Not belonging? What makes a functional learner identity in the undergraduate mathematics community of practice?

Yvette Solomon
(2007) *Studies in Higher Education* **32:1** 79-96

Keywords: Undergraduates; Mathematical experience; Learner identities; Community of practice model

Abstract
Analysis of interviews with first year undergraduate mathematics students shows that 'not belonging' is a prevalent theme in their accounts of the experience of studying mathematics, even though their choice of degree-level study indicates a belief that they are at least at some level 'good at maths'. Instead, they tend to describe themselves as marginalised: they are aligned with mathematical procedures but do not contribute to them. A perception of oneself as a 'legitimate peripheral participant' - as a novice with the potential to make constructive connections in mathematics – is rare. This paper examines the potentially conflicting communities of practice within which undergraduate students find themselves, and presents a typology of their related learner identities. The analysis shows that undergraduate functionality in the sense of belief in oneself as a learner is not necessarily associated with the identity of novice/apprentice as might be predicted by a community of practice model. On the contrary, students who describe identities of heavily alignment can appear unworried by their lack of participation in mathematics, successful as they are in the more dominant local communities of practice. It is argued that these, together with an institutional culture of entrenched beliefs about ability and ownership of knowledge, determine students' experiences and identities in ways which are noticeably gendered. The implications for teaching in mathematics and in Higher Education more generally are discussed.

Introduction

Identity is central to any socio-cultural account of learning. As far as mathematics is concerned, it is essential to students' beliefs about themselves as learners and as potential mathematicians (Kloosterman & Coughan, 1994; Carlson, 1999; Martino & Maher, 1999; Boaler & Greeno, 2000; De Corte et al, 2002; Maher, 2005), and it has vital gender, race and class components (see Burton, 1995; Becker, 1995; Bartholomew, 1999; Boaler, 1997; Cooper, 2001; Dowling, 2001;

Kassem, 2001; Black, 2004; Gilborn & Mirza, 2002; Cobb & Hodge, 2002; Nasir, 2002; Abreu and Cline, 2003). In this paper I explore the learner identities of a small group of first year undergraduate mathematics students with respect to the communities of practice within which they function, comparing their accounts in terms of Wenger's (1998) three modes of belonging – alignment, imagination and engagement – and combinations of these. Exploring student identities in this way emphasizes two important aspects of mathematics learning. Firstly, it makes transparent the role of beliefs about mathematics and mathematical abilities in the development of identity. Secondly, gender differences emerge which suggest that classroom communities and practices have a considerable effect on the development of identities of alignment, imagination and engagement, and how these are experienced. I will argue that what makes a functional identity in this particular group of students – that is, a perception of self as able to succeed in undergraduate mathematics - is not necessarily an identity of potential engagement, or, in Lave and Wenger's (1992) terms, legitimate peripheral participation in the wider world of mathematics. Paradoxically, within this community those students who do aim for a more participatory role may in fact doubt their ability to continue as mathematics undergraduates, developing identities of exclusion, rather than inclusion.

Identity in mathematics communities of practice

The role of identity in understanding exclusion from and also inclusion in mathematics is most visible in formal learning contexts where learners are subject to institutional structures which impose categorisations on them as good at or not good at mathematics via assessment, curriculum and classroom interactions. As Boaler (2002, p.132) points out, a situated perspective on learning underlines how 'different pedagogies are not just vehicles for more or less knowledge, they shape the nature of the knowledge produced and define the identities students develop as mathematics learners through the practices in which they engage'. Many researchers (for example Boaler, 1997, 2000, 2002; Burton, 1999a; Fennema & Romberg, 1999; Maher, 2005) argue that mainstream classroom mathematics teaching excludes learners, and that mathematics can only be made accessible to all in a participatory pedagogy which encourages exploration, negotiation and ownership of knowledge, all of which involve an identity shift for many learners. Closely related to pedagogic styles are teacher-pupil interactions and grouping systems: the experience of ability grouping has a major part to play in shaping mathematics identities in terms of the development for some pupils but not others of an identity of engagement which are reflected in different kinds of teacher-pupil interactions (Bartholomew, 1999). Faced with higher ability sets, teachers are more likely to focus on pupil learning and involvement with the subject, and to engage in between-equals banter. Of particular interest in the current context is the observation that girls in top sets are likely to be positioned and position themselves as having 'less right' to be there and to experience a high level of anxiety (see also Boaler, 1997; Boaler, Wiliam & Brown 2000).

In the post-compulsory years identity persists as an issue despite the choice element in studying mathematics beyond the age of 16. Gender also emerges as a major related concern at this stage: for example, Landau (1994) notes girls' lack of confidence and the negative effects of accelerated GCSE courses, while Kitchen (1999) notes that gender is a major factor in the changing patterns of A-level maths entry, performance and transition to HE. Mendick (2003a,b; 2005a,b) also argues that 'doing mathematics is doing masculinity' – for girls, choosing to study beyond the compulsory years therefore involves considerable 'identity work'. When it comes to entering into university mathematics, the development of learner identities reaches a new level of complexity. The under-representation of women in degree-level mathematics has been examined by a range of feminist researchers, most typically feminists of difference who have contested the exclusive masculinity of mathematics (see for example Becker, 1995; Burton, 1995; Rogers, 1995). Other writers (e.g. Bartholomew & Rodd, 2003) have explored the emotional aspects of young women's mathematics identities, arguing that the dominant discourses of mathematics make it difficult for women to acknowledge themselves as successful potential mathematicians.

