Emotional response to mathematics lessons	Year 8	4.01	3,353	0.96	7.147***	0.321***
	Year 10	3.87		1.04		
Home support for achievement in mathematics	Year 8	4.69	3,062	0.95	21.501***	0.426***
	Year 10	4.31		0.87		
Extrinsic social gain motivation	Year 8	2.71	2,911	1.11	9.012***	0.284***
	Year 10	2.93		1.05		
Perceptions of teachers	Year 8	4.65	3,362	0.88	4.027***	0.248***
	Year 10	4.58		0.94		

Note. n/s $= p > .05$; ***$p < .001$.

whether the declines were statistically significant. The analysis was conducted separately for students as learners of mathematics and of physics. The analysis indicated that there was as a statistically significant decline in 12-year-olds' perceptions of their physics education over a 2-year period for a number of constructs: emotional response to physics lessons (from 3.90 in Year 8 to 3.76 in Year 10); perceptions of physics lessons (from 3.94 in Year 8 to 3.88 in Year 10); and perceptions of physics teachers (from 4.41 in Year 8 to 4.36 in Year 10). Despite this decline, there was an increase in students' perceptions of support between Years 8 and 10 as measured by advice–pressure to study physics (from 3.60 in Year 8 to 3.74 in Year 10); however, there was an overall decrease in students' perceptions of home support for achievement in physics (from 4.15 in Year 8 to 3.99 in Year 10). Students' physics extrinsic material gain motivation increased (from 3.96 in Year 8 to 4.17 in Year 10), as did their extrinsic social gain motivation (from 2.71 in Year 8 to 2.93 in Year 10). There was no change in the intrinsic value in physics over the 2 years but there was a decline in the physics self-concept (from 3.81 in Year 8 to 3.60 in Year 10).

Table 4. Changes and relationship between physics constructs at Year 8 and Year 10 for the entire cohort.

	Year group	Mean	*N*	*SD*	*t*-value	Correlation
Advice–pressure to study physics	Year 8	3.60	2,922	1.36	4.667***	0.299***
	Year 10	3.74		1.26		
Extrinsic material gain motivation	Year 8	3.96	3,255	0.96	11.166***	0.364***
	Year 10	4.17		0.95		
Intrinsic perceived value of physics	Year 8	4.10	3,219	0.91	0.533 n/s	0.346***
	Year 10	4.09		0.96		
Self-concept	Year 8	3.81	3,261	1.02	11.549***	0.464***
	Year 10	3.60		1.07		
Perceptions of physics lessons	Year 8	3.94	3,118	1.02	2.694**	0.335***
	Year 10	3.88		1.05		
Emotional response to physics lessons	Year 8	3.90	3,080	0.96	6.712***	0.297***
	Year 10	3.76		1.01		
Home support for achievement in physics	Year 8	4.15	2,716	1.21	6.986*	0.372***
	Year 10	3.99		0.96		
Extrinsic social gain motivation	Year 8	2.71	2,911	1.11	9.01***	0.284***
	Year 10	2.93		1.05		
Perceptions of teachers	Year 8	4.41	3,087	1.00	2.335***	0.247***
	Year 10	4.36		0.96		

Note. n/s $= p > .05$; *$p < .05$; **$p < .01$; ***$p < .001$.

The findings for mathematics were similar to those of physics. There was a statistically significant decline in students' reported perceptions of their mathematics education over a 2-year period for certain constructs: emotional response to mathematics lessons (from 4.01 in Year 8 to 3.87 in Year 10) and perceptions of mathematics teachers (from 4.65 in Year 8 to 4.58 in Year 10) although, unlike physics, there was no change in perceptions of mathematics lessons. In addition, although there was an increase in advice–pressure to study for physics, for mathematics there was a decrease (from 4.47 in Year 8 to 4.33 in Year 10) and there was also a decrease in students' perceptions of home support for achievement in mathematics (from 4.69 in Year 8 to 4.31 in Year 10). Unlike physics, students' mathematics extrinsic material gain motivation for mathematics decreased (from 4.83 in Year 8 to 4.77 in Year 10) although, as with physics, their extrinsic social gain motivation increased (from 2.71 in Year 8 to 2.93 in Year 10). There was a decrease in the intrinsic value in mathematics over the 2 years (from 4.10 in Year 8 to 4.04 in Year 10). There was also a decline in the mathematics self-concept (from 4.14 in Year 8 to 3.93 in Year 10).

