The Mathematics Enhancement Project: Combining Research and Development

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This is the report of the establishment and first stages of a major project working with senior secondary students in low socio-economic schools in Auckland, New Zealand. The project is the result of a Scoping Study conducted during 1999/2000, and is planned to involve eight decile 1 & 2 schools in one region of Auckland over a 5-year period. It is aimed at enhancing the achievement and participation of Year 12 and Year 13 mathematics students in their final years at school and promoting their transition into mathematical programmes in tertiary education. This paper outlines the results of the Scoping Study, the research objectives of the project, the methodological principles being used, and the preliminary results of the first 6-months work.

In 1998 The University of Auckland established the Woolf Fisher Research Centre at the Manukau Institute of Technology (MIT) in a joint arrangement with that institution. MIT serves the city of Manukau, a part of greater Auckland which contains some low socio-economic areas. The Research Centre asked the Mathematics Education Unit of the university whether it was interested in research in these areas and offered to support such activity. As a result a Scoping Study was undertaken, funded by the Woolf Fisher Research Centre, to investigate what work could usefully be done. This study was conducted from October 1999 to March 2000.

The Scoping Study

The Scoping Study involved a needs analysis, a review of research, a base-line study, and the writing of a proposal for a research and development project. A teacher-researcher, Mary Graham, was employed to conduct the study. The Scoping Study Report (Graham & Barton, 2000) contains details of, and references for, the findings summarised below.

The needs analysis was based on seminars of teachers, interviews with principals, and a survey of students. All components stressed the development of teaching as the main target area of any effective project. Secondarily there was concern for a) the immediate needs of students who are currently in the system, and b) the importance of community support for any initiative. The main need was time: for teachers; for students; and time to deal with all the issues confronting education in this region. The second need was financial resources. The third need was for motivation: for students; for teachers; for schools; and for the community. A final need is to raise the expectations of staff and students.

The review of research examined the social and cultural contexts mathematics education in this area, examined other programmes, and finally focussed on teacher development and the use of technology in mathematics education. The main findings were as follows.

- While the socio-economic context is an important factor in achievement and needs systemic solutions, it can be ameliorated at an individual school level.
- The cultural context is also an important variable, and ways must be found to acknowledge and value the cultural contributions of the students in every classroom.

- Other factors such as math phobia, mathematics staff recruitment, mathematics curriculum, and school organisation, must all be taken into account, as in other schools.
- Lessons from other programmes include constructing positive rather than remedial interventions, finding role models, and the participation of the community.
- An effective programme will be long-term, will involve teacher-initiated classroom reflection and research, will be school-based, will recognise the complexity of teacher's lives, and should involve mathematical development.
- The literature on effective teaching provides a framework for evaluation and a list of criteria such as 'academic learning time' – at the same time as warning that behavioural indicators are not all that is needed to evaluate improvements in teaching and learning.
- Electronic technology is a key element of a modern mathematics classroom and enhances mathematical development in many ways.

The baseline study ran into some difficulties because of not wanting to place extra burdens on school staff, however enrolment and Bursary (Year 13 national examination) data was obtained. Sample data included the following.

- On average, approximately 6% of Year 9 students progressed to Bursary Maths with Calculus, and approximately 5% to Maths with Statistics.
- Over the last five years the seven decile 1 and 2 schools have averaged 24, 23, 11, 4, 3, 3, 2 students sitting Bursary mathematics subjects each year, respectively. From 1995-98 a total of 24 A grades were obtained, 21 of these in two schools.

The project proposal was aimed at raising the quality of mathematics and improving the numbers of students entering mathematics programmes at tertiary level. In developing the proposal a set of ten principles were established in consideration of the contexts and practical realities of the current situation. The project proposal reflected the four components: teacher development, student support, community participation, and research. It was concluded that the project would only have significant impact if it was large enough to cover all aspects of the mathematics learning environment, and to develop a critical mass in the schools. The funding implications were greater than initially anticipated. The resolution of this situation is to utilise funding from a large variety of sources: Ministry of Education, the hosting institutions, educational trusts, and private sources.

