Mindsets and diversity: Understanding and addressing attainment gaps amongst undergraduates in highly mathematical subjects

Jenni Ingram, Vicky Neale, Natsuno Funada, and Kyla Smith

University of Oxford

Undergraduates studying highly mathematical subjects at university level often have a long history of success in mathematics, particularly in school-level mathematics. We report on the interim findings of a study of undergraduates who all achieved the highest possible grades in their school examinations but whose performance in university mathematics examinations reveal attainment gaps that are not predictable by prior attainment. Focusing particularly on attitudinal factors such as mindset and beliefs about ways of working with mathematics we examine students' perceptions of what enables or prevents them from being successful with their mathematics at university level using a mixture of questionnaires and interviews.

Keywords: Undergraduate mathematics; student attitudes; mindset

Introduction

There has been considerable research for some time into why some students choose to continue studying mathematics and highly mathematical subjects. This research has included interventions, initiatives or changes in pedagogy both at school level and university level. Yet despite this research, differences in which groups of students are choosing mathematics persist at all levels of education where mathematics is a choice.

Many studies have focused on how undergraduate mathematics programmes influence students' attitudes towards mathematics at university and how students' attitudes towards mathematics affect their choices in terms of which modules they take and continuing into postgraduate study (e.g. Rodd & Bartholomew, 2006). A great deal of this research has focused on women and why fewer women continue with mathematics at all levels of education. For example, Solomon (2007) demonstrates that even successful students can develop negative relationships with mathematics, which can then turn them against further study. She argues that this is gendered, partly due to women being more likely to want to understand the mathematics they are studying, whilst also wanting to keep pace with what they are being taught.

Whilst much of this research has focused on gender, differences related to social class, culture and ethnicity also exist at undergraduate level. However, whilst large datasets of school attainment in mathematics exist and can take into account the social class and ethnicity when examining relationships between students' attainment and choices to continue with mathematics (e.g. Noyes & Adkins, 2016), the data available at undergraduate level is often restricted to individual universities where sample sizes for different groups of particular students, with the exception of gender, are too small to draw any meaningful conclusions. Thus, the differences related to class, culture and ethnicity are challenging to quantify, particularly when examining the choice of continuing with postgraduate study. The focus on gender can lead to an assumption that there is a 'problem' with women in relation to mathematics (Walkerdine, 1989), with the location of that 'problem' either lying in women or in the mathematics (epistemology or pedagogy). Furthermore, recent research also problematises whether it is gender that predicts students' achievement or whether it is other factors, such as personality (e.g. Alcock, Attridge, Kenny & Inglis, 2014), which underlie the observed differences in attainment and participation.

Often, teaching styles, the behaviour of lecturers as well as the nature of mathematics being taught are offered as explanations for why students begin to make choices that take them away from mathematics. As MacBean, Graham and Sangwin (2004) point out, mathematics is often viewed as distinctive from other disciplines in that few topics at undergraduate level lend themselves to real debate or allow differences of opinion.

Brown & Rodd (2003, p.11) report a number of ways of participating in mathematics among their group of first class students, "their patterns of engagement being very different and their motivations varying hugely": some students in their sample focussed on individual pursuit of right answers and instrumental application, while others relished mathematical debate.

The aims of this study are to explore possible attitudinal factors that might influence differences in attainment in highly mathematical degrees, and then to develop strategies and interventions to address these differences. This paper focuses on the first of these aims.

Methods

This paper reports on some of the interim findings based on questionnaire and interview data in the first year of a two-year project and the questionnaire data from the second year. First and third year undergraduates in highly mathematical subjects such as mathematics and computer science were surveyed towards the end of the first term. Interviews were then conducted with volunteers from the survey. All the participants were high achievers in mathematics at school, all achieving the highest possible grades in their end of school exams. In the first year of the project 97 undergraduate students completed the questionnaire and 7 students volunteered for the interviews. In the second year of the project 98 undergraduate students completed the questionnaire and 13 students volunteered for the interviews, which at the time of writing have not been analysed.