There are more general issues, however, which affect the majority of students, not just women: although we might expect degree-level mathematics students to show some participatory engagement in Wenger's sense, mathematics teachers complain that these students fail to engage with the subject other than in an instrumental fashion (Hoyles et al., 2001; Alibert & Thomas, 1991), and that they see mathematics simply as a rote learning task (Crawford et al.,1994). Students who choose to study mathematics are defensive about their choice to do mathematics at university, tending to rely on 'being able to do it' and positive test results for their identity confirmation (Brown, Macrae & Rodd, in preparation). While such student characteristics may be seen as undesirable, it is nevertheless the case that dominant discourses valorise speed and correct answers (Boaler, Wiliam & Brown 2000), and this needs to be taken into account in an attempt to understand undergraduate student identity. Successful students do not necessarily display identities of participation which neatly match Wenger's (1998) engagement model. For example, Brown & Rodd (2003:11) 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. Their images of mathematics varied correspondingly, as 'a meaningless game which is fun to do, maths as a source of the processes of following through tedious details, maths as a practical subject/ a beautiful subject, or even, considered on a meta-level, as a high status subject that is character and mind-developing' (ibid.). It is possible, then, for highly successful students to display characteristics which are more closely indicative of learners on the margins of a practice, not learners on an inward trajectory towards engagement, or novices who are 'legitimate peripheral participants', to use Lave and Wenger's (1992) terminology.

The indications are that undergraduate mathematics identities need to be understood in terms of the interface between different practices, some of them diametrically opposed or contradictory. In the analysis which follows, I explore the complexities of the communities of practice which these students are party to, or potentially are party to, via their different modes of belonging as the communities intersect.

The study

Participants

The data presented here were collected in interviews with twelve first-year undergraduate mathematics students at an English university with a strong research culture. The students were self-selecting, having responded to a request delivered via their tutors to help with a project concerning mathematics learning in which they would get an opportunity to talk about their own study experiences. Ten respondents were aged 19-20, and included four women and six men; the eleventh was a twenty-three-year-old male mature student, and the twelfth was a thirty-four year old female mature student. Schools in England offer two mathematics qualifications between the ages of 16 and 18: in addition to the standard Advanced Level General Certificate of Education in Mathematics, some students take Advanced Level Further Mathematics, which builds on the material of the standard syllabus. Of the regular age students all had taken Advanced Level Mathematics and one had taken Further Mathematics; both mature students had entered the university with a further education college access award in mathematics. All were taking the basic first-year mathematics course offered at this university, but six were taking an additional mathematics course, compulsory for intending mathematics single majors. Three students (one male, two female) were registered for a single major degree in mathematics, one (female) for a single major in applied mathematics, two (both male) for a joint degree in mathematics combined with computer science, one (male) for a joint degree in mathematics and management, one (female) for a combined sciences degree with mathematics options and four (one female, three male) for major degrees in other subjects with mathematics as a minor subject.

While all students enter the university in order to study a particular major or joint major degree, a small number opt to change their intended major at the end of their first year, pursuing instead another degree programme. Some of the students in the sample were intending to make these sorts of changes. The three mathematics single major students were intending to continue as mathematics majors into the second year of university and the applied mathematics student was moving to environmental science and taking statistics as a minor only. Of the three students who were combining mathematics with another subject as joint majors, one was continuing as joint, one was intending to take mathematics as a minor subject only, and one was intending to change from a joint degree in mathematics and computer science to a single major in mathematics. The remaining students – taking mathematics as a minor or as part of a general science degree - showed a similar variety of intentions. One notable instance was Richard's complete change of major from management to mathematics. Ten of the twelve were planning to continue with mathematics in some form in their degree – only Diane and Charlie were not. These details are summarised in Table 1, which shows each participant's registered major on entry to the university, and their intended major for the second and third years of their degree.

Table 1: Student profiles

Student name[1]	Male/ Female	Registered major on entry: Mathematics majors/joint majors are in bold	Intended second and third year subjects: Mathematics majors/joint majors in bold; mathematics minors in italics
Carol	**F**	**Applied mathematics**	Environmental Sciences: *mathematics* minor
Debbie (mature)	**F**	**Single major mathematics** RS minor	**Single major mathematics**
Sarah	**F**	**Single major mathematics** Art minor	**Single major mathematics**
Larry	**M**	**Single major mathematics**	**Single major mathematics**
Pete (mature)	**M**	**Mathematics/computer science joint**	**Mathematics/computer science joint**
Steve	**M**	**Mathematics/computer science joint**	**Single major mathematics**
Joe	**M**	**Management/mathematics joint**	Management: *statistics* minor
Sue	**F**	Combined sciences (includes mathematics options)	Combined sciences, including *mathematics*
Diane	**F**	Geography	Geography
Charlie	**M**	Computer science	Communication studies
Chris	**M**	Natural sciences	Natural sciences: *Statistics* minor only
Richard	**M**	Management	**Single major mathematics**

The interviews

The students were contacted by e-mail and asked to come along to the interview with a selection of work, including a topic they had enjoyed and/or found easy, and a topic which they had disliked or found difficult to do. The interviews were semi-structured, lasting for approximately one hour each and focusing on the following issues: the students' 'mathematics histories' and comparisons between mathematics at school or college and at university, the effect of different teaching styles on their learning experiences, their experiences of getting 'stuck' and strategies for resolving problems, the topics they found easy or hard (students were asked to talk through the examples they had brought with them), comparisons with other subjects in terms of the kind of work expected and how they approached the subject matter and tasks, the ir reasons for choosing mathematics at university, their views on what kind of approach would lead to success in mathematics, and their perceptions of research mathematics and of themselves as mathematicians. The students were interviewed individually when they were approximately two-thirds of the way through their first year at university. The interviews were audio-taped.

