EXIT INTERVIEWS: UNDERGRADUATES WHO LEAVE MATHEMATICS BEHIND

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We teach a mathematics education module to mathematics undergraduates and every year we encounter students who feel disaffected. Many openly admit that they opt into the module as a direct consequence of a growing disinclination for mathematics. Whilst these students are by no means representative of all mathematics undergraduates, informal discussions with the students, together with our own experiences, suggest that such students represent a meaningful proportion.

For undergraduates, disaffection can be decisive. There is an increasing recognition in recent research (for example, Brown & Macrae, 2005) that learners who might have been previously considered as part of a promising mathematical élite can become disaffected in higher education, subsequently choosing to leave mathematics behind after graduation. Burton (2004, pp. 4-5) reports on a small-scale study conducted at a UK university in which 54 per cent of female and 25 per cent of male undergraduates interviewed evinced a strong commitment to move, after graduating, to a career that did not involve mathematics.

The decision to move away from mathematics after graduation runs counter to the current promotion of post-compulsory study in science, technology, engineering and mathematics (STEM) subjects. Therefore, the experiences and attitudes of undergraduates leaving mathematics behind after graduating demand our attention and offer a potent additional perspective on the practices of undergraduate mathematics education.

Narratives and mathematical identities

In light of the concerns outlined above, we carried out four exploratory, semi-structured exit interviews with students taking our education module. Each interview was based around a set of questions that moved through the student's mathematical history and encouraged them to reflect on their learning behaviours. All four students interviewed were high achieving students at a prestigious UK university, yet each had expressed severe levels of disaffection with mathematics. The interviews were analysed using themes which had been mutually identified and grounded in the data including: fixed views of mathematical ability; self-imposed success criteria; a lack of prior experience of struggle in mathematics; the role of memory in supporting learning; and the place of questioning in learning mathematics. We recognise that these narratives involved reconstruction alongside recollection, that our own representation of these accounts is partial and subjective, and that others may interpret the stories below differently. However, our analysis here is of the discourse itself, paying attention to context and situated meanings (Gee, 2011).

Many of the themes could be understood as contributing to the students' mathematical identities (Boaler & Greeno, 2000; Black, Mendick & Solomon, 2009). We consider that identities are not fixed, but formed and reformed in the light of experiences in the affective domain; we also hold that narrative is involved in both construction and articulation of identity such that "personhood implicates narrative" (Bruner, 1996, p. 40). Thus the narratives in this research offer some insight into the identity building processes of the undergraduates involved and suggest changes in the students' identities. They demonstrate how the students positioned themselves at the time of interview with respect to the community of practice that is university mathematics and report on the students' self-efficacy (Bandura, 1995).

In broad terms, the narratives offered by the students showed a high level of consistency. Each student had found school mathematics easy and, having been one of the best mathematicians in their school year, had opted to study the subject further. Subsequently, each had found the practice of university mathematics dense, requiring more agency in learning than they had developed as learners of mathematics in school. This experience led them to move away from identifying themselves with mathematics as a discipline. The narratives thus suggested how the students' identity and agency had co-evolved as the students interacted within the communities of practice of university mathematics, with learning behaviours informing and being informed by the students' evolving agentic identities in relation to mathematics. We use the term *agentic identities* to mean the aspects of students' internally conceptualised notions of self which related to their capacity to act and influence within pertinent figured worlds (Holland, Lachicotte, Skinner & Cain, 1998). As we studied the narratives, it was clear that the students had not moved from peripheral participation (Lave & Wenger, 1991) in the community; we will let their stories suggest reasons why this might have been the case.

John's story

John was a third (final) year undergraduate taking a mathematics degree who had enjoyed mathematics at school and found it easy. His self-identification as a capable mathematician had been reinforced by attainment:

> … now I look back at it, the reason I enjoyed it was because I was able to do it. And maybe being better than other people made me want to keep on being better, which is why I kept on trying to do it.

