The Mathematics Enhancement Project: A theoretical approach to research and development

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This is a report of the establishment and first stage of a 5-year project working with senior secondary students in eight schools in a low socio-economic area in Auckland, New Zealand. The students are predominantly from Maori, Pacific Island or new immigrant families. The aim is to enhance the achievement and participation in mathematics of students in their final two years at secondary school, and to promote their transition into mathematical programmes in tertiary education. Methodological principles are outlined, and the Pilot Programme undertaken during 2001 is described[1].

Background

In 1999 the Mathematics Education Unit of The University of Auckland and the Woolf Fisher Research Centre investigated the possibility of promoting mathematics education in a low socio-economic region of Auckland. This region has a high Pacific Island and indigenous Maori population. The Scoping Study involved a needs analysis, a review of research, base-line data-gathering, and a proposal for a major research and development project.

The needs analysis concluded that development of teaching should be the main target area of any effective project, but also that there needed to be attention given to a) the immediate needs of students who are currently in the system, and b) community support.

The review of research examined the social and cultural contexts of mathematics education. The main findings were:

- socio-economic context is an important factor in achievement and solutions need to be systemic, but much can be done at the individual school level;
- cultural context is an important variable, and ways must be found to value the cultural contributions of the students in every classroom;
- other factors such as math phobia, staff recruitment, curriculum, and school organisation, must be taken into account, as in other schools;
- the need to construct positive rather than remedial interventions was identified, and this involves good role models and community participation;
- an effective programme will be long-term, will involve teacher-initiated classroom reflection, will be school-based, will recognise the complexity of teacher's lives, and should involve mathematical development;

[1] This project has been possible thanks to the generous support of Texas Instruments, and research funding from the Woolf Fisher Research Centre.

P. Valero & O. Skovsmose (2002) (Eds.). Proceedings of the 3rd International MES Conference. Copenhagen: Centre for Research in Learning Mathematics, pp. 1-10

the literature on effective teaching provides a framework for evaluation but warns that behavioural indicators are not sufficient to evaluate educational improvements;

electronic technology is a key element of a modern mathematics classroom and enhances mathematical development in many ways.

It was decided that the project should go ahead with a Pilot Project in 2001, and full implementation from 2002 to 2006.

The Project Overview

Ten principles were established for the project:

- Teaching is the most important modifiable factor, therefore teacher development is a prime focus. Teachers are the means to improvement, they are not the 'problem'.
- The longer the involvement the better the change. Interventions involving small groups are less likely to succeed than those involving whole departments. The project is long-term and inclusive of all relevant teachers.
- Intervention is most effective as early as possible, but this project will focus on senior students as another project is currently operating at junior level.
- The socio-economic and cultural context in which the project is to be undertaken is recognised.
- The activities of the project will have simultaneous, multiple payoffs for students, teachers, schools and the community.
- The project will begin small and expand when it can be shown to be effective and when funding is available.
- The project takes place within a national mathematics curriculum, an existing staffing situation, pre-determined student intakes, and parental expectations. The project will work within these.
- Students are empowered in mathematics through full understanding, therefore this project aims for excellence.
- Teachers are assumed to be professionals. The project will support teachers by creating a community of practice. The model of teaching has three components: as practitioner, as researcher, and as mathematician.
- Student learning requires multiple pathways. A variety of delivery modes and cognitive orientations will be offered.

The aims of the project are:

to enhance the mathematical achievement of the students.

to enhance the participation of the students in tertiary courses with a mathematical orientation.

The Project will work with mathematics students and their teachers in the final two years of secondary education in all eight "low decile" schools in the region.

The project will start with four schools and add two each year. The project is designed to have four interrelated components:

- a teacher development programme;
- learning support for students;
- enhancement of the image of mathematics amongst students and community; and
- research involving monitoring and evaluation, classroom-based research, and an in-depth investigation of the factors involved in mathematics education in this region.

