Students' Experience of Mathematics Enrichment

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This paper presents findings on students' experience of mathematics enrichment, arising from a recent and more extensive study designed to inform understanding of different forms and practices of mathematics enrichment in the UK. Four case studies were conducted, each focusing on a distinctive enrichment programme, namely: one set of residential Mathematics Summer Schools, offered by the National Academy for Gifted and Talented Youth; one series of Mathematics Master-classes, run by a Royal Institution Master-class group; an after-school outreach and enrichment programme, targeted at students from a disadvantaged, inner-city area, run in collaboration with NRICH; and the United Kingdom Mathematics Trust's (Junior and Intermediate) Maths Challenge competitions, undertaken in one school. Data were collected through interviews with student participants, informed by observations of enrichment practice. Whilst students reported a range of enrichment benefits, broadly related to their mathematical, and personal and social, development, support for mathematics learning in school, and exposure to higher education, their experience was more subtly related to the characteristics of the programme in which they had participated, interpreted according to more familiar experiences of learning mathematics in school.

Keywords: mathematics enrichment, students' experience, enrichment programmes, gifted education

Background

Students' apathy towards mathematics has received much public attention in recent years: many are reported to be disaffected with school mathematics and to grow more so through their years of schooling; numbers recruited into post-16 mathematics education had been falling between 1996 and 2007, following longer-term decline across the wider science fields (Smith 2004; The Royal Society 2008). In the most recent EU survey on attitude to 'science' among young people aged 15 to 25 (European Commission 2008), mathematics was the least popular discipline, even among the minority who would 'consider' studying 'science' subjects; interest in studying mathematics in the UK was among the lowest in EU Member States.

Against this background, students' participation in, and attitude to, mathematics have become key concerns for policy-makers and the mathematics and mathematics-education communities (Clarke 2004; Smith 2004). This has led to an increase in the number and variety of 'enrichment' activities, aimed at engaging young people in mathematics in general and at supporting and extending the mathematics learning of specific groups of students (e.g. those identified as being 'mathematically-gifted' or belonging to 'disadvantaged' social groups) in particular, above and beyond provisions prescribed by the school Mathematics curriculum. Such activities include:

- efforts by individual teachers or Mathematics Departments to make mathematics learning in lessons more interesting for students;
- school-based mathematics clubs run by teachers to supplement and enhance students' learning;
- competitions to stimulate interest in mathematics in large numbers of students and to identify and cultivate talent;
- summer study programmes, popular lectures, workshops and master-classes to engage students in mathematics and to expand their mathematical horizon; and
- university outreach and 'widening participation' activities to attract students to study mathematics-related courses, and to recruit, and raise the aspirations of, students from social groups currently under-represented in higher education or in mathematics-related studies and careers.

Despite the increasing amount of activity taking place under the 'enrichment' label, the 'enrichment' area is under-theorised and under-researched. The term 'enrichment' is often used common-sensically, masking the range of activities which operate under its label (Feng 2005); outcomes of enrichment are also not well-understood. The large numbers of enrichment activities — not just in mathematics, but across STEM (science, technology, engineering, mathematics) fields — and their role and impact in promoting the STEM disciplines to young people are currently receiving increased attention from policy-makers (DfES and DTI 2006; DIUS 2008).

Design and method for the study

This paper presents findings on students' experience of mathematics enrichment, arising from a recent and more extensive study which developed and refined a conceptual framework for understanding 'mathematics enrichment' in the UK. The main study itself synthesised available literature and provided new empirical evidence, gathered through four case studies (Bassey 1999), to inform understanding of different forms and practices of 'mathematics enrichment' emerging from the literature (Feng 2006): 'enrichment' which focuses, respectively, on the development of mathematical talent (e.g. Roberts 2005), the popular contextualisation of mathematics (e.g. Zeeman 1990), the enhancement of mathematical proficiency and learning processes (e.g. Piggott 2004), and outreach to the mathematically underprivileged (e.g. Bouie 2007). Each case study focused on a distinctive enrichment programme as follows:

- one set of residential Mathematics Summer Schools for 'gifted' students (in the top 5% of the attainment range) lasting three weeks, offered by the National Academy for Gifted and Talented Youth;
- one series of Mathematics Master-classes, composed of five Saturday-morning workshops led by different speakers each week, run by a Royal Institution master-class group at its local university;
- a year-long outreach and enrichment programme, composed of weekly, after-school classes, targeted at students from a disadvantaged, inner-city area and held in their local university, run in collaboration with NRICH; and
- the United Kingdom Mathematics Trust's (Junior and Intermediate) Maths Challenge competitions, undertaken in one school.