The analysis process

[1] All names are pseudonyms.

The interviews were transcribed and analysed thematically. This entailed assigning relevant pieces of text to categories initially generated from Wenger's theoretical framework, focussing on the students' relationships to mathematics within both the wider community of mathematicians and undergraduate communities. Repeated exploration of these categories and the connections between them revealed further complexities in the students' positioning of self as mathematicians and indicated issues of importance in their classroom experiences; these are presented below with illustrative quotes (see Seale, 2000, for an analysis of techniques similar to those employed here).

Mathematics identities

A socio-cultural perspective characterises identity as the experience of a common enterprise, with shared values, assumptions, purpose and rules of engagement and communication: 'we know who we are by what is familiar, understandable, usable, negotiable; we know who we are not by what is foreign, opaque, unwieldy, unproductive' (Wenger, 1998, p.153). Although their experiences of doing mathematics varied considerably, the students tended to describe themselves as lacking control over their mathematical knowledge, as following rules without understanding, and as vulnerable to failure – staying with the subject is possible only as long as they can do it, and this facility can fail at any time. It is in this sense that most of the students express identities of marginalisation in an alignment to mathematics procedures which they learn to operate but do not contribute to. Only one student described herself in terms which fit the label of a 'legitimate peripheral participant' who, as a novice, has much to learn but also has the potential to make constructive connections in mathematics and to act as a negotiator in the mathematics community.

However, there is a distinction to be drawn between membership of the wider community of the discipline and of the various other communities of practice which an undergraduate student is likely to come into contact with. The characterisation of student identities above holds only with respect to the community of professional mathematicians of which some are only dimly aware and/or may not aspire to be a part. There are more immediate communities of practice which also figure in these students' identities: the undergraduate community in general, the mathematics undergraduate community and the first year community within it, and the classroom community of learners and tutors. The students' identities and their relationships to mathematics are also shaped by their membership of these often more visible communities, as the following analysis shows.

Following rules – negative alignment

Alignment to a practice emphasizes common agreed systems of rules, values or standards through which we can communicate within a practice and through which we can belong to it. However, while alignment has this positive coordinating aspect, systems which we do not own and cannot contribute to are no more than rule-bounded situations in which we participate only as rule-followers, not rule-makers. Although initial guidance and modelling introduces the learner to the possibilities of a practice (see also Solomon, 1998), lack of ownership generates and is generated by compliance and an emphasis on procedural or 'ritual knowledge' which is ‘embedded in the paraphernalia of the activities themselves, without any grasp of what it was all really about’ (Edwards and Mercer, 1987, p.99):

> …literal compliance can be efficient, since it does not require the complex processes of negotiation by which ownership of meaning can be shared. But for the same reason, it is brittle in that it makes alignment dependent on an environment that is specifically organized, conforming, and free of unforeseen situations. Such lack of negotiability can only engender … an inability to adapt to new circumstances, a lack of flexibility, and a propensity to breakdowns. (Wenger, 1998, p.206)

A number of students described their mathematics activities as blind rule following, but they varied in terms of whether they experienced this as a source of irritation or were accepting of the situation. Such variation appeared to depend on other aspects of their identities, generated from their views of their own abilities and dispositions, and from their classroom experiences. For instance, Steve considers rule-following unproblematic, and even a bonus:

> I like learning methods and, like, getting just one answer … As a person I don’t really like making decisions, I like everything laid out for me.

Charlie equally sees no problem in rule-following without the support of intermediate steps:

> If I've got the knowledge … it's – like - learn and just memorise it. I hate the long way of doing something and then there's an easier way, I say you're never going to use it again so why did they teach it you in the first place?

Although he values understanding when it underpins being able to do the work, Joe has a similar attitude to Charlie to tutor demonstrations which are not assessed:

> All the things we look at we're told how to prove it, but then we were told we didn't need to know how to prove it …. so I just thought 'forget that'.

Chris too is not bothered about understanding as long as there are rules to follow:

> [If] I'm told so and so and so and so is this, then I won't go and read and try and understand why, I just remember the result ... I just accept what people say ...

Pete recognises a role for understanding but sees this as sufficiently offset by being able to follow rules successfully:

> I seem to score well on tests, I do manage to get the mechanical bits, I don’t, I’m not very good at proof, or understanding necessarily but I can learn things and how to do them and apply them but… [I’m not very good at] trying to understand it or … just thinking about it and coming up with ideas in it.