The MEP Project

Preliminaries

After the Report and Project proposal were presented to the Woolf Fisher Research Centre, the Mathematics Education Unit decided that the project should go ahead under the direction of Bill Barton. During 2000 funding was sought and found in Texas Instruments (supplying graphics calculators), the Woolf Fisher Research Centre (research costs), and the awarding of Teacher Study Awards to two teacher-researchers (who could undertake project research as part of their studies). Although the University of Auckland Appeals Committee adopted the project, their wheels moved too slowly to be useful for 2001.

These somewhat limited resources led to the project being modified in its first year of implementation.

Aims and General Description

The aims of the project are:

- to enhance the participation of students from Manukau and its environs in tertiary courses with a mathematical orientation; and
- to enhance the secondary school mathematical achievement of students in this area.

The project has four interrelated components. The prime component consists of a teacher development programme for senior mathematics teachers in decile 1 and 2 schools. To this is added learning support for senior students; a programme to enhance the image of mathematics amongst students and the community; and a research component involving monitoring and evaluation, classroom-based research, and an in-depth investigation of the factors involved in mathematics education in this region.

In 2001 the project is working with two schools in the area, and, as it proves successful, will add two other decile 1 or 2 schools per year. All mathematics teachers of Year 11, 12 and 13 will be involved in each school. In 2001 this is limited to Year 12 and 13 teachers. Community involvement in all aspects of the programme will be a significant factor. The research team for 2001 consists of: Willy Alangui (a PhD student from the Philippines with experience in indigenous issues), Jessie Autagavaia and Albert Poleki (both teachers on one-year study awards at the university), and Bill Barton (from the Mathematics Education Unit).

The teacher development programme is both long-term and school-based. In those parts focusing on their own practice teachers will be expected to undertake action-research projects under their own control. As money becomes available teachers will be funded to gain university credit from their involvement, and will be able to participate in other research aspects if they wish. Benefits to teachers to encourage participation will include provision of technology and opportunities to be relieved or supported in their classrooms by other teachers.

The student support component will promote motivation and learning on an additive basis, i.e. building on existing school processes. This will primarily be through the teacher-researchers being present during classes as much as possible, and using the pre-service mathematics programme at the University of Auckland. There will be contact with tertiary mathematics departments through visits and on-line links, and additional resources developed with teachers.

The community programme will need to be designed in conjunction with community members from the schools involved. This aspect is not being developed in 2001.

Monitoring and evaluating the project, and teacher classroom research, are two parts of the research component. However the third, and most important part, is research into factors affecting mathematics education in this environment. In 2001 four “factor studies” of this kind are being undertaken: one on language issues, one on background mathematical knowledge, one on responses to graphics calculator technology, and one on the roles and attitudes of indigenous students.

Principles

As a result of the Scoping Study, the project is guided by the following principles.

Principle 1 - Teacher focus. Of all the factors which contribute to student participation and achievement and which are subject to change, teaching is the most important of all. Therefore effective teacher development will be a prime objective. This is not to indicate that teachers, or teaching, is the 'problem'. Rather, teaching and teachers are the main means to any improvement.

Principle 2 - Long-term & full involvement. The longer the involvement the better the change will be, and any project under two years in length is unlikely to have any lasting effect. Furthermore, interventions involving isolated individuals or even small groups of individuals are unlikely to be successful.

Principle 3 - Location in school at senior level. While research and opinion indicate that intervention is most effective as early as possible, this project will focus on senior students because another development project, the AIMHI project, is currently operating successfully in the region at junior level.

Principle 4 - Recognition of context. This project has a responsibility to recognise the context in which the project arises. For example socio-economic issues which allow some groups to be excluded from quality education, and cultural issues of whose knowledge is the basis for assessment and thus the social judgements of personal worth.

Principle 5 - Double pay-off. Schools, researchers, students and parents all have their own objectives. For example, schools have responsibilities as institutions, students have short-term goals such as passing examinations, teachers must bear in mind the current curriculum, and researchers have long-term, generalised objectives. If all participants are to want to participate, and to feel empowered by the project, then its activities will need to have multiple payoffs.

Principle 6 - Start small¾ increase involvement. The project will begin as a relatively small project and then expand as/when it can be shown to be effective.

Principle 7 - Work with existing curriculum, resources, and personnel. This project takes place within very specific contexts, such as the New Zealand Mathematics Curriculum, the existing staffing situation, pre-determined student intakes, and parental expectations. It is impractical to seek to work outside these parameters (although it is possible to aim to change some of them).