The teacher development programme is both long-term and school-based. As part of this teachers will undertake action-research projects under their own control and will be funded to gain university credit. Benefits to teachers will include provision of technology and opportunities to be relieved or supported in their classrooms by other teachers.

The student support component will build on existing school processes. Primarily this will be through the teacher-researchers being present during classes, using tutors, and using pre-service mathematics teachers. There will be contact with tertiary mathematics departments through visits and on-line links, and classroom resources developed with teachers.

The community programme is to be designed in conjunction with community members associated with the schools involved.

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 influencing mathematics education in this environment. The research questions for this component are:

What are the social circumstances that lead to the need for this project?

What are the school- and classroom-based factors that prevent students reaching their potential in mathematics, and how may they be changed?

A further research 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 and resources; and classroom variables such as on-task time, mathematical quality of tasks, and classroom relationships

Theoretical and methodological issues

Political considerations

Any project working in low socio-economic communities or with particular ethnic communities face issues to do with power, positioning and politics. On one level these issues are cast aside in order for action to take place: a teacher in a classroom faced with a mathematical query from a student rarely pauses to consider the ethnic relationship or socio-economic background of the student or the classroom. At another level the issues are always there: a teacher in a classroom operates within a set of behaviours, values and attitudes which have been established in particular ethnic and socio-economic contexts. With respect to the first level, this project does not seek to politicise classroom interactions. However, with respect to the second level, the project will bring about an awareness of ethnic and socio-economic aspects of the habitual behaviour of all participants, students, teachers, researchers, the school, and the community alike. The underlying assumption is that awareness will lead to critical reflection, and any changes will be made by individuals themselves.

But there is another level at which issues of power, positioning, and politics must be explicitly approached. This is the philosophical approach to the project, as reflected in the project documents, its aims and methods employed, and the reports and recommendations which emanate from it. We expect that not only will our responses evolve throughout the project, but also new issues will arise.

The most important of these issues is the positioning of Maori and Pacific Island students, and/or students from low socio-economic backgrounds (as measured from census data), as “the problem”. There is data showing under-achievement of low socio-economic groups and of Maori and Pacific Island students (Te Puni Kokiri, 2000; Ministry of Education, 1997). However the causes are widely debated. In particular we note that the creation of a category that can be identified as under-achieving immediately sets up expectations that make the statistics self-fulfilling. Zevenbergen (2001) uses the concept of cultural capital to analyse issues of race, class and gender in mathematics education. Her conclusions place responsibility for under-achievement on the structural hegemony of educational institutions and their defining documents. In addition there is research which describes (Pacific Island) cultural characteristics which impact on school learning (Mara, Foliaki & Coxon, 1994, Pasikale, 1996, 1999; Silipa, 1999), including specific features which are likely to impact negatively on school mathematics (Manu’atu, 2000). Pasikale (1996) reminds us that the cause is not deficiency, but mismatch:

> Success in learning is intricately linked to concepts of self-image and social image. Educational success for Pacific Islanders **can only** be assured if the cultural assets learners bring to the learning environment are not negated by the goals and practices of educational institutions. (p. ix)

This project seeks to use Bishop’s concept of cultural conflict (Bishop, 1994) practically, as a positive force, by turning it into a stimulus for learning. The first step in this process is recognition, the second is adaptation, and the third is the creation of opportunity. However these steps need to take place on the community level as well as in the classroom.

Another major issue is the political basis of assessment and social judgements of personal worth. Senior mathematics achievement is measured through national examinations. The usefulness, appropriateness, reliability and validity of such a measure has long been questioned, but attempts to use other methods run into problems of recognition for vocational purposes or further education. Whose knowledge and who sets the gates are important questions. It will be necessary to address the gate-keeping consequences of mathematics education for the participants in this project.