Within each case study, the ideas and experiences of enrichment held by the staff organising, and the students participating in, the respective programme were explored through analysis of official documents and interviews with organisers and students, informed by observations of enrichment practice.

The data reported in this paper were collected through end-of-programme, semi-structured interviews with 40 student participants between 2005 and 2006, supported by observations of enrichment practice made over a more extended period (2004–2006). Participants were chosen in consultation with enrichment providers or their teachers so as to cover, potentially, a range of views and experiences of participating in enrichment. Interviews lasted, on average, 50 minutes. Themes were developed inductively from the data as well as deductively from the literature, and refined iteratively through constant comparison.

'Enriching' experiences of mathematics

Participants from each of the four programmes identified a range of experiences which they valued and perceived as 'enriching'. Typically, students reported investing sustained effort into solving mathematical problems: salient features of the way they worked include thinking mathematically to find ways forward and identifying strategies from their own repertoire. This contrasts with their reported experience of solving school-mathematics problems, which they usually completed very quickly using known techniques:

> [You can't] come up with an answer [straight-away]. You have to be systematic [and] build upon it. [In school], it won't take [long to answer a question. If] they give [you] 6 marks, then [you do] 6 bits. […] You know what method to use. [Here], you don't know. You have to work out [what's best to do].
>
> (Outreach participant)

As such, students typically found enrichment problems more 'challenging' and 'difficult' than problems commonly encountered in school. Although a small number preferred the 'security' of solving 'known problems', students generally found the material introduced to them interesting and relished the substantive challenge.

In addition, a key part of the Summer Schools, Master-classes and Outreach involved participants in collaborative work (e.g. discussing mathematical ideas and working with, and learning from, adult 'specialists' and fellow participants):

> It was all about finding out new things and watching what other people did and seeing how you can improve yourself. […] You could just be together and work as a group, discussing [the problems], seeing what each can find out about the answers, sharing [ideas] in a group.
>
> (Master-class participant)

In these three programmes, emphasis was placed on exploring mathematically and on elucidating mathematical thinking:

> [You] have to think about [the problem and] explore it a lot. It wasn't just [getting to the] answer. […] The whole idea was that you explored your answers a bit more: [….] to get at its nature rather than just leaving an answer — to question it a bit more and think why.
>
> (Master-class participant)

Such experiences were valued by participants of these three programmes as an integral part of their 'enrichment'. Where students were able to work on Maths-Challenge problems in class, the experience was similarly considered 'enriching'.

Enrichment 'benefits'

Participants from the four programmes also identified a number of ways in which they felt they had 'benefited' from their enrichment experience. These relate broadly to:

their mathematical, and personal and social, development; support for mathematics learning in school; and exposure to higher education. Looking beyond these broad categories of 'benefits', however, specific experiences were more subtly related to the characteristics of the programme in which the student had participated, interpreted according to more familiar experiences of learning mathematics in school.

For example, all Master-class and Summer-School participants interviewed felt that they had benefited mathematically, and personally and socially, from their experience. However, in the Master-classes — a programme where enrichment exposure was limited to a small number of weekly workshops — identified benefits were primarily in terms of gains in mathematical knowledge. In the Summer Schools — a programme where participants were in contact with one another over a relatively-long uninterrupted period and in wider social contexts — personal and social benefits and mathematics-related gains were identified in almost equal measure; references to both were interwoven in participants' accounts:

> [I've gained] a lot of knowledge, [a] lot of understanding and a lot of friends. I suppose I've gained some independence as well. I definitely understand maths more. And I suppose [I've] gained knowledge [about] how to challenge myself.

The Maths Challenge competitions, meanwhile, were thought to be engaging and exciting. The quality of the Maths-Challenge problems was consistently praised:

> I didn't know there [could be] that much fun working through these problems. I think that's why I found [the Maths Challenge] enriching. […] It's just using your mind so much more. [When] you open the textbook, you know what topic [the questions are] on. But you don't with the Maths Challenge. [That's] what makes it more exciting.