Overall differences in responses between mathematics and physics

A *t*-test was conducted on the means for each gender aspiration group comparing their responses for mathematics and physics. For almost every construct and across both years, low-aspiring girls reported more positive responses on the mathematics survey than on the physics survey; all findings were statistically significant at 0.05. The only instances for which girls reported more positive responses on the physics survey than on the mathematics survey were Year 8 intrinsic value and Year 10 intrinsic value. There was no significant difference between the mathematics and physics survey responses for Year 10 social gain motivation, Year 8 perception of lessons, Year 8 perceptions of teachers, and Year 8 emotional response to lessons.

Similarly, for almost every construct and across both years, high-aspiring girls reported more positive responses on the mathematics survey than on the physics survey. The only instances where girls reported more positive responses on the physics survey than on the mathematics survey were Year 10 advice–pressure to study and Year 8 intrinsic value. There was no significant difference between the mathematics and physics survey responses for Year 10 intrinsic value, Year 8 perceptions of lessons, and Year 8 emotional response to lessons.

Discussion

Our research has several significant findings. The survey data collected in Year 8 suggest that extrinsic material gain motivation, perceptions of lessons, and self-concept had the strongest effect sizes associated with gender aspiration groups for both subjects. For mathematics the effect size of intrinsic value of mathematics was also equally strong. The finding for self-concept is particularly important given that our analysis indicated that girls with high aspirations in both subjects in Year 8 had higher self-concepts than all students with low aspirations, but by Year 10 these differences had disappeared for mathematics and for physics, girls' self-concept was lower than that of boys. In general, the findings also suggest that despite high aspirations, boys with high aspirations reported more positively about their motivation, support received, and perceptions of their education than did girls with high aspirations. Leading on from this, girls with low aspirations reported the least favorable responses about their motivation, support received, and perceptions of their education. As students progress through secondary education, girls' perceptions of their mathematics and physics education become more negative (cf. Boaler, 2009). Furthermore, for students overall, there appears to be a decline in their perceptions of their mathematics and physics education at Year 10 compared to their survey responses when they are in Year 8.

Our two interviewed students (Amber and Rhoda) reported having extrinsic material gain motivation as determinants of subject choice. Our analysis in this article demonstrates that at Year 8 and Year 10, high-aspiring girls had lower levels of extrinsic material gain motivation than high-aspiring boys; their motivation was higher than for students with lower aspirations levels. These findings indicate that having high levels of extrinsic material gain motivation may possibly be linked to high aspirations. In our analysis of an older cohort of students within this same project, we have found using linear modeling that there is strong effect size of extrinsic material gain motivation and aspirations to continue with each of these subjects (Mujtaba & Reiss, 2013a; Mujtaba, Reiss, Rodd, & Simon, 2015).

Our analysis demonstrates that high-aspiring girls (in both mathematics and physics) are more positive about aspects of their mathematics and physics education, support received, and motivation than are low-aspiring boys for nearly all survey questions (though we have noted that this is not the case for self-concept). In addition, high-aspiring girls have similar responses to some (but not all) questions about their physics and mathematics education when compared to high-aspiring boys (see Tables 1 and 2). It is quite likely that studies that use quantitative methods and treat girls and boys as homogenous groups (e.g., Brandell & Staberg, 2008) lose important differences within gender groups. It is certainly possible for girls from particular social or ethnic groups to be positive toward STEM subjects (e.g., Archer, DeWitt, Osborne, Dillon, et al., 2012). Our interviewed girls indicated that there were aspects of their mathematics and science/physics education that they were positive about, and both of them expressed their passion for physics although the interviews did not reveal any special support or encouragement they received from teachers. Indeed, Rhoda's interview indicated that teaching styles and teachers' perceptions created mathematics anxiety; Amber's interview similarly revealed the role that teaching played in her negative perceptions of school science. In fact, encouragement to continue with these subjects after compulsory education was in large measure the result of family rather than school factors.

There were key similarities between mathematics and physics with respect to low-aspiring girls. However, boys and girls with low aspirations responded very differently; for example, relative to such girls, boys with low aspirations reported receiving more advice to continue with mathematics/physics (from friends, family, teachers), more home support to study these subjects post-16, higher extrinsic material gain motivation, higher intrinsic value of the subjects, higher self-concept, and greater positive emotional response to lessons.