As both Chris and Pete indicate, it is possible to get right answers through mechanical means, and they were satisfied with this, relegating understanding to a lesser priority. Richard, who was very focused on his test results, liked mathematics because he could do it and get it right. He has a clear preference for a subject which he perceives as having right and wrong answers which are given by the rules, and are outwith the realm of opinion or debate:

> I don't care as long as I can do it. … What I like about it [is] the fact that it gives you a right answer, if there's a definite answer, I'll be alright. …. There's a right and wrong in maths … there's nothing that's open to the teacher's opinion …

While he continues to get right answers, Richard is unconcerned; however, his tolerance for failure to get the right answers is minimal:

> If I was struggling I'd drop it. I was alright at English but as soon as my grades started going down I dropped it. I just don't enjoy doing something I'm not good at. I have to be the best.

A very different feeling about rules, achievement and understanding is described by Sue, however, who experiences mathematics as confusing and pointless. In her view, 'there doesn't seem to be any sort of reason … in maths it seems they change the rules when they want'. Her irritation and frustration with the situation and her perceived role in it is situated in her experience of her mathematics classes, where, for her, the need to follow rules without understanding signifies marginalisation from the wider community of mathematics rather than belonging. While she maintains a hope that she will understand more if she persists with mathematics and tries to become party to the meaning behind the rules, Carol's similar frustrations lead her to resist and reject it. Her experience of non-participation in class leads her to describe learning mathematics in terms of 'them' and 'us', particularly when it comes to pure mathematics, which, she believes, does not allow her to express her own understanding:

> I always wonder about maths, because I'm not really the kind of person that just accepts things, I always like to see the proof of it all and they just reel off all this stuff - "And this is how you do this" - and I'm, "Well, why?" ... Calculus: different styles of integration - do they explain why? No - "they just are". Which is useful (sarcastically) ... Probability and stats you can do more hands on, you can do more work yourself, you can have your own data you can do your own thing.

Reflecting on mathematics: imagination and engagement

A few students expressed a more positive relationship with mathematics, reflecting on their position within the wider practice of mathematics, on the patterns within it and their identity as learner mathematicians. They thus showed imagination in terms of a positioning of self within the social nexus of practices and an awareness of actions as part of historical patterns and potential future developments, of others' perspectives and of other possible meanings - 'a process of expanding our self by transcending our time and space and creating new images of the world and ourselves' (Wenger, 1998, p.176). They willingly reflected on what they were doing as students of mathematics, and considered explicitly how their approach helped them, often with reference to their own particular learning styles and experiences. Larry, for example, reflected on his success in maths:

> Maths is based on a set of facts which you can follow through without having to rely on other things, you could use past experience. You could apply [basic rules] like if you know a method - a method that makes sense - you can combine that to get something else.

Here, Larry expresses an identity of being in control of learning mathematics. Debbie, while not understanding as well as Larry appears to do, enjoys the exploration of mathematics:

> It's weird because even though I didn't really understand it - it took me a while to get to understand certain things - I did sort of feel to myself "I think I'm going to like this". You know, "I like the concept of it", you know, "I like proof, I think I'm going to be all right with that".

A true sense of engagement in terms of an attempt to 'appropriate the meanings of a community and develop an identity of participation' (p.202) is evident in Sarah's account only. While she describes a preference for the security of being told what to do by tutors, she also finds herself independently looking for patterns and exploring them:

> I find it a lot easier for them to say "this is what you are going to do, and this is how it's done", so in a way I am not very creative in my maths, but in a way I am as well, because sometimes I'm working and I think, "Oh maybe this could work", and I get all excited and it usually doesn't work but still I am thinking about it … Sometimes, I might see, like, a connection between some things and I will think, "Oh maybe this would work and then maybe I would be able to prove that, and this, and the other".

Accounts such as Sarah's are rare. Notice the contrast between her willingness to be guided by her tutors and Carol's far more adversarial stance; while both these students seek some sort of self-expression in mathematics, Carol seems to perceive herself as excluded, as wasting her time, but Sarah sees herself as potentially included, and indeed acts as though she is included. Her attitude to mathematics is correspondingly different; she appreciates its aesthetic:

> It is nice. And also at the end you have this nice thing and you have worked all through it.

Positioning identity within multiple communities of practice

In the preceding analysis I have selected comments which illustrate particular modes of belonging, most frequently a negative form of alignment, but also modes of imagination and engagement. However, the analysis also shows that these modes are not experienced in the same way by all students: as I have already suggested, we need to capture an individual's position with respect to multiple communities of practice in order to fully understand the complexities of mathematical identities. While Wenger's model attempts to capture complexity in its definition of identity as 'a layering of events of participation and reification by which our experience and its social interpretation inform each other'(1998, p.151), it neglects to explore in detail the nature of identity in multiple, and possibly conflicting, communities of practice. While my discussion of Sue above illustrates an identity of not belonging in terms of her negative account of rule following, a more holistic reading of her interview shows a clear element of imagination: she reflects on her experience of learning mathematics, and attempts to make sense of it as part of her university experience, and to situate it in her own mathematics history and future. There is a mis-match between the values of the wider community of practice of mathematics and those of the immediate undergraduate and classroom communities of practice which Sue is part of. Although she described herself throughout her interview as confused about mathematics, her attempts to understand both mathematics as a discipline and the merits and demerits of her particular approach to it suggest perhaps that she is not so much marginalised from the wider mathematics community than from the undergraduate and classroom communities, with their emphasis on getting right answers, following rules, and speed. Here she reflects on the difficulty of undergraduate mathematics, attempting to draw on resources, knowledge and experiences that she has developed elsewhere:

> With physics and chemistry moving from GCSE to A-level, the things we accepted at GCSE were then explained at A-level … we still used them at GCSE but we just had to accept that … you need to know this now but you can't understand them yet. …..In maths … maybe it's because I haven't studied the whole picture, I've just got this little bit, and with being told I've got to accept things, and I've just accepted things as I've gone along, and now I've got to a point where I can't just accept things. I need to understand things that I'm being told, but I've got to accept a little bit more before I can start understanding…. Maybe if I carry on doing maths it might click again.