His perception of mathematics as something that was "very

much factual" led him to draw confidence from routine methods and practice, to associate success with producing a large quantity of work, and to derive self-efficacy from absolute and comparative measures of performance:

> ... I like the definite-ness … I like the guarantee that it was right, so I didn't have to check, because I knew, in myself, that it was right, because I knew what I'd done was right … I liked getting it right, I liked beating other people.

John chose a mathematics degree through elimination; he had only continued to study his strongest subjects at A-level (exams taken at school at age 18), and then narrowed these choices down until he was focused on A-levels in mathematics and further mathematics. [1] In hindsight, he felt this strategy had not been prudent: "suddenly maths doesn't seem so interesting … and I'm trying to do different things now." John had come to recognise that university mathematics constituted a new community of practice, describing it as "a totally, totally different field" which he had been unprepared for. His perception of legitimate participation had changed and thus his identity as a mathematician too; in particular, the focus on proof in university mathematics had caused a shift in his personal figured world of mathematics:

> I used to think it was solving problems … effectively solving problems in different ways. But the new maths that seems to be at university is learning things off by heart, learning lots of lines off by heart … we're learning other people's work, which isn't useful any more … what I feel that I've learnt in the last three years is very little compared to what I've learnt in half a year in any other year of my life, learning maths. Because everything you do in maths you learn to forget.

This idea of "learning to forget" was associated with a sense of playing the system; he had tried at first to understand all of the material, but had found this strategy unhelpful and thus had resorted to cramming. He was frustrated that "practising doesn't help", and was "definitely fed up with it … my enjoyment of it … after about half the first year disappeared." In order to navigate the remainder of his degree, John had elected to take a number of modules outside the mathematics department, taking advantage of seminar groups where he felt more able to ask questions. He also chose some mathematics modules that contained coursework, intending to reduce the strain on his short-term memory. At the time of the interview, he was seeking to move into a career in consulting, business or finance, where he could use his abilities at problem solving in contexts with definite answers. He had been severely disappointed by his choice of degree:

> … so in the last three years, what I've actually learned in maths … is extremely insignificant … I've got a friend in the first year who asked me to – if I could help them. I couldn't – it was strange 'cause I thought I would have been able to, and it's strange not being able to help them … It makes me wonder what I've done in the last few years … it just shouldn't be like that.

Adam's story

Adam was another final year student, with largely similar experiences of school mathematics, which had "seemed to make sense, it was clear and logical":

> Everything was laid out in an obvious way. I never really had, I don't think, a lot of difficulty picking up anything while I was at school … if I ever had difficulty it was only a little while and a lack of practice.

Adam had found the further mathematics A-level more challenging, but problems had been surmounted through practice and one-to-one tuition. Adam thought that mathematics was "particularly satisfying … when it worked out quite neatly" and enjoyed the challenge and competitive aspect of solving puzzles. Unfortunately, just like John, Adam felt that he was totally unprepared for university mathematics:

> … looking back I wish somebody had told me how different it would be. I mean, it's not just it being harder…particularly in maths, there's much more of a need to persevere, to kind of get to a certain level of understanding with it. And I don't think I ever really had that, enough of that …

Adam's alienation from the practice of undergraduate mathematics seemed to be compounded by the pedagogy adopted in lectures, leading him to move towards working with others outside of lectures:

> … as much as the lectures were of use and that's the introductory point, I never really felt that that probably helped me learn … [I was] working individually up to a certain stage but I would always hit barriers and hit them so often that it was so much more productive to work in a group or in a pair …

Although he felt he was regaining confidence in his own abilities, there was still an element of self-criticism in his narrative that reflected his own perceived lack of self-efficacy:

> … it's the lack of a structured response or seeing a problem, I never seem to know where to start … now I'm a lot better, but that, just trying to overcome that took a long time, and a lot longer than I would have expected … it felt like no matter how much practice I had … I never felt like I was a hundred percent confident going into an exam …

Like John, Adam had used memorisation for an exam, but knowingly as a "last resort." However, this compromise and his continuing high standards had arguably led to him become the more frustrated of the two:

> But really, you feel quite hopeless at the end … every year, it's not necessarily during exam times but there's always a period in the term where you feel like this is hopeless, I can tell it doesn't matter what I do, this is never going to work … trying and trying and then you just sort of reach this point, you're like "Oh, it's not worth it any more". And I sort of wish that hadn't happened.