We do not mean to imply that only teachers are important. Indeed, the above findings show the importance of students being encouraged by family members to continue with mathematics/physics. Furthermore, other factors will be important, such as the curriculum (Homer,Ryder, & Donnelly, 2013), the assessment methods that are used, and the careers advice that students receive. No one, for example, seems to have explained to Amber that she can still study astronomy despite not having done A-level mathematics (by taking a foundation year). It is unfortunately the case in England that school careers advice has decreased over the years and is very rarely science specific.

Despite the significance of other factors, there is clear evidence, not only from this study, of the importance of classroom teachers in student engagement with mathematics and science (e.g., Mendick, 2006; Reiss, 2004; Zohar and Bronshtein, 2005). Our findings illustrate the importance of teachers for both mathematics and physics. However, it appears that girls with high physics aspirations experience teacher support less positively than do boys with high aspirations. For mathematics this was not the case and both groups of students responded in a similar favorable way at both Years 8 and 10. These findings suggest that the classroom environment can disadvantage girls within physics lessons and quite possibly may have an impact on physics subject choice in the longer term. Indeed, our multivariate analysis in another paper of an older cohort of students (within this same project) demonstrated that teachers not encouraging students to continue with physics post-16 was negatively associated with aspirations to study physics post-16 (Mujtaba & Reiss, 2013a, 2013b). More positively, of course, the classroom environment provided by teachers can encourage students to continue with a subject once it is no longer compulsory, and there is now a developing literature that provides specific guidance for classroom teachers (e.g., Institute of Physics, 2015). Indeed, the fact that in England over the years the proportion of the cohort studying mathematics at A-level who are girls has substantially increased provides encouragement for physics. However, it is not at all clear why there have been these improvements in mathematics yet not in physics. Further research is warranted here.

These findings also suggest (see Tables 1 and 2) that low-aspiring girls experience the same classroom environment in a different way than boys (regardless of aspirations) and girls with high aspirations. Girls with low aspirations were the most disadvantaged of all groups (mirroring the qualitative findings of

Archer, DeWitt, Osborne, Dillon, et al., 2012). They scored low on most of the mathematics/physics-specific constructs compared to other students (e.g., self-concept, intrinsic value, extrinsic material gain motivation, teachers' encouragement to continue with subjects post-16).

In general, all girls (regardless of aspiration group and age) were more likely to report positively about their mathematics education, their motivation in mathematics, and the support they received in mathematics as compared to physics. At the same time, our findings suggest that many girls experience inequalities in both their mathematics and their physics education and that girls with low aspirations to continue with mathematics/physics post-16 are the most alienated group. Our findings indicate that many girls in England still perceive that there are powerful barriers preventing them from accessing these high-status subjects post-16. This is something that should be attended to by policy, research, and professional practice.

Notes

1. GCSEs are taken by students at age 16.
2. A-levels are General Certificate of Education Advanced Levels, mostly taken by students at age 18 after 2 years of study.

Funding

Funding for this study was provided by the Economic and Social Research Council (RES-179-25-0013).

References

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012). Science aspirations, capital, and family habitus: How families shape children's engagement and identification with science. *American Educational Research Journal*, *49*(5), 881–908.

Archer, L., DeWitt, J., Osborne, J., Willis, B., & Wong, B. (2012). "Balancing acts": Elementary school girls' negotiations of femininity, achievement, and science. *Science Education*, *96*(6), 967–989.

Archer, L., DeWitt, J., Osborne, J., Willis, B., & Wong, B. (2013). "Not girly, not sexy, not glamorous": Primary school girls' and parents' constructions of science aspirations. *Pedagogy, Culture and Society*, *21*(1), 171–194.

Asante, K. O. (2012). Secondary students' attitudes towards mathematics. *Ife Psychologia*, *20*, 121–123.

Bennett, J., Lubben, F., & Hogarth, S. (2006). Bringing science to life: A synthesis of the research evidence on the effects of context-based and STS approaches to science teaching. *Science Education*, *91*, 347–370.

Boaler, J. (2009). *The elephant in the classroom: Teaching students to learn and love maths*. London, England: Souvenir Press.

Brandell, G., & Staberg, E.-M. (2008). Mathematics: A female, male or gender-neutral domain? A study of attitudes among students at secondary level. *Gender and Education*, *20*(5), 495–509.