A third issue concerns teachers. In many educational initiatives teachers are not involved at a level which gives them any control. While this is manifest as a practical issue, its solution lies in the philosophical approach to teachers and teaching. This project regards teachers as professionals (not service providers), see Principle 9. As part of our theoretical framework, the word professional captures the assumptions that experience is valued (rather than past practice being viewed as wrong), and that the existing situation is current best practice (i.e. there is no ‘ideal’ situation which can be implemented in isolation).

The resulting model of development has the following characteristics:

It includes the good from the past, and implies that it is always possible to improve (as opposed to rejecting the past and implying that what went before was wrong).

It is a gradual implementation tailored to the resources available (as opposed to requiring new infrastructure and complete retraining).

It is dependent on the active, voluntary participation of those involved (as opposed to being imposed, unresponsive, and insensitive to their needs).

It is education theory and research driven (as opposed to being driven by a political ideology).

Methodological issues

There are two characteristics of this project which are unusual in mathematics education research in New Zealand, and which need methodological consideration.

The first is that the research runs hand in hand with development. This has both positive and negative consequences. For example, on the one hand, the researchers become very familiar with the working of the classroom and the progress of the students. They have both an investment in, and inside knowledge of, the effects of their research. On the other hand, it has already proved difficult at times to separate the research and development actions of the researchers. This raises the question of how research interventions can be designed in isolation, and the question of objectivity in evaluation.

A second characteristic of the research is that it is a complex of interrelated research studies. There are many factors. They are not simply additive, but 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 different researchers. Managing this process is difficult enough, but holding it together academically needs explicit strategies.

A useful framework for the project has been adapted from the methodology of critical mathematics education of Skovsmose and Borba (2000). Their triad of Current Situation, Imagined Situation and Arranged Situation, (see Figure 1) and the links between them, can be enlarged from the scale of a single research study to a project of many studies taking place alongside development.

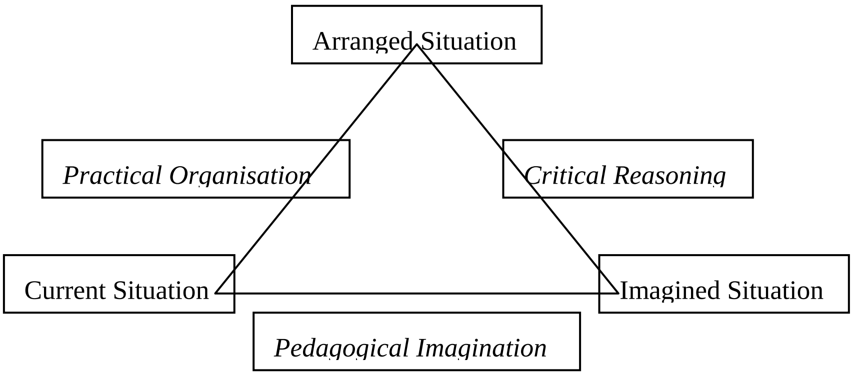

Figure 1. Triangular Model of Research in the Classroom
(Adapted from Skovsmose & Borba, 2000, p. 12)

Skovsmose and Borba conceive development as the trajectories followed by each of the vertices of this triangle as it is repeated. In order to use this for a multi-faceted project, it is necessary conceive of the triangle in three dimensions. Thus the Arranged Situation must become the reality of what happens in the classroom as a result of all project activities. There may be only one classroom situation, but it is the result of several Imagined Situations. The result of this change is that the vertices Current Situation and Arranged Situation should be taken to be a single, constantly changing, trajectory (see Figure 2).