Adam was considering moving into something practical involving finance. He felt that he would have been better off choosing a different degree, although still something related to mathematics.

> I'm sort of a bit disappointed having … gotten all this way and I thought I would always be a champion for maths … I still go back to my school maths and think yeah, yeah that was great and I still solve those kinds of puzzles …I'm still a champion for that side of things … but university maths maybe not so much.

Mark's story

Mark was also in the third and final year of his degree. At school he had considered himself to be good at mathematics and had, like John, reinforced this aspect of his identity by comparing himself with his peers:

> … I was good at it, I could sort of not work but still get the same marks as people around me who did work a lot more.

Mark's decision to do a mathematics degree was strongly influenced by those around him. He explained that "I've certainly always been pushed towards maths" and outlined how many members of his family had careers which relied heavily on numbers and computation. Another distinctive feature of Mark's narrative was his repeated reference to memory, which helped to frame his trajectory. Like the others, he expressed frustration at the perceived need to memorise material for examination:

> … during an exam you've got so many definitions you're expected to remember, stuff from previous years as well, and just to be able to like, just regurgitate all these random theorems and definitions they expect you to know is, just gets a bit … extreme ... the people who tend to get the higher marks tend to be the people who can do that.

In this quotation, Mark demonstrates that he still actively assesses his performance against the attainments of those around him. This habit requires him to explain his own perceived drop in success, which he does by suggesting a shift in the performance of his memory:

> My memory, for some reason has got unbelievably poor … for exams I can't memorise a proof, so I either have to work it out there and then or just hope I can remember sort of snippets of it. That'll make me remember it all, but I've always struggled, certainly, yeah, pretty much since I've got to uni …

Mark expanded upon his strategies in this interview, alleging that he was "much more of an intuitive thinker than methodical … I'll try and spot a pattern, same as most people do, but I can generally make leaps that most people don't see, a lot of the time … it works, most of the time." It is possible that his assertion that he was an "intuitive thinker" may reflect a partially understood indicator of what qualifies as a good mathematician, inferred from his new community of practice. Certainly his claim is simultaneously bold and tempered; it demonstrates again how Mark's own mathematical identity is still very much supported by comparing himself against others, whilst the final qualifier constitutes an escape clause, explaining away instances where Mark does not achieve as highly as his peers. His tendency to evaluate himself against others was apparent once more at the end of the interview when Mark compared his university course to that of another university, arguing that his own course was more difficult.

Like Adam, Mark had found working with others to be a useful approach and he talked about regularly working with a group of friends who had complementary thinking styles. Uniquely, Mark discussed the benefits that he had gained from writing an essay on an area of mathematics in one of his modules. This unusual approach to exploring some mathematics had helped him clarify his thinking. After graduating Mark is considering taking a second degree and going into medicine; he is leaving mathematics behind as he "wouldn't enjoy using it in the workplace … I can't see where I could use it where I'd be happy with the job I had."

Cathy's story

Unlike the other interviewees, Cathy was in the second year of her degree. Interestingly, whilst she related that mathematics in school tended to be "really easy", her account of her school experiences centred not on her individual attainment, but on the community of learners that had existed at school. Although the others had mentioned inspiring and approachable mathematics teachers, Cathy went into much more detail about her teacher, his methods and the class as a whole: "everyone was really good friends and it was a really nice class." This sat in contrast with her experiences of a residential week spent preparing for an additional university admissions examination where she "felt like the most stupid person in the class." Despite this experience, though, Cathy embarked on a mathematics and business degree, "'cause it left my options open." She later regretted this choice:

> … believe me, the last few years like every single week I'm like, "why did I do a maths degree?"… I just, despise maths at university. Like really, really don't like it. And I think if I didn't have any extra-curricular activities to keep me here then I really wouldn't be here any more.