Unlike Carol, Sue accepts the apparent inconsistency or opacity of mathematics rules, assuming that they do make sense if only she can stand back and take in the wider picture. As yet unbeaten by the challenge of confusion, she displays imagination in the sense that she is able to 'accept non-participation as an adventure' (Wenger, 1998: 185). In the remainder of this paper I explore how individual student identities come to display a particular mix of modes of belonging by examining the interplay of structures, practices and cultures. We can then begin to understand what constitutes a functional learner identity, in the sense of belief in oneself as a learner, in the undergraduate mathematics community of practice.

Fixed ability beliefs

While Sue's account shows how a negative alignment experience can be offset by imagination, she nevertheless hovers on the threshold of a negative mathematics identity, a characteristic she shares with others in the group. In large part this fragility is due to the almost universal fixed ability beliefs which are perpetuated by the pedagogic practices that surround them and permeate the undergraduate community of practice. Thus Carol, in spite of her robust and critical outlook on mathematics teaching, puts her non-participation down to perceived deficiencies in herself; her beliefs about ability and the nature of mathematics itself all militate to build a self-excluding identity:

> I don't know whether I've got to the stage where I think it's too difficult or I'm not bothered any more or if I don't really see the point of doing it any more. … I think with maths, you're good at it or you're not particularly good at it … you can struggle for years and years to understand maths and never grasp the concept, I think it is an all or nothing subject.

Ultimately, Carol subscribes to the idea that 'you can either do it or you can't'. Despite her rather more sophisticated and imaginative recognition that mathematics is about making connections, Diane also believes that successful students have a built-in overview of mathematics which enables them to solve novel problems:

> I think that they can bring all the bits of maths that they've already done together whereas I think I need someone to say 'You have to take this from here and this from here and put

> them together to work out the answer to this one' ..... I think people who are good at maths can recognise that already and use the information that they've already got….

She invokes brain functions in mathematics ability when asked whether her mathematics performance could improve:

> I could be taught to do maths but I don't think I could be taught to be good at maths. I think that's just something about the way the brain works or something.

Pete also believes in a biological basis for being good at mathematics, claiming that good students 'have some innate ability'. Sarah stands out from the other students in her claim that hard work can reap benefits in terms of developing a mathematical way of seeing:

> *Do you think that you can improve as a mathematician?* Yes, I think I could … I definitely think I could put more effort in and … go through and look at all the different examples and what happened in those examples and by doing that you learn and you learn to be able to see what is going to happen.

Nevertheless Sarah still invokes the idea of an uncoached mathematical 'talent' which echoes Diane's, and she contradicts her claims about hard work by giving voice to another dominant belief in the undergraduate community, that really good mathematicians never fail and don't even have to try:

> I think some people can and some people can't …. [They] usually don't do much work at all … they leave it to the last minute and they just do it and then they get full marks … I am good at maths compared to most people but compared to them I am awful because … they just have the mind for it, they can just see.

Debbie also refers to the companion belief that good students are fast workers:

> You know, some people … you get the impression that they don't really even have to think much. … I don't think that my brain is as clued up as some of these that obviously can just do it.

The prevalence of such beliefs in these students' accounts alongside indications of imagination and engagement suggests a reason why students such as Debbie, Diane, Carol and Sue struggle to maintain a positive mathematics identity despite their apparently more participatory trajectory into the wider mathematics community. While Diane, for example, recognises explicitly the need to make connections in mathematics, the discourse of fixed ability, performance and speed of understanding which pervades this undergraduate community has a detrimental influence on her identity. Sue interprets her need to understand as problematic, while Carol believes that she has reached her limit. Even Sarah describes herself as 'awful'. Looking closer at what these students say about the institutional structures and practices that they are part of shows how these continue to support the notion of fixed ability, thus undermining potential participation in mathematics and creating identity mixes which are *experienced as* marginalised. I explore these issues further in the next section.

Institutional structures and practices

Identities of non-participation in mathematics have important consequences. As the case studies here illustrate, these students experience mathematics as something 'done to them' rather than 'done by them'; they do not share in the ownership of meaning, let alone meaning making – they are excluded from that vital aspect of participation which Wenger identifies: negotiation. Engagement in a practice entails an identity which includes the role of legitimate negotiator of meaning - those who participate fully in a practice are part of the process of development of ideas and meanings, and in this sense have ownership of meaning. To some extent this is also the case for legitimate peripheral participators - their ideas and contributions are treated as valid, to be taken seriously, to be built upon. As the case studies show, however, the majority of the students did not perceive themselves as potential negotiators or owners of meaning. It might be argued that undergraduates cannot expect to find themselves in this position anyway, but many critical mathematics educators have argued that this is not only possible but necessary from the early years onwards (see Maher, 2005 and Burton, 1999a) to HE levels (see Rogers, 1995). The important issue here is how undergraduates experience and make sense of this situation, and how this influences their self-perception and choices.

