Motivating Years 12 and 13 study of Mathematics: researching pathways in Year 11

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We report on a collaboration, between 4 teachers in 4 schools and a university team of 3, over a period of 21 months, to enthuse Year 11 students (taken from the top 25% ability range) about mathematics and encourage their further study of mathematics in Years 12 and 13. Each school used a different pathway to achieve these goals: this involved acceleration, enrichment, the Free Standing Mathematics Qualification or an early start to A level. The research was developmental in both studying the practices and processes involved while contributing to teachers' continuing professional development in mathematics.

The project

Funded by the NCETM[1], this project involved a 21 month investigation into how teachers can motivate and enthuse able mathematics students (taken from the top 25% ability range as judged by tests and examinations) by developing pedagogy in different approaches at KS4. It was motivated by a desire to encourage more young people to enjoy mathematics and take it further in their studies. From an NCETM perspective, the professional development of the teachers concerned was paramount. To achieve these various aims, the project took a developmental research approach which involved 4 teachers in 4 schools and 3 university academics. Project activity included: For the teachers

- Creating a mathematical pathway in Year 11, designing and delivering the related course, and studying its progress and outcomes;
- Participating in collaborative activity through meetings at the university and visits to each others' schools;
- Reflecting on, evaluating and reporting outcomes.

For the academics

- Working with the teachers to encourage and study the creation and implementation of a pathway;
- Collecting data to chart progress and evaluate outcomes;
- Conducting analyses and reporting on outcomes.

Methodology

The project was conceived by Bond as a result of contacts with headteachers who wanted to improve exam performance and Year 12 uptake, and discussions with Heads of Mathematics faced with developing strategies for students who had taken GCSE (General Certificate of Secondary Education) in mathematics at the end of Year 10. It was clear that schools used a range of approaches and questions arose as to ways in which such approaches contributed to achieving project aims. Four schools agreed to participate in the project, each with a lead teacher and a different chosen pathway, as follows.

A. Entry for GCSE at the end of Year 10 followed by A/S Mathematics in Year 11

[1] National Centre for Excellence in the Teaching of Mathematics.

B. Entry for GCSE at the end of Year 11 and the Free Standing Mathematics Qualification (FSMQ) at the end of Year 11
C. Entry for GCSE at the end of Year 10 followed by the FSMQ in Year 11
D. Entry for GCSE at the end of Year 11 with no additional qualification offered, but with the course enhanced by practical work and ICT

The project provided, for each school, two hours per week off timetable for the lead teacher, with release time for regular meetings as a group at the university to discuss progress and share ideas, and £600 to buy resources of their choice. It provided also the support of a Project Officer and staff at the university and the guidance of an advisory group which would monitor the direction of the project.

The project used a developmental research methodology such that research activity contributed to promotion of development (Jaworski, 2008). Research was designed to explore the nature and outcomes of each particular pathway, and the associated development of the lead teacher. Each lead teacher organized the activity of the project within their school, liaising with their mathematics department as appropriate and teaching their own class of students throughout the year. In two schools, two teachers were involved in the teaching. Teachers were encouraged to keep a record of progress according to their aims in the project. The Project Director (Bond) and the Project Officer (Green) liaised closely with schools to support the initiation of the project and to collect relevant data (see below). Project meetings of the four lead teachers and the university team were organised to take place at the university 9 times during the life of the project. Teachers were encouraged to reflect on activity and progress and to discuss issues and concerns; the university team encouraged reflection and asked probing questions. The team asked teachers to state research questions for their own pathway and discussion in the meetings allowed these questions to be refined as the academic year progressed. Towards the end of the project, theoretical perspectives were discussed to enable teachers to consider the theories motivating their teaching and its development.