Like the others, Cathy made a number of comments about the pedagogy and learning environment at the university. She described the lectures as an exercise in writing things down, where "one tiny lapse of concentration means you've lost it." A number of comments related to a perceived culture of not asking questions:

> … every time I'm in a seminar I learn a hell of a lot more than in a lecture … you're given the opportunity to put your hand up, you don't feel as stupid…

Cathy was involved heavily in extra-curricular activities at the university and this seemed to serve not only as a release for her frustration, but also figured in her rationalisation of her current pathway:

> Like, as long as you can put down, I achieved a 2:1[2] or above … as long as you can put, tick that box, then after that they [employers] don't care anything about your degree. All they care about is your hobbies and what roles of responsibility you've taken on and what societies you're in, and what else you do. So to me,

like, I shouldn't be concentrating on my algebra, do you know what I mean?

It is possible to infer from this quote the influence of a neoliberal discourse, framing university education as a process of self-accreditation. Cathy uses this understanding to rationalise, and possibly even defend, her withdrawal from mathematics. She goes on to reinforce this stance by comparing her degree favourably with equivalent degrees from other universities. Her choice of approach had encouraged the adoption of some pragmatic strategies: "… I do the bare minimum of assignments to get by and then just panic at the end … last year it worked. But it was a horrible third term."

There was some evidence that her experiences had also had an impact on her wider self-image: when discussing her assignments she said that they were "just so hard … probably just 'cause I'm not very bright." This opinion demonstrated an inconsistency, since Cathy had previously told us that she had achieved four 'A' grades at A-level. A possible second inconsistency arose when Cathy, who helped to run the university dance society, said that her problem was "just thinking of the ideas. I think I'm not very creative."

Undergraduate responses to the pedagogy of university mathematics

Although they are highly individual and occasionally emotionally charged, the narratives summarised above resonate meaningfully together. There are similarities in the students' discussions of practical behaviours, such as their use of and reliance on memorisation, as well as in their expressions of how deeper affective attributes had challenged their perceptions of themselves as mathematicians.

The narratives as a whole point to ways in which aspects of pedagogy have impacted on all four students' emerging mathematical identities and the ways they felt themselves positioned within the community of practice that is university mathematics. It has been noted elsewhere (for example, Nardi & Steward, 2003) that secondary school teachers' choice of pedagogic strategies can influence students' developing identities as mathematicians. These narratives demonstrate that this interplay continues into tertiary education.

A clear example of the influence of pedagogy can be found in the shift described in the place and use of questioning. John's narrative draws a particularly clear distinction. At school he felt connected to a mathematical community in which questioning was a valid practice: "… I'd probably keep trying and keep persisting … until I really couldn't do it and then I'd go into school and ask someone. Maybe someone who was older than me, or a teacher or someone else …" This feeling sits in stark contrast to his views about asking questions at university: "… the people I was asking the questions to were on a different level to what my understanding was, so they were using terms and phrases which I didn't – I couldn't relate to. Not because they were wrong, but because I was maybe on a different sort of level ... [some friends] say that the people who are best at explaining stuff are people with fewer letters at the end of their name."

Adam suggested that he felt relegated to the fringe of proceedings: "… you're an invisible face in a crowd of three hundred. And on top of that, I'm doubting … whether I'm asking a question which I should already know, and maybe I've missed something silly. I've never had a lack of confidence in asking those kind of questions before, and at uni that's much more prevalent." Cathy had a similar perspective: "… I just wouldn't dare put my hand up and ask a question … anybody who did got laughed at, if they asked like a stupid question … the only time that I've ever seen people put their hand up is to correct a little mistake the lecturer's made and then, it always just causes, like either people to laugh at the lecturer or people to laugh at the person."