The initial questionnaire was designed to cover three main areas: (i) students' mindset (adapted from Dweck, 2000) (ii) self-efficacy (taken from Zimdars, 2007) (iii) attitudes and perceptions of mathematics (taken from Code, Merchant, Maciejewski, Thomas, & Lo, 2016, Op't, Eynde, & De Corte, 2003, and Stylianou, Blanton, & Rotou, 2015). In the second year this questionnaire was adapted to remove scales where there was little variation between the students, as these items were not found to be useful when planning for strategies or interventions. Additional questions were also added in light of the interview data from the first year to specifically look at the meaning students had for mindset and to gain more information about collaborative working on mathematics (based on MacBean, Graham and Sangwin (2004)), as well as to ask if their views had changed during their degree. The quantitative data were analysed using the Statistical Package for the Social Sciences (SPSS) Version 24. Descriptive statistics were mainly used to explore students' perceptions. Please note that all names used below are pseudonyms.

Findings

In the first year of the project the majority of respondents indicated a high academic self-concept, self-beliefs and a growth mindset on the questionnaire. For example, 85% of the students reported that if they tried hard enough, then they would understand the course material in their degree. 53% agreed that nearly everyone is capable of understanding mathematics if they work at it. In the interviews, the students described hard work as “pushing you in the right direction” (Steve) but also talked of a limit to what they could achieve by working hard: “despite working hard it wasn’t necessarily paying off for me” (Ann) and “I can work really hard and still not do very well” (Clare). There was a sense that a natural talent was needed to succeed at the highest levels: “People are just naturally good at mathematics and they kind of don’t have to study, and they know the things” (Becky), “it comes down to just how your brain is wired in the first place” (Luke) and “I think there is some talent there from the beginning” (Naomi). None of the interviewees reported having a natural talent in mathematics themselves, this was something other people had. Their success was attributed to their hard work.

The questionnaire also included items relating to students’ relationships with their peers and whether they feel supported by their peers. The majority of students (59%) felt that other students helped them in their learning with 54% reporting that they tried harder when they were in competition with other people. In the interviews the students reported working with friends and asking them for hints when they were stuck. Several of them contrasted this with their experiences at school: “if you were talking to other people you were probably cheating or taking their answers, or giving away your answers” (Ann). They also talked about having to adjust to a new way of working collaboratively during their first term of their first year.

In both the questionnaire and the interviews the students overwhelmingly described themselves as persevering when they got stuck and not giving up (84%) or asking for help from others (82%) when stuck on a problem for more than 10 minutes. There was a sense that mathematics problems involved thinking about for “maybe three days or one week before the deadline” (Becky) so they can mull over them over time and “trying again and learning not to give up per se but when to move on” (Steve). However, the mathematics courses were often felt to be ‘fast,’ with students expressing that it was difficult to “keep up with some pace” (Naomi) and it was “very easy to fall behind” (Steve).

The questionnaire at the beginning of the second year of the project reported similar levels on the growth mindset scale, but there were some interesting results in the additional questions we asked (see Figure 1). Around three quarters of the students agreed to some level that they had a natural talent in mathematics. Whilst slightly more than 50% felt that being good at maths requires natural intelligence, a significant majority also agreed that nearly everyone is capable of understanding maths if they work at it. For these students, being good at mathematics appears to be a combination of a natural talent and hard work.

TABLE 1

Item Analysis: Mindset Questions (N= 70)

	SA	*A*	*SWA*	*N*	*SWD*	*D*	*SD*
Q6.1. Maths ability is something about a person that cannot be changed very much.	0%	10%	13%	1%	29%	23%	24%
Q6.2. I have a natural talent in mathematics.	14%	31%	29%	9%	9%	7%	1%
Q6.3. Nearly everyone is capable of understanding maths if they work at it.	20%	23%	34%	6%	13%	4%	0%
Q6.4. Being good at maths requires natural (i.e. innate) intelligence in mathematics.	4%	9%	41%	11%	13%	13%	9%

SA = strongly agree, A = agree, SWA = somewhat agree, N = neither agree nor disagree, SWD = somewhat disagree, D = disagree, SD = strongly disagree

