Reforming Mathematics Education: A Case Study Within the Context of New Times

Reforming Mathematics Education: A Case Study Within the Context of New Times

Robyn Zevenbergen
Griffith University
< r.zevenbergen@mailbox.gu.edu.au >

This paper employs an ethnographic approach to researching the implementation of a reform within a secondary school mathematics department. The study was conducted in a junior secondary/middle school context. Drawing on teacher interviews data, it is argued that there appears to be three main themes in teacher responses to reforms – the Conservatives who prefer the status quo, the Pragmatists who are concerned about practical issues related to implementation of reforms; and the Contemporaries who see the value and need for reform.

Schools and curriculum areas are under considerable pressure from authorities and the wider community to change their practices in order to create better learning environments for all students. This is particularly the case in many regions where authorities or schools have embraced various trends in current educational reforms. In a recent report in The Australian, the interviewee commenting on the demise of mathematics in Australia, noted how appalled he was to see the teaching of mathematics in contemporary classrooms as being the same he had experienced where he was "shocked to see the students using the same maths texts he had done a decade earlier … and they were garbage then" (The Australian, March 22-23, 2003, p.1). He went on to claim that the "root problem is at high schools level." In Queensland, the Education Department is currently trialling the "New Basics" reform. The underlying philosophy of this reform has the potential to radically alter the ways in which schools approach teaching. As part of these reforms, schools have been encouraged to have critical friends. In such a context, I have been working with a local high school for the past two years. This paper draws on some of the work being undertaken within the mathematics department in terms of reforming their practices to be more in line with the philosophy of the New Basics reforms.

Reform and Mathematics Departments

It has long been recognized that many areas of education in schools are in need of reform. This has been clearly indicated in the Queensland Schools Longitudinal Reform Study (Education Queensland, 2001) where the authors noted that while (Queensland) teachers overall offered very supportive learning environments, there was limited intellectual quality in terms of pedagogies that fostered deep learning in students. This longitudinal study has become the catalyst for reforming education in Queensland schools[1]. Significant emphasis is being placed on a number of schools to develop approaches to teaching that will encourage students to develop deep understandings that have authentic links to other areas of school and beyond school. The fundamental goal of the reforms of Education Queensland, and education authorities in general, is to

[1] It is contended that the issues identified by the longitudinal study are not unique to this context but are endemic in contemporary schooling.

improve instruction (mathematical and other) so that all students, not just the elite, can learn better – both content and pedagogically.

Traditionally, mathematics teachers and departments can be resitatnt resistant to change (Gutierrez, 1996). In spite of considerable research that documents the need for the teaching of mathematics to move away from process, rote and memorisation practices, there has been minimal impact on the teaching of school mathematics. For example, recent graduates were found to rely on algorithmic learning approaches, rote memorization and a focus on procedural knowledge in spite of exposure to new learning theories and approaches (Bischoff, Hatch, & Watford, 1999). Similarly, Gutierrez (1996) and Wilson and Lloyd (2000) found similar practices in experienced teachers who had undergone considerable professional development. In part, the teaching practices adopted by teachers are due to the beliefs they hold as to how students best learn mathematics (Cooney, 1994) and the time that teachers have been part of a department (Gutierrez, 1996). Often such beliefs are heavily influenced by the school experiences of the teachers. Research has shown that teachers' content and pedagogical knowledge have a strong influence on the ways that they teach and assess mathematics (Perry, Howard, & Tracey, 1999; Borko, Mayfield, Marion, Flexer, & Cumbo, 1997). In her study of teachers' beliefs, Andrews (1996) found a significant correlation between teachers' beliefs and practices with the period in which they undertook their initial teacher training. This outcome has been documented internationally (Fullan, 1995) and raises issues for reformists as to how to change the practices and beliefs of teachers who undertook initial teacher training some time ago. Given the current teacher population demographics this is particularly relevant and may go some way in theorising resistance to change.

With current reforms in education heavily emphasizing the importance of technology in teaching mathematics, many initiatives and research support the idea of technology being used to support and enhance mathematical learning. There is strong evidence to suggest that technology can enhance mathematical learning. As with the more traditional approaches to teaching mathematics, the use of technology to support the learning of mathematics is not well developed across many classrooms. Manouchehri (1999) reported that in his study when computers were used in the teaching of mathematics, it was for drill and practice rather than exploration.

Manouchehri and Goodman (1998) reported that many obstacles prevented mathematics teachers implementing reforms including the need for more planning time; lack of conceptual knowledge of mathematics; an inadequate knowledge of how to structure reforms so as to build bridges between the teaching for understanding and basic skills; lack of professional support; and the need for progressive leadership to guide and lead change. Wood (1999) argues strongly that when radical reforms in teacher practice are demanded, it is not sufficient to blame teachers for their inability to enact changes. The changes being demanded of teachers in recent times require a substantive ideological shift in their role in classrooms. She argues that the changes being demanded of mathematics teachers in terms of new approaches often lack a "clear formulation [on how to enact the reforms] but also requires a substantive change in teachers' beliefs" (p.165). In this context, this paper explores teachers' reactions to a radical change in teaching practice within a secondary school mathematics department.