Solomon (2007), examining how first-year undergraduate mathematics students form functional learner identities, found that they "tend to describe themselves as marginalised: they are aligned with mathematical procedures but do not contribute to them" (p. 79). In a similar way it is arguable that these four accounts are indicative of students who never saw themselves as progressing beyond the margins of the community of practice (Lave & Wenger, 1991): instead of increasingly viewing their activity as legitimate participation, they reconceptualised their achievements in negative terms and remained on the periphery as a pragmatic choice.

Explaining the changes: what qualifies as success?

Framing these undergraduates' experiences as deliberate marginal practice gives rise to a key question: what might explain these learners' change in attitude towards mathematics, given that other students with similar trajectories manage to maintain a positive identity in relation to mathematics and move towards identification as part of the university-based community of practice? Although it is impossible to answer this question fully for each individual, it seems evident from the data that each student's view of what constitutes success and achievement has a major influence on their developing identities.

Two of the themes that emerged from the data suggest that these undergraduates had adopted demanding success criteria. One of these themes was the measurement of success relative to others: all of the students interviewed evinced a strong awareness of their achievements relative to their peers, with Cathy commenting "now I can't be the best, I just need to know that everyone else is as bad as me." The second theme was the goal of perfect or near-perfect attainment which mathematics had previously seemed to permit. John admitted that at school he "didn't want to fail, 'cause anything less than a hundred percent was bad." Adam had similar views: "At school, almost the goal in every question was to get to the answer. And that felt a lot more satisfying and productive in a way because I was always aiming for 100 per cent. And coming to university, that target comes down quite a long way..." The expression "100 per cent" also featured tellingly in Cathy's narrative:

> I think the problem, my problem is that I'm used to getting like near enough to 100 per cent ... in school I was always like sort of top of the school … if you get in an assignment, like sort of 60 per cent, that's actually tech-

> nically quite good, 'cause it's like a 2:1 at university, which is good enough to get you into most of the major companies and stuff, but I see 60 per cent and I'm like, "Oh my God, I'm failing, I'm so stupid."

This drop is likely as much representative of the shift in the nature of mathematical activity as much as of any increase in difficulty. This is recognised in Adam's narrative, for example, where he bemoaned that often "there's no set method for me to approach this, I kind of have to just, you know, fight with it, look at what's happening in other places and try and kind of botch something together." We find his use of the terms "fight" and "botch" suggestive, noting a contrast with his description of school mathematics as an "almost effortless" enterprise where "usually things just seem to fit into place."

The futility apparent in the tenor of the interviews can thus be understood as a consequence of the fact that success, in the terms the undergraduates had established for themselves, was no longer available to these students. Their agentic identities seem to hinge almost exclusively on success criteria clustered around competition and decontextualised attainment; the perceived mores of university courses seem to have required the students drastically to reconfigure their personal goals and success criteria in order to continue to see themselves as successful. The students that we interviewed appeared not to have been able to adapt sufficiently well or quickly for reasons that we can only surmise. We know that they had begun to feel "hopeless" and to despise the learning they were required to do.

This understanding is consonant with Dweck's (2000) findings that fixed ability beliefs and fixed models of intelligence can cause difficulties for learners. The frequency of comments about percentages, scores and being "better" than other learners in the interviews certainly suggests that fixed ability beliefs were influential in forming the students' mathematical identities at school. This is unsurprising, since many elements of current assessment and inspection regimes valorise performance above understanding (for example, Reay & Wiliam, 1999). These attitudes and beliefs are perpetuated and strengthened by the pedagogic practices used at university (Solomon, 2007, pp. 88-89). If the students had a fixed theory of intelligence they would have considered sustained struggle and effort to be indicative of failure. At school their paths had been "easy" and "almost effortless", encouraging a way of thinking which would have burdened them with the need to rationalise the difficulties of university mathematics by challenging their belief in their own ability to perform as legitimate mathematicians. Certainly Cathy indicated that she saw the struggle that she had to engage with as an indication that she had reached the limits of her ability. Declaring the situation as "futile" offers students a rationalisation, and provides some emotional refuge by negating the need to keep struggling. We suggest, however, that this refuge comes at a significant cost to agentic mathematical identity and encourages a tactical withdrawal from mathematics, leading in these cases to a move away from mathematics after graduating.