Data, both quantitative and qualitative, were collected throughout the project and analysed by the university team. Quantitative data included school data, three student questionnaires, three teacher questionnaires and public examination results. Data were also collected from a fifth school to act as a 'control'. Qualitative data included recordings of the meetings (summarised), the developing research questions, two interviews with each of the four teachers (first interviews transcribed), interviews with students in two schools, teachers' written reports , and a diary (one teacher only).

Quantitative data were first coded by hand and entered into Microsoft Excel spreadsheets for checking. Data from the second questionnaires, for both students and teachers, were analysed and graphs produced using Excel. All other data were transferred to SPSS for analysis and production of tables and graphs. Due to the small and highly specific nature of the sample of schools, caution has been used in interpretation of these data. Results which may appear significant (e.g. using a multi-dimensional chi-squared test on cross-tabulated data) might well not generalise to a wider population or other circumstances. Our hope is that teachers in other schools where circumstances seem similar to those in the project schools will feel able to draw their own tentative conclusions and then to conduct research to verify them.

Of the extensive qualitative data, the first set of interviews with teachers (June 2009, transcribed) and the teachers' written reports have so far provided the main data for analysis, supported by the other forms of data. Analysis has involved a cyclic process of reading, re-reading and categorisation of the data. This process is still ongoing and what we present here are tentative initial categorisations. A detailed report has been written for the NCETM,

including detail of data and analyses and the full teacher reports. A copy can be obtained by contacting one of the authors[2].

Findings from the project

Quantitative analysis

School data, examination results and progression

Data collected from the four schools and the control school included information on students numbers, gender, SATS and examination results. These data varied according to the nature of the top set – for example in School A, where the top set was 1 out of 10, various results and indices were not surprisingly higher than in the other three schools which had two or three parallel four-class streams each with a top set (i.e. 1 out of 4). Also, the time allocated to mathematics varied considerably between schools with School A having 5 hours per week and School D only 2 hours and 20 minutes. The gender balance was quite even in all classes except in School A (59% male) and School D (66% male). With regard to progression rates – i.e. students transferring into Year 12— complete data were hard to obtain due to transfers between schools, students dropping out of Y12 mathematics courses at various points and even students who leave school, only to return later. In almost all classes a decline is indicated in uptake expectations between October 2008 and April 2009, and a further decline in the actual uptake, after drop-outs. Results from the control school suggest that this decline is a common feature to which the project made little difference.

Student questionnaires (initial and final)

These two questionnaires were identical, including: 12 questions on a 5 point scale to measure perceptions of a) confidence, b) teacher supportiveness, and c) usefulness of mathematics for themselves; and 10 questions on a 5 point scale to measure d) enjoyment and e) usefulness of mathematics for society; each index was tested for reliability. Data and boxplots can be found in our NCETM report.

There was no appreciable change in confidence levels (which were quite high) between October 2008 and April 2009 although an increase in lower end outliers suggested that some students were feeling examination pressure or starting to feel that mathematics was not for them. Enjoyment levels remained quite high overall. Project classes had an increased spread leading to a higher median than the control. Student views on teacher supportiveness, which were largely positive, increased for classes A and D. Perceptions of control classes were lower. Students' views on the usefulness of mathematics for themselves and for society remained at a high level for both project schools and control. Students were largely graded at SATS levels 7 and 8. An analysis was done for each of the 5 indices against the two SATS levels. SATS-8 students demonstrated mainly high confidence levels and positive enjoyment levels, whereas there was a wider range of confidence for SATS-7 students whose enjoyment levels were generally lower though still mainly positive. Levels of perceived teacher supportiveness were generally high for SATS-8, and lower, although still positive, for the SATS-7 students. The Spearman's rho correlation of confidence with teacher supportiveness was much higher for SATS-7 than for SATS-8, suggesting the crucial role that (perceived) teacher attitude can play for the SATS-7 students.