A number of the students reported that mathematics, particularly pure mathematics, was presented as a non-negotiable finished product, as a set of rules and strategies to be learned, not constructed (see also Solomon, 2006). The net result of this teaching strategy was that pure mathematics was generally perceived as ‘hard’ and - more importantly - as a subject which they could not contribute to or be creative in, or even simply catch up in. For example, Joe complained that:

> The lecturers are always setting us more challenging work which we don't understand .. you never really feel like a mathematician because you don't understand how it works.

Sue expressed bewilderment as she described getting answers but not owning the knowledge:

> [It’s] very frustrating, because you know you know how to do it, it's just the problems are so much more complex and they sort of go in more, I don't know, just things from nowhere, and you do get the answer in the end but you just don't know.

Diane similarly reports confusion and isolation as she compares herself to the ‘good’ students who, as we have already seen, are fast workers:

> They seem to know exactly what to do and they’re just integrating and differentiating all over the place and I have to wait for the lecturer to do it. That’s why I think I’m not good at maths.

Carol and Diane both compared the mathematics department teaching adversely with that in environmental science and geography:

> You can't feel like a mathematician until you've learned quite a lot of stuff. [In environmental science] you’re asked what you think about things. (Carol)

> In geography they just want to see that you’ve understood the question and see if you can bring your opinion into it. Whereas maths it’s to see if you’ve understood. Full stop. (Diane)

Why do students such as Richard seem to be happy with their apparent alignment, and why is Sarah's evident engagement tempered with an identity of marginalisation? The gender differences in response to mathematics pedagogy observed in research by Boaler, Mendick and others discussed earlier seem to be at play again within the various communities of practice of this first year group and their classes. It appears that Richard, Steve, Joe, Chris, Pete and Charlie experience positively the atmosphere of reward for speed and correct answers, and in this sense they are full participants in the undergraduate community of practice and its related pedagogy - they feel at home with mathematics as it is taught in this university in large, anonymous groups. This group comprises both intending majors and minor students – we might expect that intending majors would feel differently but this is not the case – indeed Larry is the only male student to state that he is bothered by not understanding. Girls and women are frequently reported as experiencing such a teaching style as negative however (Becker, 1995; Willis, 1995) and the presentation of mathematics as a finished body of knowledge dealt with by mathematicians who never stumble down a blind alley is reported to be particularly disempowering for women (Rogers, 1995; Burton, 1995). The women in the study emphasised how much they wanted to understand, and their accounts were dominated by a sense of constant danger of feeling out of their depth - ownership is important to them but always threatens to be unattainable. Thus Diane wistfully remembers her school days of small group support for understanding in an account which is reminiscent of Maher's (2005) work on proof with high school students:

> In my A-Level … we'd all work together to get the same answer and I think that really helped because we were teaching each other which would help us to understand. … Because each of us understood different parts of it we were like, 'No, no, you're wrong, you're wrong', and say, 'Well explain yourself then'. … I think it really helped me get through A-Level because you learn from each other as well …

Her outlook contrasts starkly with Richard's:

> I think I'm the kind of person who should care about understanding but I don't … I am competitive … getting the right answer is more important … I understand well enough to carry on.

While the men rarely raised issues of teaching or group dynamics, the women were very likely to volunteer their appreciation of the value of working in a group, partly because the group lends reassurance that they are not alone in not understanding. Carol described why she informally sought out other students when she was stuck, highlighting at the same time the lack of discussion in class:

> I think it's just reassurance that you're not completely stupid because you can't do it, and just bouncing ideas off another person is better than sitting in your room attempting a question 50 times because you don't know how to do it. …. It's easier to talk amongst yourselves [outside of lessons] whereas in a tutorial you kind of feel under pressure just to not say anything in case it's the wrong answer.

Charlie admitted that the norm was for the group as a whole to avoid interaction in class because 'You don't want to look stupid if you're doing something really simple'. Diane in particular comments on the need to make and discuss connections in mathematics; her belief that she is unable to do this causes a major loss of confidence. Rather than supporting a participant identity, however, her epistemic insight into the role of connections causes her to feel increasingly inadequate and marginalized, not the reverse. Why should this be? It appears that the structure of mathematics learning as she is currently experiencing it disallows the making of connections - there is no time to do so and the reward system is not geared to it . In terms of this analysis, the immediate undergraduate community of practice does not enable legitimate peripheral participation in the discipline of mathematics. Rather, it marginalizes learners who seek to participate beyond a focus on correct answers, causing them to doubt their ability. Diane, in the many comments in which she compares herself adversely with those who are 'good at maths', says that the 'good' ones are the confident ones, and they are usually male:

> [They are] usually men .....they're getting too big headed and they know 'I can do this' …. They're all smug and they sit there and they're filling in the answers and then they sit back and sort of look over at what the other guy who's sitting next to them… like, 'Huh, you've done it wrong there' ….. Some of them are just really confident that they can do it and then they do it and they're really good.