A supporting contrast to this discussion is offered by Povey and Angier (2004) who detail the experiences of undergraduates at a different English university which accepts learners with a weaker entry profile and actively strives to engender a social, collaborative approach to learning undergraduate mathematics. Povey and Angier claim significant levels of success, measured in terms of both attainment and affect, and maintain that "offering a different pedagogy, one that values agency and authorship, one that places the learning community as central, has enabled some failing and some initially weak students to construct authoritative mathematical identities" (p. 63). Consonant support can be marshalled from research into the American "Emerging Scholars" programme (for example, Duncan & Dick, 2000) which also involves collaborative pedagogy and claims increased levels of motivation and achievement.

Concluding remarks

We offer these stories as part of a growing body of evidence that the dominant discourse of fixed mathematical ability, combined with a lack of prior experience of mathematical struggle, can impact on and disadvantage individual learners in a pronounced way. In these students' stories a paucity of challenge at school, where enjoyment equated with "easy" and "can do", can be understood to have contributed to their reactions at university. Ostensibly each of these learners will have succeeded by gaining a mathematics degree, but on a personal level the experience has been taxing and potentially damaging.

In light of the accent on, and the worth attributed to, a mathematics degree as both human and cultural capital, it is valid to consider what might have ameliorated the experiences of these undergraduates. In their research concerning American undergraduates switching majors, Seymour and Hewitt (1997) discovered that "what distinguished the survivors from those who left was the development of particular attitudes or coping strategies" (p. 30). There is merit in attempting to generalise this finding further, evaluating and disseminating pedagogical approaches and intervention strategies through further research that involves a greater range of institutions and contexts. Moreover, it seems readily apparent to us that in order to prepare students better for university mathematics, there is great worth in explicitly developing resilient learning behaviours in promising mathematics students at secondary school. An approach to learning which validates struggle and co-operation, and encourages learners to connect self-efficacy in mathematics to meaningful effort as well as attainment, might assuage some of the difficulties learners experience when first moving into university communities of practice in mathematics. We have written about ways in which such behaviours might be encouraged elsewhere (Johnston-Wilder & Lee, 2010) and argue that further research is needed to establish how teaching approaches might best foster and develop such mathematical resilience in higher achieving students. There would also be considerable value in conducting longitudinal studies which seek to examine how different school-level approaches to inculcating resilient learning behaviours might impact on the mathematical progress and trajectories of learners who go on to study mathematics at undergraduate level.

In conclusion, it strikes us that many higher achieving students may have moved through school mathematics without

seeing the need to develop a facility to negotiate sustained and substantial challenge. These exit interviews suggest that this oversight might come at a price.

Notes

[1] "Further mathematics" is the title given to a second, additional mathematics A-level available in the UK. It involves more advanced concepts and techniques that follow on from A-level mathematics.

[2] 2:1 refers to an "upper second-class honours" degree within the British degree classification system. This division is respected and used as a criterion for selection by many firms and postgraduate courses.

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What draws people to mathematics – to teaching – to teaching mathematics?
(Dick Tahta, FLM 4(1), p. 47)

Is mathematics really essential?
(John Mason, FLM 4(3), pp. 24-25)

The study of women and mathematics must enter the classroom. How the study of mathematics is portrayed in classrooms and how young women respond to it needs examination.
(Jere Confrey, FLM 4(2), p. 40)