This notwithstanding, the students interviewed gauged the 'benefits' they had derived primarily in relation to mathematics learning in school, and in some cases, particularly as 'revision' or 'practice' for high-stakes public examinations and as a means for judging their performance — even 'ability' — relative to other students nationally and in their school. The latter reflects the culture of assessment in schools through which the students understood the Challenges. Where 'enrichment' was not followed up and students simply 'sat the test', learning was thought to be limited. Indeed, some students had mixed feelings about the competition and its associated rewards:

> If you do well, then it [helps]. But if you don't do so well, then you're really congratulated for taking part, but you still might feel inside that you've not done very well compared to [others].

Similar reactions are likely to occur wherever competition is a salient feature of an enrichment programme.

The enrichment 'benefits' identified by students, the relationship between 'benefits' and programme characteristics, and students' interpretations of their 'enrichment' experience in the light of more familiar experiences with school mathematics are further illustrated in the following subsections.

Personal and social 'benefits'

The personal and social benefits most commonly identified across the four programmes were increased confidence and sense of capability, and opportunities to meet and work with other students.

For Outreach participants, increased confidence and sense of capability was attributed to positive problem-solving experiences and the sharing of mathematical

ideas; seeing other participants' endeavours and achievements was motivating and encouraged participants to recognise possibilities for themselves:

> [I saw others] working on [the problems. It] gave me a thirst to [prove myself], because at the end of the day, [we're] the same age [and] we've got the same abilities. [You see people working] and you just think, 'I can do it as well!' […] When you actually accomplish the puzzle, [you get] self-satisfaction. [That] boosts your confidence.

Meeting and working with (like-minded) students from other schools was also thought to be enriching in its own right.

For Summer-School participants, confidence was derived from the whole (social and academic) programme, which made them feel more independent and motivated (generally and towards studying mathematics). Participants also valued opportunities to work with like-minded students of similar levels of attainment:

> Everyone wants [to] work, [which] makes it a much better [working] environment. [The other students are of] equal ability to you, so they're pushing you [to] achieve the highest standards possible.

Through these opportunities, participants reportedly developed better interpersonal skills and began to feel less isolated.

For Maths-Challenge participants, confidence and sense of capability stemmed from 'successful' participation (defined differently by different students according to their prior experience) and favourable comparisons with other competitors:

> [What I particularly like is getting] a certificate at the end — that's good. And you can compare your scores with your friends. […] For a certificate, you feel like you've done well at something, [and] most of the time, I do better than my friends, so it feels good.

To some extent, this is consistent with enrichment goals to recognise and reward achievement, and to improve participants' confidence and self-esteem through the competitive process. The potentially-negative connotations which may be associated with such comparisons, however, were not intended. No social benefit was mentioned by Maths-Challenge participants; neither were social experiences a part of the intended provision.

Finally, Master-class participants made very few references to stimulating social exchanges or to having benefited socially from their experience; none reported any increase in mathematical confidence. This may be due to the limited time available for participants to build comfortable relationships with speakers and fellow participants, wherein stimulating social exchanges could take place. The Master-classes were successful primarily in providing an introduction to a variety of mathematical topics (see below).

Mathematical benefits

Mathematically, participants from all four programmes felt that enrichment had broadened their mathematical experience and horizon. In the Master-classes and Summer Schools, this was brought about primarily through introducing participants to stimulating aspects, and unfamiliar applications, of mathematics not normally taught in school; in Outreach, participants were encouraged to think mathematically by way of the problems posed and to apply their knowledge flexibly to solve challenging and unfamiliar problems. In accordance with these methods, the specific way in which Master-class and Summer-School participants felt that their mathematical experience

and horizon had been broadened was through becoming more aware of the breadth and pervasiveness of mathematics and its applications:

> You were introduced to maths in lots of different contexts. […] It makes you see that maths isn't just [about] numbers; it's in many different things.
>
> (Master-class participant)

Outreach participants, meanwhile, reported increased perseverance and improvements in the way they went about tackling unfamiliar problems:

> I've learnt a lot [in] the way I approach a question. [At] the beginning, I'd pick a random number [to try]. But now, [I'm] more systematic. […] And previously, if I couldn't do [a problem, I'd just] sit there until the answer comes. But as the sessions have gone by, [I've tried harder] to get the answer.

Those Outreach participants who reported greater appreciation for problem-posing and problem-solving also reported greater satisfaction and progress.