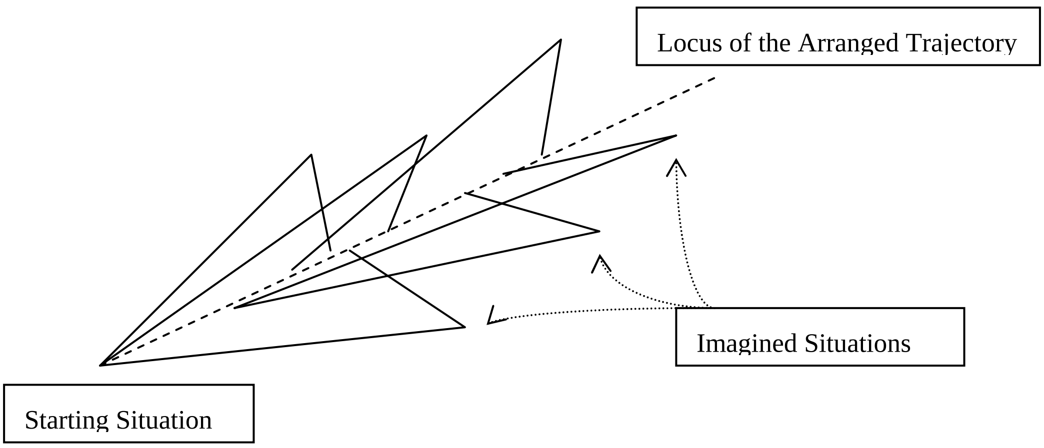

Figure 2. Model for a Research & Development Project

To this model we have added an evaluative component. The locus of the Arranged Trajectory is not controlled by any one research study nor by any developmental initiative, rather it must be evaluated as a whole. The final adaptation of this model then, is that it must take place within a Cone of Improvement. It is hoped that this construct will initiate discussion on what dimensions might be suitable as defining characteristics of this cone.

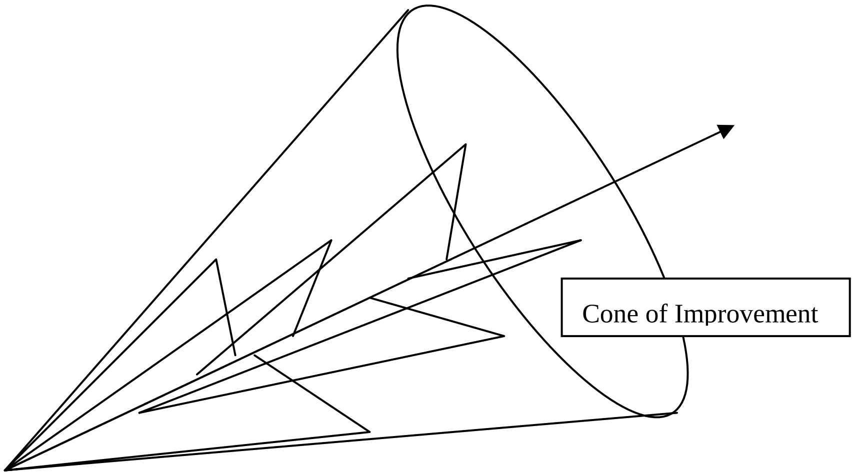

Figure 3. Evaluating the Trajectory

Pilot Project 2001

The 2001 Pilot Project involved two state co-educational schools, each of which had 15-20 Year 13 students taking the two mathematical national examinations available: Mathematics with Calculus and Mathematics with Statistics (most students take both). One Year 12 class was also involved from each school. Two teachers from each school were involved. The Research & Development Team consisted of one university staff member, two teachers on full-time study leave, and one doctoral student.

The Pilot involved four research studies, student support, monitoring, and teacher development. Most effort went into the research studies and student support. Each class was visited about once a week by the same researcher. This person, while conducting their research study, supported students by being another reference person in the class, for example, by undertaking some teaching or testing role, or producing and marking worksheets.

The four research studies are summarised below. The first three follow the same basic design of observation for two terms, and intervention and evaluation for two terms. (The results of the interventions are currently being evaluated, and will be reported during the MES3 conference presentation).

Language issues

The aims of this study are:

To describe: the language abilities of students and teachers; the language use in the mathematics classes; the language-related difficulties experienced in the learning of mathematics; and the strategies used to make use of diverse language difficulties and to overcome language difficulties.