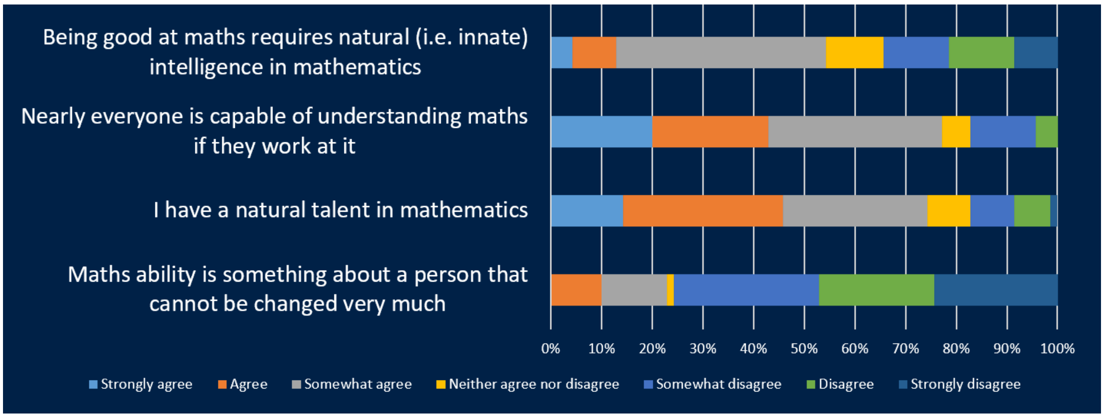

Figure 1: Additional mindset questions

We were also interested in how their experiences in school mathematics contrasted with their experiences at university, as this was a contrast made in the interviews in the first year of the project, particularly by first year undergraduates. The questionnaire revealed the success they had experienced at school in terms of finding maths easy, scoring high marks and not having to work hard at mathematics. 70% of the students also reported that their working habits at school are no longer suitable at university. Further exploration of this aspect of students' experiences formed part of the interviews that took place after the conference.

TABLE 2

Item Analysis: School Maths Questions (N= 67)

	SA	*A*	*N*	*D*	*SD*
Q9.1. When I was at school, I didn't have to work hard to get excellent marks.	48%	30%	8%	13%	2%
Q9.2. When I was at school, I felt that maths came easily to me.	67%	31%	2%	0%	0%
Q9.3. When I was at school, I didn't struggle with maths problems. .	51%	27%	9%	12%	2%
Q9.4. When I was at school, I could solve all the maths problems I was given.	48%	30%	5%	15%	3%
Q9.5. When I was at school, I enjoyed being able to get close to 100% on my maths work.	75%	15%	6%	5%	0%
Q9.6. My working habits at school are no longer suitable at university.	42%	28%	10%	13%	6%

SA = strongly agree, A = agree, N = neither agree nor disagree, D = disagree, SD = strongly disagree