Cann, R. (2009). Girls' participation in post-16 mathematics: A view from pupils in Wales. *Gender and Education*, *21*(6), 651–669.

Department for Business, Innovation and Skills. (2009). *Higher ambitions: The future of universities in a knowledge economy*. London, England: Author. Retrieved from http://webarchive.nationalarchives.gov.uk/+/http:/www.bis.gov.uk/wp-content/uploads/publications/Higher-Ambitions.pdf

Goldberg, G. L., & Roswell, B. S. (2002). *Reading, writing and gender: Instructional strategies and classroom activities that work for girls and boys*. London, England: Eye on Education.

Guzzeti, B. J., & Williams, W. O. (1996). Gender, text and discussion: Examining intellectual safety in the science classroom. *Journal of Research in Science Teaching*, *33*(1), 5–20.

Homer, M., Ryder, J., & Donnelly, J. (2013). Sources of differential participation rates in school science: The impact of curriculum reform. *British Educational Research Journal*, *39*, 248–265.

Institute of Physics. (2015). *Opening doors: A guide to good practice in countering gender stereotyping in schools*. Retrieved from http://www.iop.org/publications/iop/2015/file_66429.pdf

Joint Council for Qualifications. (2014a). *A, AS and AEA results summer 2014*. Retrieved from http://www.jcq.org.uk/examination-results/a-levels/2014/a-as-and-aea-results-summer-2014.

Joint Council for Qualifications. (2014b). *Results: 2011*. Retrieved from http://www.jcq.org.uk/examination-results/gcses/2014/gcse-and-entry-level-certificate-results-summer-2014.

Leedy, M. G., LaLonde, D., & Runk, K. (2003). Gender equity in mathematics: Beliefs of students, parents, and teachers. *School Science and Mathematics*, *103*(6), 285–292.

Lovelace, M., & Brickman, P. (2013). Best practices for measuring students' attitudes toward learning science. *CBE - Life Sciences Education*, *12*, 606–617.

Mendick, H. (2006). *Masculinities in mathematics*. Maidenhead, England: Open University Press.

Mujtaba, T., & Reiss, M. J. (2013a). A survey of psychological, motivational, family and perceptions of physics education factors that explain 15-source-old students' aspirations to study post-compulsory physics in English schools. *International Journal of Science and Mathematics Education*, *12*(2), 371–393.
Mujtaba, T., & Reiss, M. J. (2013b). What sort of girl wants to study physics after the age of 16? Findings from a large-scale UK survey. *International Journal of Science Education*, *35*(17), 2979–2998. doi:10.1080/09500693.2012.681076
Mujtaba, T., & Reiss, M. J. (2016). Girls in the UK have similar reasons to boys for intending to study mathematics post-16 thanks to the support and encouragement they receive. *London Review of Education*, *14*, 66–81. doi:10.18546/LRE.14.2.05
Mujtaba, T., Reiss, M. J., Rodd, M., & Simon, S. (2015). Methodological issues in mathematics education research when exploring issues around participation and engagement. In J. A. Middleton, J. Cai, & S. Hwang (Eds.), *Design, results, and implications of large-scale studies in mathematics education* (pp. 335–362). Dordrecht, The Netherlands: Springer.
Murphy, C., & Beggs, J. (2005). *Primary science in the UK: A scoping study. Final report to the Wellcome Trust*. London, England: Wellcome Trust.
Noyes, A. (2003). Mathematics learning trajectories: Class, capital and conflict. *Research in Mathematics Education*, *5*(1), 139–153.
Osborne, J. F., & Collins, S. (2000). *Pupils' and parents' views of the school science curriculum*. London, England: King's College London.
Paechter, C. (2001). Gender, reason and emotion in secondary mathematics classrooms. In P. Gates (Ed.), *Issues in mathematics teaching* (pp. 51–63). London, England: Routledge-Falmer.
Randall, G. J. (1987). Gender differences in pupil–teacher interaction in workshops and laboratories. In G. Weiner & M. Arnot (Eds.), *Gender under scrutiny: New inquiries in education* (pp. 163–172). London, England: Hutchinson.
Reiss, M. J. (2004). Students' attitudes towards science: A long term perspective. *Canadian Journal of Science, Mathematics and Technology Education*, *4*(1), 97–109.
Reiss, M. J., Hoyles, C., Mujtaba, T., Riazi-Farzad, B., Rodd, M., Simon, S., & Stylianidou, F. (2011). Understanding participation rates in post-16 mathematics and physics: Conceptualising and operationalising the UPMAP Project. *International Journal of Science and Mathematics Education*, *9*(2), 273–302.
The Royal Society. (2011). *A "state of the nation" report on preparing the transfer from school and college science and mathematics education to UK STEM higher education*. London, England: Author.
Sjoberg, S., & Schreiner, C. (2005). How do learners in different cultures relate to science and technology? Results and perspectives from the project ROSE (the Relevance of Science Education). *Asia–Pacific Forum on Science Learning and Teaching*, *6*(2), 1–17.
Smail, B. (2000). Has the mountain moved? The girls into science and technology project 1979–83. In K. Myers (Ed.), *Whatever happened to equal opportunities in schools?* (pp. 143–155). Buckingham, England, and Philadelphia, PA: Open University Press.
Smith, E. (2011). Women into science and engineering? Gendered participation in higher education STEM subjects. *British Educational Research Journal*, *37*(6), 993–1014.
Zohar, A., & Bronshtein, B. (2005). Physics teachers' knowledge and beliefs regarding girls' low participation rates in advanced physics classes. *International Journal of Science Education*, *27*(1), 61–77.

