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The Student Experience of Online Mathematics Enrichment

インターネットを利用した生徒の数学に対する見方に関する研究

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Following concerns about the falling number of mathematics majors at University level, consideration has being given in a number of countries to enhancing provision for those school pupils who show the potential to study mathematics at University. Prevalent amongst this provision are enrichment opportunities and material designed to provide a wider picture of mathematics. This paper reports findings from a study of internet-based enrichment material in mathematics and focuses on the student experience of such online provision. Data from questionnaires and interviews suggest that this enrichment material helped the pupils who used it to gain a wider appreciation of mathematics and raised the profile of mathematics as a subject that could be interesting enough to pursue beyond school. Issues of equity in access to the material remain.

本稿は、インターネット教材*nrich*について、特に生徒がこのページを通してどのような経験を得たかということに焦点を当てて考察したものである。アンケート及びインタビューにより得られたデータから、このホームページは、生徒に数学のよさを理解させることと、学校で教えられる教科としての枠を越えた数学の側面に対する見方を助長させることができるということが示唆された。今後の課題としては、このページへのアクセスの公平さに関することである。

Introduction

In a number of countries and over a number of years, demand for undergraduate units in mathematics has increased as rising numbers of undergraduates are required (or elect) to study an element of mathematics as a component of their degrees. At the same time, the number of students choosing to *major in mathematics* has fallen, or, at best, has remained static despite a substantial increase in the total number of students entering University. In the US, for example, the number of mathematics majors peaked in the early 1970s and is currently about the same as it was 40 years ago (estimate based on figures in Madison 1990). The US Committee on the Mathematical Sciences in the Year 2000 (1991 p2) report that “interest in majoring in mathematics [in the US] is at an all time low”. Similar disquiet has been expressed in the UK (London Mathematical Society 1995, National Committee of Inquiry into Higher Education 1997) and in many other parts of the world (Leder *et al* 1998).

Concerns such as these have led to efforts to enhance the provision of mathematics for those school pupils with the potential to study the subject at University. In the UK, the needs of the more able pupil have recently been highlighted by a

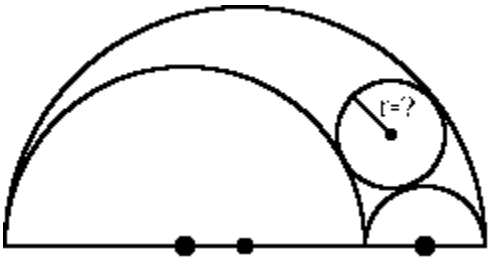
government-funded research review (Freeman 1998) and a parliamentary report (House of Commons Education and Employment Committee 1999). This paper reports findings from a study of enrichment material in mathematics provided through the internet (Jones and Simons 1999). The data indicate that use of this enrichment material had an impact on the beliefs the pupils held about mathematics. The pupils gained a wider appreciation of mathematics and the profile of mathematics as a subject was also raised. It became more of a subject that could be interesting enough to study beyond school. Yet the data also revealed that the majority of users of the material were white boys and that a large proportion accessed the material from home, giving an indication of the likely socio-economic status of their families.

Theoretical Framework and Related Research

Studying mathematics can evoke strong emotions in pupils. In a comprehensive review, Schoenfeld (1992 p359) concludes that pupils "abstract their beliefs about formal mathematics .. in a large sense from their experiences of the classroom" and further that "students' beliefs shape their behaviour in ways that have extraordinarily powerful (and often negative) consequences". Beliefs that doing mathematics solely means following the rules laid down by the teacher and that knowing mathematics only means remembering and applying the correct rule allow no space for essential attributes of mathematical activity such as creativity and problem-solving. Such beliefs are implicated by Schoenfeld as explanatory factors for the ever decreasing proportion of students who wish to study mathematics as a main subject the further up the education system they progress. Malmivuori and Pehkonen (1996) report how beliefs impact on pupil achievement in mathematics and Brown (1995) illustrates the influence of teachers on children's image of mathematics. Further reports of research on the impact of pupil beliefs in mathematics can be found in Pehkonen (1996).

Curriculum enrichment "is the deliberate rounding out of the basic curriculum subjects with ideas and knowledge that enable a pupil to be aware of the wider context of a subject area" (Freeman 1998 p44). It is an approach that is consistently advocated for the more able (see, for example Koshy and Casey 1997) and has been recommended in various ways in the teaching and learning of mathematics over a number of years (see, for example, House 1987, Kennard 1996, Sheffield 1999). The 'NRICH online mathematics enrichment project' was established in the UK in 1996 to promote an interest in mathematics and to assist the mathematical development of children who have the potential to go on to study mathematical subjects at university. The principle method of meeting these aims is through the provision of regular online mathematics 'magazines' containing puzzles, problems and games, enhanced by mathematics undergraduates acting as peer-teachers providing an electronic answering service for learners. An example problem, most suitable for older school pupils, perhaps older than age 15, is shown overleaf. The problem is from the November 1999 edition of the online magazine.

Just touching[1]



Two semi-circles are drawn on one side of a line segment. Another semi-circle touches them externally as shown in the diagram. What is the radius of the circle that touches all three semi-circles?