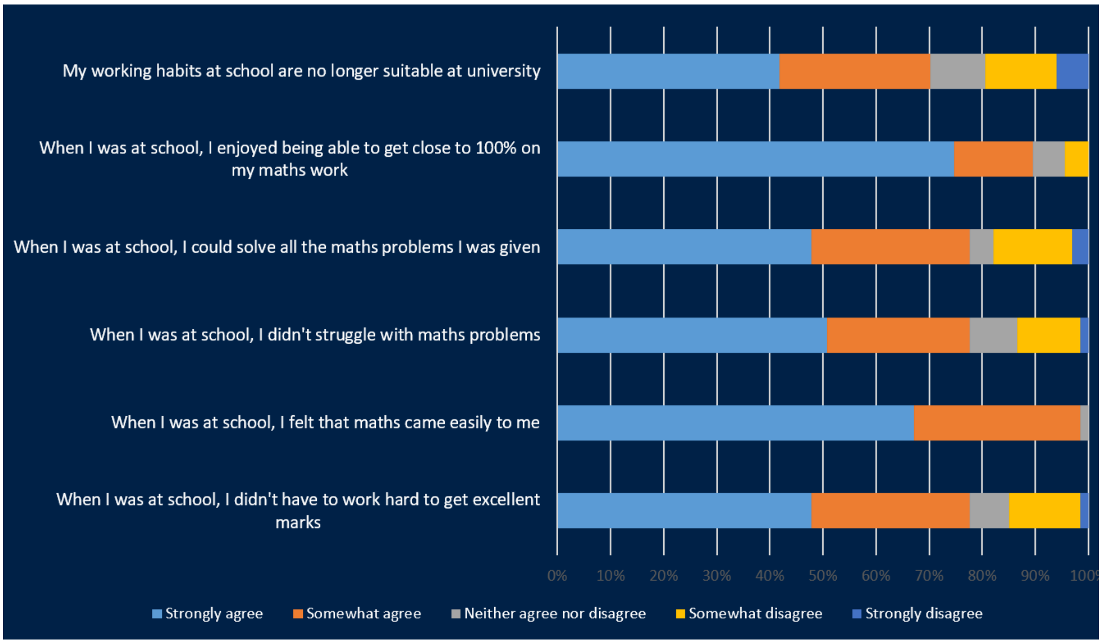

Figure 2: Experiences at school

We also asked in the questionnaire if their answers to the questions would be different if we had asked them at the end of their time in school. Most students agreed that the way that they worked at mathematics had changed, with more females agreeing than males, and more 3rd years agreeing than 1st years. Furthermore, more female students felt that they used to think they had a natural talent in mathematics but don't now compared to male students, and similarly 3rd year students were more likely to agree than the first-year students. Interestingly, Kendall's Tau-b correlations indicated students who had less confidence ($\tau_b = .369$, $p < .001$), less sense-making ($\tau_b = .194$, $p < .001$) and lower self-efficacy ($\tau_b = .264$, $p < .05$) were more likely to agree that their answers would have changed between school and university.

Discussion and conclusion

One of the challenges we faced when researching the factors that influence students' achievement and participation in mathematics is that many of the students taking mathematics-related degrees are invested in this decision, and are also influenced, not necessarily consciously, by the social and cultural norms they encounter during their study. This affects how students respond in questionnaires and interviews. The findings above illustrate the complexity of students' perceptions and attitudes. Whilst the majority of students reported having a growth mindset for example, they also talked about a limit or ceiling to their own learning, and a point where hard work would not enable them to understand the mathematics they are meeting.

We asked our interviewees if they felt like they were in a minority, and all except 1 reported that they did. Whilst for all the women it was their gender that put them in the minority, they did not perceive this as a barrier and they were aware of, or participated in, initiatives to support women in mathematics. For the men it was often their culture or background (including social class) that they felt positioned them as in a minority, and in their discussions the focus was on how this made them feel isolated at times and the barriers they faced.

Whilst there continues to be gender differences in attainment and participation at undergraduate and graduate level mathematics, there are also social, cultural and ethnic differences that are more difficult to explore at scale. Furthermore, whilst many initiatives designed to address and reduce these differences are evaluated positively by those who engage with them, there are again challenges in researching the impact when the priority rests with improving the teaching and learning of mathematics at university.

References

Alcock, L., Attridge, N., Kenny, S., & Inglis (2014). Achievement and behavior in undergraduate mathematics: personality is a better predictor than gender. *Research in Mathematics Education 16*(1), 1–17.

Code, W., Merchant, S., Maciejewski, W., Thomas, M., & Lo, J. (2016). The Mathematics Attitudes and Perceptions Survey: an instrument to assess expert-line views and dispositions among undergraduate mathematics students. *International Journal of Mathematical Education in Science and Technology 47*(6), 917–937.

Dweck, C. S. (2000). *Self-theories: Their role in motivation, personality, and development*. Psychology press.

MacBean, J., Graham, T., & Sangwin, C. (2004). Group work in mathematics: A survey of students' experiences and attitudes. *Teaching mathematics and its applications, 23*(2), 49–168.

Noyes, A. & Adkins, M. (2016). Studying advanced mathematics in England: findings from a survey of student choices and attitudes. *Research in Mathematics Education 18*(3), 231–248.

Op't, Eynde, P., & De Corte, E. (2003). Students' mathematics-related belief systems: Design and analysis of a questionnaire. *Paper presented at the Annual Meeting of the American Educational Research Association*. Chicago, IL: April 21-25.

Rodd, M. & Bartholomew, H. (2006). Invisible and special: young women's experiences as undergraduate mathematics students. *Gender and Education, 18*(1), 35–50. DOI: 10.1080/09540250500195093

Solomon, Y. (2007) Not belonging? What makes a functional learner identity in the undergraduate mathematics community of practice? *Studies in Higher Education, 32*(1), 79–96

Stylianou, D., Blanton, M., & Rotou, O. (2015). Undergraduate students' understanding of proof: Relationships between proof conceptions, beliefs, and classroom experiences with learning proof. *International Journal for Research in Undergraduate Mathematics Education 1*, 91–134.

Walkerdine, V. & Girls and Mathematics Unit (1989) *Counting girls out.* London, Virago.

Zimdars, A. (2007). *Challenges to Meritocracy? A study of the social mechanisms in student selection and attainment at the University of Oxford.* (Unpublished doctoral dissertation). University of Oxford, UK.