Appendix: The items that make up the constructs that relate to mathematics

Mathematics self-concept. Students were asked five questions about their self-concept: I am good at maths; I do well in maths tests; I need help with maths*; When I am doing maths, I always know what I am doing; Thinking about your maths lessons, how do you feel you compare with the others in your group?

Perceptions of mathematics lessons. Students were asked seven questions about their perceptions of lessons: I look forward to maths classes; In my maths lessons, my teacher explains how a maths idea can be applied to a number of different situations; In my maths lessons, I have the opportunity to discuss my ideas about maths; I enjoy my maths lessons; I can see the relevance of maths lessons; When I am doing maths, I am learning new skills; When I am doing maths, I pay attention.

Emotional response to mathematics lessons. Students were asked four questions about their emotional response to mathematics lessons: I find it difficult to apply most maths concepts to everyday problems*; When I am doing maths, I am bored*; When I am doing maths, I get upset*; When I am doing maths, I daydream.*

Advice—pressure to study mathematics. Students were asked five questions about the advice–pressure they received to study mathematics: My friends are going to study maths after their GCSEs;

* Items were reverse coded.

My teacher thinks that I should continue with maths beyond my GCSEs; My friends think that I should continue with maths after my GCSEs; I have been advised by someone else that maths is a good subject to study after my GCSEs; Someone in my family thinks that I should continue with maths after my GCSEs.

Intrinsic value of mathematics. Students were asked seven questions about their intrinsic value of mathematics: Maths teaches you to think logically; To be good at maths, you need to be creative; To be good at maths, you need to work hard; Maths is interesting; Maths is important in making new discoveries; Those who are good at maths are clever; In maths, it is interesting to find out about the laws that explain different phenomena.

Extrinsic material gain motivation in mathematics. Students were asked five questions about extrinsic material gain motivation in mathematics: I think maths is a useful subject; I think maths will help me in the job I want to do in the future; People who are good at maths get well-paid jobs; Maths helps you in solving everyday problems; These days, everybody needs to know some maths.

Extrinsic social gain motivation in mathematics. Students were asked three questions about extrinsic social gain motivation in mathematics: Being good at maths impresses people; Maths improves your social skills; Being good at maths makes you popular.

Perceptions of mathematics teachers. Students were asked eleven questions about their perceptions of mathematics teachers: I like my maths teacher; My maths teacher has high expectations of what the students can learn; My maths teacher believes that all students can learn maths; My maths teacher wants us to really understand maths; My maths teacher believes that mistakes are OK as long as we are learning; My maths teacher is interested in me as a person; My maths teacher seems to like all the students; My maths teacher is interested in what the students think; My maths teacher treats all students the same regardless of their maths ability; My maths teacher is good at explaining maths; My maths teacher marks and returns homework quickly.

Home support for achievement in mathematics. Students were asked five questions about home support for achievement in mathematics: Someone in my family wants me to be successful at school in maths; Someone in my family wants me to be the best in my class in maths; Someone in my family wants me to talk to them about my maths work; Someone in my family thinks that I should continue with maths after my GCSEs; Someone in my family thinks that anyone can do maths if they try hard enough.