Conclusion: Excluding practices and identities of exclusion

What generates identities of non-participation and/or marginalization? Much research indicates that mathematics teaching is frequently excluding, and that it treats many students as powerless and unimportant 'outsiders', permanently marginalizing many (Boaler, 1997, 2002; Burton, 1999a; Fennema & Romberg, 1999). This same research indicates that mathematics can only be made accessible to all in a participatory pedagogy which encourages exploration, negotiation and ownership of knowledge and the development of a corresponding identity of participation. However, an identity of legitimate peripheral participant is rare in the group of students interviewed in this study. The analysis in terms of modes of belonging presented here shows how identities are differentially experienced within multiple communities of practice and hence goes some way to explaining why this is the case.

Identities of exclusion are most obviously voiced by the women in this study although they are less marginalized according to Wenger's model than the men in terms of their approach to the discipline of mathematics. The connected approach which they seek, epitomized in Diane's quest for links and patterns and in Sarah's perception of the possibility of creativity and negotiation, is not only necessary at research level (Burton, 1999b) but at all levels according to Burton (1999a) and Fennema & Romberg (1999), including degree level (see Rogers, 1995). However, traditional teaching and assessment does not make this explicit, maintaining instead the appearance of support for a performance orientation of the kind demonstrated most clearly in Steve's and Richard's heavily aligned accounts. What distinguishes the students' accounts is that, for the time being anyway, Richard, Charlie, Joe, Chris and Steve – and to some extent Pete - are happy with this state of not belonging, and indeed do not express excluded identities, while Carol, Sue and Diane are not. Even Sarah, the most confident of the women, believes that some people 'just have the mind for it', and does not count herself among them. Richard, Charlie, Joe Chris and Steve accept their state of strong alignment whereas Carol, Sue, Debbie, Sarah and Diane strive for imagination and engagement. To the extent that their experience of mathematics teaching and learning emphasizes speed and performance, the men in the study have the more functional identities in the undergraduate community of practice in terms of their belief in their ability to succeed in accordance with these values, and they are full participants in this community. The women, on the other hand, face failure regularly as they strive to meet the twin criteria of speed *and* understanding.

Thus the position of promising novice represented by Sarah's account is not associated with a positive identity, while that of the heavily aligned and non-participating Richard does not bring with it a negatively experienced identity. The resolution of these contradictory findings is brought about by recognising their position in multiple communities of practices with opposing rules of engagement, and consequently of differential experiences of identity. As Brown & Rodd (2003) show, there is more than one way of being a successful student in undergraduate mathematics. The analysis presented here indicates, however, that some potentially successful students develop negative relationships with mathematics which marginalise them and can turn them against further study. Within the undergraduate community of practice, the dominant discourse of performance within which mathematics identities are constructed dictates the apparent functionality of particular identities.

The implication of this analysis is that teaching at undergraduate level needs to challenge such dominant discourses and to work towards greater transparency in the discipline of mathematics. These conclusions are applicable to Higher Education generally in terms of the intersection of communities of practice which emphasise summative assessment and surface learning on the one hand, and disciplinary engagement and a deep learning approach on the other. The rules of this latter community of practice are frequently opaque and experienced as exclusive. Undergraduate students need to be able to negotiate the boundaries between practices, and some may do this more successfully or perhaps more willingly than others. As in the case of mathematics, addressing this issue is necessary if we are to ensure that university learning is accessible to all.

References

De Abreu, G and Cline, T (2003) Schooled Mathematics and Cultural Knowledge. *Pedagogy, Culture and Society* 11 (1), 11-30.

Alibert, D. & Thomas, M. (1991) Research on mathematical proof, in D. Tall (Ed.), *Advanced Mathematical Thinking* (Dordrecht: Kluwer).

Bartholomew, H. (1999) Setting in stone? How ability grouping practices structure and constrain achievement in mathematics. Paper presented at the *Annual Conference of the British Educational Research Association*, University of Sussex, Brighton.

Bartholomew, H. & Rodd, M. (2003) A "fiercely held modesty": The experiences of women studying mathematics, *New Zealand Journal of Mathematics* 32 Supplementary Issue 9–18.

Becker, J. (1995) Women's ways of knowing in mathematics, in P. Rogers & G. Kaiser (Eds.) *Equity in Mathematics Education.* (London: Falmer).

Black, L. (2004) Differential participation in whole-class discussions and the construction of marginalised identities, J*ournal of Educational Enquiry*, 5 (1), 34-54.

Boaler, J. (1997/2002) *Experiencing School Mathematics: Teaching styles, sex and setting* (Buckingham: Open University Press).