Further details of the project and access to the current edition of the online magazine and to the NRICH archive can be found on the NRICH website: http:\\nrich.maths.org.uk

In what follows we report some of the findings of a study of how the use of the NRICH website facilities impacts on the mathematical development of children who have the potential to go on to study mathematical subjects at university.

Methodology

The overall design of the study incorporated a range of methods. For the component of the study reported in this paper, the principle method was a questionnaire completed by pupils who accessed the website during May 1999. In addition, visits were made to a sample of schools, and interviews were conducted with a range of pupils (some 20 in all). The methodology reflected the technology-based nature of the NRICH project. The questionnaire was web-based, a suitable method as the target population was well-defined (Schmidt 1997), and some pupil interviews were conducted through e-mail correspondence (Roselle and Neufeld 1998). Standard techniques were adopted to develop and test the questionnaire with piloting of both a paper and electronic version (Oppenheim 1992, Dillman 1999). The questionnaire covered type of access, form of usage of NRICH material, and evaluative comment on the material. The questionnaires also sought information on the type of school and household (or other location) where NRICH material was accessed. Respondents could also offer to be contacted again by e-mail to provide follow-up information. Respondents were assured of the confidentiality of all the data. Full details of the methodology, including copies of the questionnaire and interview schedules, can be found in Jones and Simons (1999).

Analysis of data

We begin with data from the questionnaire collected during May 1999. As was anticipated, a number of incomplete or frivolous responses to the questionnaires were logged and so close scrutiny was paid to the data in order to ensure the validity of the data set used for analysis and hence the reliability of any conclusions drawn from the analysis. Data sifting and analysis followed standard procedures to ensure no bias was inadvertently introduced. Following these procedures, 199 pupil questionnaire responses were accepted for analysis.

The analysis of the questionnaire data revealed the following:

- pupils from 15 different countries accessed the NRICH website during May 1999
- nearly 60% of the pupils who accessed NRICH were from the UK (Australian pupils were the next highest category, with over 95% of them attending private schools)
- over two-thirds of the pupils were boys
- almost two-thirds were white (the next highest ethnic group was Chinese, the majority being from Singapore and Australia)
- almost three quarters were of secondary school age (aged 11-16)
- the pupils attended a range of institutions, with the largest number, although just less than 30% of the total, attending secondary comprehensive schools (pupils from private preparatory schools came a close second with most of these being Australian)
- over half of the pupils were recommended to try the NRICH website by their teacher (browsing the net and information from a parent were the other main ways of finding out about NRICH)
- around half of the pupils accessed NRICH at school while almost exactly the same proportion accessed NRICH at home - there was no difference in the pattern of place of access between boys and girls. Only a handful accessed NRICH from a public library or other public access location.
- for most pupils there was no ‘maths club’ provided as an extra-curricular facility at their school
- the majority of pupils accessed NRICH about once a month. They mostly accessed the pages of mathematical problems and puzzles. There was little difference between the relative usage of NRICH by girls and boys.
- pupils had positive views about the facilities provided by the NRICH project with almost half saying that NRICH was better than the mathematics they did in school
- most pupils thought that NRICH had made them more interested in mathematics and more likely to continue studying mathematics

Virtually all the comments made by pupils on the questionnaires were complimentary about the NRICH project. Some typical examples were:

> *“All the Nrich problems are challenging to me, not like the problems I do at school. Doing the* [NRICH] *problems has made me feel how it feels to be stuck on a mathematics problem and do not know how to do it.”*
> 11 year old boy from Singapore.

> *“I really like this site and think it is great, although my friends don't like maths that much I am trying to wean them onto this site because it is really interesting and helps me with my maths.”*
> 12 year old girl from England.

"I think N-rich is really cool and has made me think differently about mathematics."
12 year old boy from the USA.

"NRICH is cool. It does not just do the simple types of mathematics but it does problem solving as well. It is really fun and is great to log onto during breaks."
12 year old girl from a private upper school in England.

All the pupils interviewed for this study (some 20 in all), either in school, or using e-mail correspondence, were complimentary about the NRICH project facilities. They invariably said that the mathematical problems on the NRICH website enlivened sometimes routine mathematics lessons or gave them interesting things to think about during breaks or lunch-time. Almost all the pupils interviewed had submitted solutions to NRICH and very much liked seeing their solution published on the NRICH website. Making the website more interactive so that problems could be solved 'online' was one suggestion made that would improve the site in the eyes of the pupils.

Other evidence, from the school visits and from the questionnaire completed by 450 teachers (full details in Jones and Simons 1999), shows that pupil exposure to NRICH problems and puzzles (in schools where teachers accessed the site) was likely to be wider than the pupils were aware of. Teachers reported accessing the NRICH website to use it as a source of interesting mathematical problems to enhance their regular classroom teaching. Indeed, one teacher admitted that:

"The reason that I do not recommend NRICH to my pupils is that it is an important resource for me to use in the class."
Teacher in an English suburban primary school.