Principle 8 - Aiming for Excellence. Students gain control of mathematics through full understanding of the subject, not simply by remediation of skills in order to pass tests or examinations.

Principle 9 - Professional model of teachers & multi-faceted model of teaching. Teachers are assumed to be professionals. They have specialist knowledge, unique experience, and are responsible for their own development. The project is oriented to supporting teachers by creating a community of practice. The model of teaching adopted has three equal components: teaching as classroom practice, teaching as researching, and

teaching as being a mathematician.

Principle 10 - An eclectic model of learning. Student learning requires multiple pathways, i.e. different delivery modes, different cognitive orientations, different pacing, and different expressions of understanding.

Research

The rest of this paper focuses on the research component of the project, and serves as a first report of an on-going project. Further details of results will be given at the conference presentation, and in subsequent MERGA presentations.

Aims

The overarching research question is:

How can inequity in mathematics education be successfully addressed ?

The monitoring and evaluation research is aimed at making decisions on whether the project continues or expands. The research questions for this component are:

- Is this project achieving its aims?
- What aspects (or combination of aspects) of the project are contributing to positive change in mathematics education for senior students in the target schools?
- How can this project be developed to better achieve its aims?

The research questions for teachers' action research are:

- What models of teacher practice are feasible and successful in the particular contexts present in these schools?
- What are the effects of various classroom practices on student participation and achievement in mathematics?

The third research component is investigative research aimed at developing an understanding of the factors at work in mathematics education and what action is necessary to overcome inequity in mathematics education in Manukau and its environs in particular, and in underachieving communities in New Zealand in general. The research questions for this component are:

- What are the social circumstances which lead to the need for a project such as this, and which of these does the community want changed ?
- What are the school-based and classroom-based factors which are preventing students reaching their potential in mathematical education, how are these interconnected, and how may they be changed ?

General Issues

The first important characteristic of this research is that it runs hand in hand with a development project. This has particular methodological considerations, both positive and negative. On the one hand, the researchers, by their on-going involvement in the working of the classroom and progress of the students, become more like teacher-researchers. They have both an investment in, and close inside knowledge of, the effects and implications of

their research. On the other hand, it has already proved difficult at times to separate the research and development actions of the researchers in the classroom. This is both a question of objectivity, and also a question of what how research interventions get designed and evaluated apart from the normal processes of the class.

A second characteristic of the research is that it is a complex of interrelated research studies. How does one research the factors that affect mathematics education at senior levels in low socio-economic schools? There are a myriad of factors, which are not simply additive, but which interrelate in complex ways. Practically there needs to be focus on individual aspects, analytically there needs to be a holistic approach. The long-term nature of the project and its funding mechanism mean that there will be several one-year research studies, some of which will need to be followed up by a different researcher. Simply managing this process is difficult: holding it together academically is going to need some explicit strategies. At this early stage, the coordination is being maintained theoretically by keeping common research aims firmly in mind, and regular meetings and seminars on the research process.

For 2001, the four "factor studies" each have more or less the same design. The first semester will be spent trying to provide a description of the factor under study as it is manifest in the two schools taking part, and designing possible interventions. The second semester will be spent trialing and evaluating the interventions.

Monitoring and Evaluation

The monitoring and evaluation part of the research is being done as a continuation of the Scoping Study. One aspect not fully addressed in that study was whether the situation for mathematics is worse than for other subjects. That is, is the poor achievement and participation in this subject merely a symptom of poor achievement and participation across the board, or is it especially bad for mathematics? The answer to this question might change the focus of intervention. Initial indications are that the situation is indeed particularly severe in mathematics.

Teacher Research

The key initial task is to be in a position to be able to report on teacher change. This involves reporting on the existing state of teachers and teaching, and establishing a monitoring process to measure change.

The dimensions to be reported upon will be:

- teacher beliefs and attitudes
- curriculum implementation & resources
- classroom variables, in particular the three criteria mentioned in the project proposal: on-task time, mathematical quality of tasks, and classroom relationships

The work with teachers is beginning with a phase of participatory collaboration. Three of the researchers are regularly in the senior classes and working with the teachers. An observation record has been developed with the teachers which is practical (i.e. it can be made while undertaking tutoring and teaching roles in the class), visual (i.e. gives an

immediate picture of the lesson, particularly student on-task behaviour), and compoundable (i.e. can be combined in a series of records to give an accessible picture of change over time). No teacher meetings have been held to date, but will have been by July.