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Project teachers' predictions of their students' perceptions

Half way through the 2008/9 academic year, a second, shorter questionnaire was completed by students with questions 1 to 5 on 3 levels (a lot, a bit, not at all) and question 8 on 2 levels (Yes/No). The main statements for their consideration were:

1. I am enjoying Year 11 mathematics
2. The course is demanding in terms of workload
3. I am being stretched mathematically
4. My understanding of mathematics has improved in Year 11
5. The course has inspired me to carry on studying mathematics next year

8 Could the teaching be improved?

At the same time, their teachers were asked to predict the response profiles they expected from their classes. Findings and predictions on enjoyment matched fairly well, with teachers only slightly overestimating. However, teachers greatly overestimated their students' workload. We noted interestingly that class B (taking GCSE and FSMQ simultaneously) recorded a high level of enjoyment and also the highest incidence of the workload being very demanding. Teachers substantially overestimated the intellectual demand level ("I am being stretched mathematically"), although almost all students were finding the work challenging to some degree. Almost all students reported some improvement in understanding, and teachers' estimates were close to students' recordings. Teachers slightly overestimated the numbers of students who said they intended to continue to Year 12, although the overestimate was most marked on just one school (C) which ultimately had a lower uptake than the other schools. Regarding Question 8, remarkably, the prediction of Teacher A, that 100% of students would say that teaching could not be improved was exactly correct. Teachers B and C rather overemphasised the number who would say "yes". Teacher D estimated his students' responses very accurately.

Teaching styles

At the beginning and end of the academic year, teachers were asked to complete a questionnaire designed to assess the strengths of three factors comprising their teaching styles: *transmission*, *connection* and *discovery* (Askew et al, 1997). Briefly, *transmission* teaching views mathematics as a body of knowledge and skills to be passed on from teacher to student; *connectionist* teaching views mathematics as an interconnected body of ideas and reasoning processes which the teacher and student construct together, and *discovery* teaching views mathematics as a personal construction of the student. Responses indicated that Teacher A moved from being just within the connectionist zone, to being substantially within this zone; teachers B and C stayed in a very similar positions within their zone (B in the transmission zone and C in the discovery zone) and D moved from being substantially within the transmission zone to the boundary between transmission and discovery. Thus the project seemed to have the most marked effect on Teacher D.

Qualitative analysis

While the quantitative data pointed mainly towards students' perceptions and achievements, and their teachers' associated expectations, the qualitative data pointed mainly towards teachers' perceptions of their teaching and its development through the year. We present here the broad picture of findings so far.

Teachers' goals for the project

Teachers were asked to say something about their goals for the project (or the goals of their school). Teacher A, who had taught his class (top set of 10 sets) since Year 9 and whose class

had already taken GCSE in Year 10, wanted to see if taking A/S level in Year 11 was "do-able". Could he take a class of 30 students through half an A level in Year 11? Teacher B, who was new to the school and who had had the project thrust onto her in her first year in the school, presented a school perspective. They wanted to "do something extra" with their "more able" students (2 parallel top sets), "give them more experience with maths". They wanted "to push them a bit further than GCSE" (offering also the FSMQ). Teacher C, whose students had taken GCSE at the end of Year 10 (some were trying to raise their GCSE grades) said that he was looking for a course that would "stretch our more able pupils", something that would take them a bit further, give them insight into what A level maths would be like". Thus the school offered the FSMQ to parallel top sets alongside GCSE retakes. Teacher D also wanted to "stretch our more able students" but without fast-tracking. The students were taking GCSE in Year 11. He wanted to introduce them to mathematics that would give them a taste of A level, and would reinforce and be complementary to GCSE, but without offering a separate qualification.

Thus the goals expressed by the teachers fitted well with the stated goals of the project. The pathways were different; two schools having already taken Year 10 classes through GCSE were looking for a suitable course for Year 11; two schools were in the process of preparing students for GCSE at the end of Year 11. One school in each category decided to take on the FSMQ course, one (B) alongside GCSE in Year 11, and one (C) in parallel, for some students, with some retaking GCSE and seeking higher grades. We now report on particular issues or outcomes.