Of course the majority of teachers did say that they had, on occasion or perhaps regularly, recommended NRICH to their pupils. Teacher recommendation tended not to be restricted to more able pupils in mathematics but was used more widely. Nevertheless, the majority of the teachers using NRICH felt (many strongly) that NRICH was particularly good for pupils who had a talent for mathematics.

The majority of teachers questioned thought that using NRICH had made their pupils more interested in mathematics, although around 20% said that they did not know. Evidence for this improvement was generally in terms of increased interest in mathematics shown by pupils and by pupils accessing the NRICH website of their own accord. In general the teachers thought that NRICH enhanced the pupil view of mathematics by regularly providing novel and interesting problems that often afforded a new way of approaching a standard school mathematics topic.

Summary and Discussion

Evidence from this study suggests that pupils using the NRICH website facilities gained by having access to interesting mathematical problems. For some pupils, these

mathematical problems were more stimulating than the mathematics they regularly did at school. Many pupils who accessed NRICH did so from home which is an indication that the NRICH materials are intriguing enough to attract pupils in their own time. Some pupils accessed NRICH quite frequently, another indication of the quality of the materials. Only a minority of pupils made use of either the bulletin board facilities available through the NRICH website or the answering service. Those that did so spoke highly of the service and how it stimulated further thought. These pupils particularly valued the opportunity of being able to ask mathematical questions and receive replies. Seeing their solutions published on the NRICH website was also popular with pupils.

Girls were under-represented as NRICH pupil users. Certain ethnic groups from the UK might also have been under-represented (such as pupils of black Caribbean and Pakistani heritage) but the numbers of respondents was not sufficient to draw any firm conclusions. Data on the socio-economic class of pupils was not collected as it is notoriously difficult to collect such data accurately and reliably but the large proportion of pupils who accessed NRICH at home is one indication of the likely socio-economic status of their families. Few pupils accessed NRICH through a public library or other public access location.

The main impact of NRICH on the pupils who accessed the site was in terms of helping them to gain a wider appreciation of mathematics and raising the profile of mathematics as a subject that could be interesting enough to pursue either within or outside school or for further study. Quantifying this impact was beyond the scope of this study. The web-based nature of the NRICH project was also an important factor and was associated with the functionality and accessibility of the NRICH website which was judged by both pupil and teacher users to be well-designed.

Concluding comments

Research indicates that the beliefs about mathematics held by pupils can be deep-rooted and difficult to influence (Schoenfeld 1992, McLeod 1994). Hannula (1998) reports, in a case study of one particular pupil, that change can happen as a result of the pupil experiencing different learning materials and classroom approaches. The evidence from the NRICH project supports the idea that enrichment material designed to provide a wider picture of mathematics can encourage pupils to view mathematics as a subject that could be interesting enough to pursue beyond school.

According to data from the Third International Mathematics and Science Study (Beaton *et al* 1996 p 126) around 80% of 12 and 13 year old pupils in England like mathematics at school while only about 5% say that they dislike mathematics “a lot” (comparative figures for Japan, for example, are 53% and 11%). Over 90% of this age group of pupils in England thought that they usually did well in mathematics (this compares to 44% in Japan). It is possible that this positive disposition to mathematics of pupils in England is a factor in making them open to the possibility of viewing mathematics as an interesting subject, one worthy of consideration for further study

beyond school (as part of TIMSS, pupils were not specifically asked if they found mathematics interesting nor whether they were envisaging studying mathematics at University).

In another component of the TIMSS study, teachers were asked what particular abilities were very important for pupil success in mathematics (Beaton *et al* 1996 p 142). When asked about the importance of pupils being able to think creatively, teachers in England were next to the bottom of the list of countries with just over 30% saying that it was a very important factor (only France, out of the 41 countries, was lower with 20%). This lack of stress on creativity in mathematics by teachers may also be a factor in influencing the impact of enrichment material, such as that available through the NRICH project, which encourages a view of mathematics as a creative subject, on pupils' views of mathematics.

While the impact of the NRICH material was found to be positive on those pupils that accessed it, issues of equity in access to the material remain. The ability to access the internet is growing both in schools and in homes but the distribution of access is not equitable across income groups. The study reported in this paper found that most pupil users of NRICH were white boys and that a large proportion of NRICH users accessed the site from home. Access from public libraries and other places of public access was very low. Efforts need to be made by Government agencies in order to reach those categories of users currently under-represented so that all may benefit from access to material such as that provided by NRICH.

If projects such as NRICH are to be fully successful in encouraging more students to continue with mathematics, it appears that the experience of students in studying mathematics at University would also benefit from some attention. Seymour and Hewitt (1997) report how, in addition to fewer undergraduates choosing to major in mathematics, a disturbing number of mathematics majors switch to other courses during their University careers. Amongst the reasons they found for this 'switching' was loss of interest in the subject, the belief that other subjects were more interesting, poor teaching and the feeling of being overwhelmed by the pace and load of curriculum demands. While projects such as NRICH are showing their value, the scale and nature of the issues to be tackled in ensuring that pupils experience mathematics as an interesting and rewarding subject of study requires the collaboration of all those involved.

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