In addition, the majority of Master-class, Summer-School and Outreach participants interviewed felt that their interest in mathematics had increased. The majority of Outreach and Summer-School participants also reported improvements in their perception of mathematics. Maths-Challenge participants, however, reported limited mathematical gains, perhaps because enrichment exposure was only brief; the majority interviewed felt that the Challenges had made no difference to their interest or perception of the subject.

Support for mathematics learning in school

With the exception of the Master-classes, which participants perceived primarily as an opportunity to experience stimulating mathematics that is not necessarily associated with the mathematics they learn in school, the remaining programmes were each thought to 'benefit' mathematics learning in school in some way.

For Maths-Challenge participants, a key 'benefit' of participating in the competition was the support they gained for school-work through revision and practice afforded by the Challenges and the experience of working under test conditions in preparation for high-stakes public examinations:

> It gives you practice in [doing maths under] exam conditions. So it's helpful [for seeing] how you would react if some exam [is] sprung on you: [to] see what you already know and what you don't. [So regardless of how well you do], it's just an experience that will help you for other exams.

This confounds the fact that the Challenges were never conceived as such a means of enhancing school performance; interpretations of 'enrichment' as examination practice (in light of the culture of assessment in schools) were wholly unintended.

Almost all Outreach participants felt that their enrichment experience had consolidated mathematical ideas taught in school, and that this was helpful to them in their school-work. Indeed, some students participated in the programme in order to remedy perceived shortfalls in their school mathematics education, treating their enrichment experience as extra tuition. Whilst remedying shortfalls in school mathematics provisions was not a part of the intended 'enrichment', such an interpretation can be understood given that participants were drawn from specifically-targeted 'disadvantaged' schools.

A minority of Summer-School participants reported becoming more aware of connections within mathematics — a subject which had previously been presented to them in a more fragmented way in school. That said, there was no evidence that students felt any more appreciative of school mathematics after participating in the

Summer Schools. Indeed, from the many contrasts participants from all four initiatives had made between school mathematics and enrichment, enrichment was unlikely to have enhanced students' appreciation or liking for school mathematics in any of the four cases.

Exposure to higher education

Raising participants' educational aspirations and enabling participants to gain insights into higher education were central to the enrichment intentions of the Outreach programme and the Summer Schools. Both programmes were hosted in universities expressly for the purpose of bringing participants into higher-education settings. The benefits of being in a university, however, were felt only by Outreach participants and those (older) Summer-School participants at or towards the end of their secondary education. In addition to being able to see inside a university, these older Summer-School participants also valued the subject expertise from the institution:

> [This] is quite a good university for maths. So maths would be a good course to do here [because] the lecturers will know more about the subject [and] be better at teaching. [It's amazing] just how interesting it is and how [deeply] you go into [the maths. Being] a maths lecturer, [our tutor] has told us quite a bit about what we're doing and how it relates to degree and graduate work.

Outreach participants, on the other hand, valued the prestige associated with 'studying' at university and the change in environment that this afforded. The latter, in particular, encouraged them to adopt a more mature attitude towards learning and enabled them to shed the constraints associated with being interested in mathematics:

> [Being at university] makes you [feel] older [and more grown up]. People don't just sit there and do nothing. […] Everyone's working and everyone's interested in [thinking] about [maths].

In the case of the Master-classes, although the act of exposing students to a university environment was thought to be enriching, exposing participants to higher-education settings was not a central part of the conceived enrichment. Predominantly, participants acknowledged that the Master-classes had given them an opportunity to visit a university (which they thought of as a comfortable space for meeting and learning), but the experience of being inside a university was not associated with their experience of mathematics or learning.

Conclusion

The general consensus among participants was that enrichment presented valuable opportunities for them to engage in mathematics which they would not normally experience in school. Participants from all four programmes were able to identify a range of enrichment 'benefits' and experiences which they perceived as 'enriching'. These relate broadly to their mathematical, and personal and social, development; support for mathematics learning in school; and exposure to higher education.

Beyond this level of generality, participants' experiences were more subtly related to the characteristics of the programme in which they had participated, interpreted according to more familiar experiences of learning mathematics in school. So whilst 'enrichment' can offer valuable opportunities to extend students' mathematics learning, it can only really be 'effective' if offered alongside rich 'everyday' experiences of learning mathematics in school, because that 'daily diet' of mathematics is the basis on which students interpret and understand any additional 'enrichment' experience.

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