DO-ability – what works

Teacher A asked whether the plan to take 30 Year 11 students through half an A level in one year was "do-able". His research showed that it *was* do-able, and outcomes from the process indicated considerable success as detailed in his diary. The idea of 'do-ability' seemed to permeate the rhetoric of the school research for all four teachers. "What works" was a common focus. Teachers initially all focused on what they would do, or what they had done, and the extent to which it worked relative to their goals in the project and the context of their school. *What works* included: planning for the classroom, types of activities and tasks, how students respond, what issues arise and what all of this looks like in practice. In the early stages, not much was said about what teachers learned or could learn from the project. The focus for all of them was on what students would or could gain from the planned activity, and on outcomes in terms of examination results and achievement of student targets.

Preparing for teaching

Teachers put a lot of time into their planning of activities and resources for their students. This involved thinking hard about what would be interesting and motivating for students. Teacher B, who was new to her school and to teaching A level mathematics, spent considerable time working on mathematics herself. Teacher A prepared songs and quiz-based tasks related to curriculum areas. Teacher D prepared computer-based activities such as spreadsheets for numerical differentiation and activities with graphical calculators. Teacher C engaged in collaborative planning with a colleague to find "different ways of doing the topics". All produced video-recorded examples of innovative practice for sharing in project meetings

Valuable to work with colleagues (in school and in the project)

Teachers emphasised the importance for them of sharing their thinking, planning and reflecting with colleagues, both in terms of sharing ideas and gaining ideas from others, and

in terms of gaining support where there were issues and problems. Teachers B and C valued opportunities to share ideas with and/or gain support from colleagues in their own school. All valued the opportunity to share ideas and issues with one other. Schools A, B and C made choices at department and school level, whereas in School D it was largely the choice of the one teacher, albeit supported by his Principal. Disappointingly, for Teacher D, his department showed little interest.

Time pressure

Teachers B, C and D emphasized pressure of time on what they were able to achieve. The time allocation for mathematics in School A was more generous than the other schools, with School D the least generous. While we are aware that teachers generally experience time pressure and that there are competing demands on allocation of time to subjects within a school, it was clear that achieving the goals of this project was considerably circumscribed by time factors and associated pressures.

Teachers' learning through reflection

Project meetings put emphasis on what the teachers were learning from their activity and its outcomes. For all of the teachers this seemed to require a refocusing of their attention and a use of different language to describe what they were experiencing. Reflecting on their experience and offering some analysis of it in terms of their own learning in a project meeting required a more personal introspection. However, the supportive nature of project meetings encouraged the teachers to share personal issues and concerns. All expressed growth of understanding of, and confidence in, the new activity. The teachers commented overtly on the value of project time in school in which to reflect, and the nature and outcomes of this reflection: e.g., "I have certainly done more reflecting on what has happened.… You start thinking about what would you do differently next time. I have also been trying to notice when something has been successful and then try to come up with something similar next time … ways of teaching … which would work in a similar way, so yes I have developed that way".

In conclusion

Perceptions of pathway success were strongly related to school factors such as time devoted to mathematics and the degree of support for the project within a school. Schools A, B and D indicated their intention to continue the same pathway in future years. School C saw problems between students retaking GCSE and coping with the demands of the FSMQ. Early entry for GCSE is being discontinued. Further research can usefully explore whether these findings accord with practices more widely.

References

Askew, M., Brown, M., Rhodes, V., Johnson, D., & Wiliam, D. (1997). Effective Teachers of Numeracy. London: King's College, London.

Jaworski, B. (2006). Developmental research in mathematics teaching and learning: Developing learning communities based on inquiry and design. In P. Liljedahl (Ed.), *Proceedings of the 2006 annual meeting of the Canadian Mathematics Education Study Group*. Calgary, Canada: University of Calgary.