Boaler, J. (2000) Mathematics from another world: Traditional communities and the alienation of learners. *Journal of Mathematical Behavior,* 18 (4), 379-397.
Boaler, J. & Greeno, J. (2000) Identity, agency and knowing in mathematics worlds, in J. Boaler (Ed.), *Multiple Perspectives on Mathematics Teaching and Learning* (Westport, CT: Ablex).
Boaler, J., Wiliam, D. & Brown, M. L. (2000) Students' experiences of ability grouping—disaffection, polarisation and the construction of failure. *British Educational Research Journal,* 26 (5), 631-648.
Brown, M., Macrae, S. & Rodd, M. (in preparation) Mathematics undergraduates' attitudes to their course *Students' Experience of Undergraduate Mathematics Project* (via personal communication, August 2005)
Brown, M. & Rodd, M. (2003) Successful undergraduate mathematicians: a study of students in two universities. Paper presented at the *Annual Conference of the British Educational Research Association*, Herriot Watt University, September, 2003.
Burton, L. (1995) Moving towards a feminist epistemology of mathematics, in P. Rogers & G. Kaiser (Eds.) *Equity in Mathematics Education.* (London: Falmer).
Burton, L. (Ed.) (1999a) *Learning Mathematics: from hierarchies to networks.* (London: Falmer).
Burton, L. (1999b) The practices of mathematicians: what do they tell us about coming to know mathematics? *Educational Studies in Mathematics,* 37(2), 121–143.
Carlson, M. (1999) The mathematical behavior of six successful mathematics graduate students: influences leading to mathematical success. *Educational Studies in Mathematics,* 40(3), 237-258.
Cobb, P & Hodge, L. (2002) A relational perspective on issues of cultural diversity and equity as they play out in the mathematics classroom. *Mathematical Thinking And Learning*, 4(2&3), 249–284.
Cooper, B. (2001) Social class and 'real-life' mathematics assessments, in P. Gates (Ed.) *Issues in Mathematics Teaching.* (London: Routledge).
Crawford, K., Gordon, S., Nicholas, J. & Prosser, M. (1994) Conceptions of mathematics and how it is learned: the perspectives of students entering university. *Learning and Instruction,* 4, 331-45.
De Corte, E., Op't Eynde, P. & Verschaffel, L. (2002) 'Knowing what to believe': the relevance of students' mathematical beliefs for mathematics education, in B. Hofer & P. Pintrich (Eds.), *Personal Epistemology: The Psychology of Beliefs about Knowledge and Knowing* (Mahwah, N.J.: Lawrence Erlbaum).
Dowling, P. (2001) Reading mathematics texts, in P. Gates (Ed.) *Issues in Mathematics Teaching.* (London: Routledge).
Edwards, D. & Mercer, N. (1987) *The Guided Construction of Knowledge* (London: Routledge).
Fennema, E. & Romberg, T. A. (1999) *Mathematics Classrooms that Promote Understanding.* (New Jersey: LEA).
Gilborn, D. & Mirza, H. (2002) *Educational Inequality: Mapping Race, Class and Gender* (London: OFSTED).
Hoyles, C., Newman, K. & Noss, R. (2001) Changing patterns of transition from school to university mathematics. *International Journal of Mathematical Education in Science and Technology,* 32 (6), 829-845.
Kassem, P. (2001) Ethnicity and mathematics education, in P. Gates (Ed.) *Issues in Mathematics Teaching* (London: Routledge) 64-76.
Kitchen, A. (1999) The changing profile of entrants to mathematics at A level and to mathematical subjects in higher education. *British Educational Research Journal*, 25(1) 57-64.

Kloosterman, P. & Coughan, M.C. (1994) Students' beliefs about learning school mathematics. *Elementary School Journal,* 94, 375-388.
Landau, N. R. (1994) L*ove, hate and mathematics* Unpublished MA dissertation thesis, King's College, University of London.
Lave, J. & Wenger, E. (1992) *Situated Learning: Legitimate Peripheral Participation.* (Cambridge: CUP).
Maher, C. A. (2005) How students structure their investigations and learn mathematics: insights from a long-term study. *Journal of Mathematical Behavior,* 24 1-14.
Martino, A.M. & Maher, C.A. (1999) Teacher questioning to promote justification and generalization in mathematics: What research has taught us. *Journal of Mathematical Behavior,* 18 53-78.
Mendick, H. (2003a) *Telling Choices: an exploration of the gender imbalance in participation in advanced mathematics courses in England* Unpublished PhD Thesis, University of London.
Mendick, H. (2003b) Choosing maths/doing gender; a look at why there are more boys than girls in advanced mathematics classes in England, in L. Burton (Ed.) *Which way social justice for mathematics education?* (Westport, CT: Praeger).
Mendick, H. (2005a) A beautiful myth? The gendering of being/doing 'good at maths'. *Gender and Education,* 17, 89–105.
Mendick, H. (2005b) Mathematical stories: why do more boys than girls choose to study mathematics at AS-level in England? *British Journal of Sociology of Education,* 26, 225–241.
Nasir, N.S. (2002) Identity, goals, and learning: mathematics in cultural practice *Mathematical Thinking And Learning*, 4(2&3), 213–247.
Paechter, C. (2001) Gender, reason and emotion in secondary mathematics classrooms, in P. Gates (Ed.) *Issues in Mathematics Teaching.* (London: Routledge) 51-63.
Rogers, P. (1995) Putting theory into practice, in P. Rogers & G. Kaiser (Eds.) *Equity in Mathematics Education.* (London: Falmer)175-185.
Seale, C. (2000) Using computers to analyse qualitative data, in D. Silverman (Ed.) *Doing Qualitative Research: A Practical Handbook.* (London: Sage).
Solomon, Y. (1998) Teaching mathematics: Ritual, principle and practice. *Journal of Philosophy of Education,* 32 (3) 377-390.
Solomon, Y. (2006) Deficit or difference? The role of students' epistemologies of mathematics in their interactions with proof, *Educational Studies in Mathematics* 62
Wenger, E. (1998) *Communities of Practice.* (Cambridge: CUP).
Willis, S. (1995) Gender reform through school mathematics, in P. Rogers & G. Kaiser (Eds.) *Equity in Mathematics Education.* (London: Falmer) 186-199.