Language Issues

The aims of this "factor study" are:

- To provide a description of:
  - the language abilities of students and teachers;
  - the language use in the mathematics classes;
  - the language-related difficulties experienced in the learning of mathematics;
  - the strategies used to make use of diverse language difficulties and to overcome language difficulties.
- To link the above descriptions to existing literature in the field.
- To develop strategies:
  - to make better use of the language skills available to the class;
  - to overcome language difficulties experienced in the learning of mathematics in these classes.

Data collection is primarily a matter of individual discussion with students, but a questionnaire has been distributed. The overwhelming feature of data so far collected is the richness of the language environment. Over 80% of students are fluently bilingual, with more than half of those able to understand at least three languages. A second tentative conclusion is that problems are as much a matter of language confidence and speaking conventions as they are of English language ability. Classroom observation of the teacher/student language interactions is also proving a rich source of data, although how this can best be incorporated in the teacher development programme is an unresolved question.

Mathematical Background

The aims of this "factor study" are:

- To provide a description of the mathematical background of students in Yr 13 Mathematics with Calculus classes, with respect to:
  - the skills needed for Bursary Mathematics with Calculus;
  - the understanding of underlying mathematical concepts;
  - the knowledge of when and how to use their skills and understanding.
- To identify strategies used by students to make use of their mathematical background knowledge in unconventional ways and to overcome difficulties caused by gaps in mathematical background.
- To develop strategies to assist students enhance their mathematical background.

A recording mechanism has been developed that allows information gathered from individual conversations, test analyses, teachers' records and classroom observations to be placed on one record for each student. These can be easily merged to give class profiles. Initial difficulty was experienced with which categories of background knowledge to use.

The data so far indicate extensive gaps at all levels of knowledge, but also depth in some areas. The question we are asking is how this depth can be used productively when students are in difficulty elsewhere.

Graphics Calculator Technology

Texas Instruments have made TI-83s available to the Year 13 classes and their teachers. This technology was new to all involved and has been introduced by the researcher. The research part of the programme is to monitor the developing community of practice: it has been done by classroom observation and a series of short questionnaires.

Unsurprisingly, many of the students have immediately taken to the graphics calculators, and now have better knowledge of them than the teachers. Half the students have used features not mentioned in the mathematics classroom. The machines are taken home by the students and have quickly become part of their classroom lives. Observations indicate that over 60% have them on their desks as a matter of routine, and virtually all students have them available every lesson. They discuss their use, and challenge each other with new uses. Questionnaires show that only one student had any previous experience, but now 75% of students use them in classes other than mathematics. What is interesting is that this has happened despite the fact that teacher use is minimal (non-existent in one case).

Indigenous Students

The aims of this factor study are:

- To provide a description of:
  - the factors linked to their identity as indigenous people which Maori students perceive will affect their mathematical participation and learning;
  - the factors which have been theorised will affect the mathematical participation and learning of Maori students which are linked to their role as indigenous people;
  - the links between the theorised and observed factors.
- To develop possible strategies to enhance the mathematical learning and participation of Maori students through their roles as indigenous peoples.

Little work has been done on this study at the time of writing. A report will be made as part of the conference presentation.

Conclusion

The Mathematics Enhancement Project is both ambitious and desperately needed. Mathematics education is in crisis in New Zealand, but the impacts of such crises are always felt most by those most in need. The inequities in secondary schools in this country have worsened over the last decade, and an opportunity to redress the balance in this area of critical need is most welcome.

The implication of this is that we must do all we can for the project to succeed. The research team therefore welcome critical comment and new ideas from all those who have an interest, some experience, and/or some expertise in the field of mathematics education in

underprivileged environments. We are particularly keen to learn from other projects, and wish to know both what has worked, and what has not been successful.

Acknowledgement

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Reference

Barton, B. & Graham, M. (2000). *Mathematics Enhancement Project: Scoping Study report.* Unpublished Report, Mathematics Education Unit, The University of Auckland.