To develop strategies: to make better use of the language skills available to the class; and to overcome language difficulties experienced in the learning of mathematics in these classes.

The overwhelming features of the observation phase were the richness of the students' language, and the paucity of the classroom language environment. Over 80% of students are bilingual, with more than half of those able to understand at least three languages. The classrooms display little mathematical language, and the seating organisation does not promote communication. Another observation was that problems are as much a matter of language confidence and speaking conventions as they are of English language ability.

Four interventions have been undertaken. The first is to work with the teacher and to produce language-rich displays to enhance mathematical vocabulary. The second is to initiate opportunities for multi-lingual mathematical discussion. The third is to promote activities in which the students must communicate mathematically. The fourth is to institute journal writing. Initial evaluations point to the third strategy as being the most favoured by students.

Mathematical background

The aims of this study are:

To describe the mathematical background of students in Yr 13, with respect to: the skills needed for Bursary Mathematics with Statistics; the understanding of underlying mathematical and statistical concepts; and 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 background gaps.

To develop strategies to enhance students' 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 in choosing which categories of background knowledge should be considered.

The data so far indicates an extensive but poorly linked background knowledge. New knowledge is seen as additional and is isolated, so that students fail to make connections between their old knowledge and the new. The question we are asking is how background understanding can be used productively when students are faced with new tasks.

There are three interventions in this study. The first involves regular homework worksheets; the second evaluates the effectiveness of an explicit teaching session; and the third addresses strategies for using what knowledge students have to bring to bear on problems. Initial evaluations indicate that isolated, teacher-initiated remedial activities can be effective (contrary to expectations), and that work relying on student initiative or motivation is subject to outside factors which render it ineffective.

Graphics calculator technology

Texas Instruments have made TI-83s available to the Year 13 classes and their teachers. This technology was introduced by the researcher and the developing community of practice was monitored. One intervention was implemented which involved worksheets directly aimed at the use of the technology in final examinations.

A large majority of the students immediately took to the graphics calculators, and developed better knowledge of them than the teachers. Half the students used features not mentioned in the mathematics classroom. Observations indicate that over 60% have them on their desks as a matter of routine, and all students have them available during lessons. They discuss their use, and challenge each other with new uses. Only one student had had previous experience, but now 75% of students use them in classes other than mathematics. 85% found them effective tools for their final examinations. What is interesting is that this has happened despite the fact that the teachers rarely use them.

With respect to the worksheets, 75% of the students reported them as useful, but few completed more than half of those offered.

Indigenous students

The aims of this study are:

To provide a description of: the factors linked to Maori students' identity as indigenous people and which they perceive will affect their mathematical participation and learning;

To develop possible strategies to enhance the mathematical learning and participation of Maori students through their roles as indigenous peoples.

This study involves interviews with all the Maori students in the participating classes (7 in all). Insights from these interviews include a positive sense of belonging as Maori students in these schools; the stereo-typing of Maori as not good (some coming from amongst Maori themselves); and an indiccation of teaching and learning preferences.

Other results

Some minor attempts were made during this Pilot Study to engage teachers in self-development. This was done tentatively because of the importance of maintaining good relations for the on-going progress of the project, and, as anticipated, considerable difficulty was found. The project team are currently searching for advice from other developers/researchers on how this may be approached.

Attempts were also made to address other issues in these classrooms: student organisation, aspirations, work habits, and motivation. The overall conclusions of these attempts were to re-emphasise the Scoping Study recommendation that the role of the teacher is key, but also to show that significant changes can be made relatively easily.

Conclusion

The Mathematics Enhancement Project is both ambitious and desperately needed. 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 need is most welcome.

The research team welcome critical comment from all those who have an interest, and/or some expertise in the field of mathematics education in low socio-economic environments. We are particularly keen to learn from other projects, and wish to know both what has worked, and what has not.

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