New Basics and Its Impact in a Mathematics Department

The New Basics reforms are premised on three components – new basics (as opposed to old basics) which are the core learnings expected of students living and working in a post-modernist society; productive pedagogies which are pedagogies that encompass four dimensions (intellectual quality, supportive school environments, relevance and recognition of difference) – each of which should be evident over time in the teaching repertoires of teachers; and rich tasks which act as long term planning, teaching and assessment tools to guide reforms. In terms of the impact of the New Basics reforms in mathematics, it becomes clear that many of the old approaches to teaching school mathematics are in need of serious reconsideration. These include:

The importance of numeracy as a key lifeskill – that is students must exit school being numerate. This is an important area of reconsideration since many students can *do* mathematics but have little *understanding* of it. Teaching mathematics has relied on rote methods where students undertake procedural knowledge to solve tasks but have little conceptual knowledge of the mathematics.

Mathematics has deep meaning – the teaching of mathematics is based around the notion of developing deep learning and understanding of the discipline as opposed to the common practice of 'doing' mathematics.

Mathematics is transdisciplinary – that is, mathematics connects in realistic, meaningful and authentic ways with other curriculum areas and the world beyond schools. For example, the teaching of graphs cannot be isolated from the contexts within which it is used. It is known that students learn to construct graphs in mathematics, but come time to interpret them in science or SOSE or in reports in newspapers or from the web, they have little knowledge or understanding of the meanings of the graphs.

Mathematics is taught in an inclusive and supportive learning environment. Knowledges of students are validly and legitimately incorporated in the teaching and learning experiences of the classroom.

Arguably such elements are an essential part of a quality mathematics learning experience but their presence have not been consistently evident in many classrooms, nationally and internationally. In part due to the overcrowded curriculum faced by many teachers, in part due to history where teaching mathematics has been premised on behaviorist notions of learning; in part due to teachers' beliefs about innate mathematical abilities and the consequent practices of streaming or ability grouping, in part due to the histories of teachers where there has been little opportunity for many mathematics teachers to see how mathematics is used in the world beyond schools. Many mathematics teachers rely on textbooks for their organization of content and teaching. In terms of examples, research (Gamoran, 1992) has suggested that mathematics teachers are the most likely to believe in ability grouping; and are the most likely to rely on use of textbook teaching in comparison with their peers in other discipline areas.

Within the national and international literature, the issues faced by the administration and teaching staff are not unique to this school, but are representative of global trends in terms of reforming a department – particularly a mathematics department. The major difference, however, is the radical difference being posed by the New Basics agenda where there is a considerable change in the ethos, philosophy and teaching. This requires radical reconceptualisation of teaching for many teachers, particularly those trained in the 60s, 70s and 80s which can impact significantly on how teaching, learning and assessment are conceptualised (Andrews, 1996).

Reforming Within a New Basics Framework

This study used an ethnographic methodology where the researcher worked closely with the school over a period of two years. The second year involved fieldwork where the researcher spent one day a week in the school for most of the year. The researcher was based in the mathematics department and worked closely with the Head of Department and liaised with teaching staff. Taking a participant-observer role, the researcher worked with staff in the development and implementation of reforms that adopted the principles of the New Basics framework. Data collection consisted of field notes; observations; interviews with staff (conducted by a research assistant to ensure confidentiality and anonymity); and surveys and interviews with students. This paper draws on the interview data from teachers. All twenty teachers involved with the teaching of Years 8 and 9 mathematics teaching participated. Interviews were semi-structured and centred around teachers' reactions to the implementation of the New Basics Unit of work; the New Basics Reforms; and professional development needs.

In consultation with the Head of Department a unit of work was developed in line with the philosophy of New Basics. The design was based on the three elements of the New Basics reform. The Head of Department negotiated what he thought would be a appropriate for the department and in line with current practice and issues within the school. This was developed and supporting materials sought out. The collection of resources was labour intensive and undertaken by two university students. Both students worked for a week collecting resources from various sites. All resources were presented to the Head of Department and were subsequently digitized for access for teachers.

The staff involved in the teaching of junior mathematics – that is Years 8 and 9 – came from a range of backgrounds. Some teachers have undertaken advanced studies in tertiary mathematics and been teaching for many years, others are newcomers to teaching (and the school) and who are taking mathematics to cover their teaching load but have not studied it beyond their own secondary school. They may have taken applied studies of mathematics such as statistics relevant to disciplines such as biology or economics. The diversity within the staff is quite wide.

Reactions to Adopting Reform Within the School

The reactions to the reform varied considerably among the staff by the end of the second year. In attempting to analyse the different reactions by staff, a number of themes emerged from the data. It became clear that some staff were concerned that the new approaches would "water down the standards" and the perceived inability of the reforms to cater for the high achieving students. Others were concerned about more pragmatic aspects of such reforms - the impact of the reforms on workplace demands. A third cluster of responses could be classified as belonging to a more innovative approach to teaching seeing mathematics as more relevant and applied rather than as a pursuit of study in and of itself.

The Conservative

Teachers expressed views that this approach reduced the standards of mathematics and that students wanting to move into higher levels of mathematics in the senior years would be disadvantaged. Implicit in the comments was the view that many of the foundation ideas will be missing thus disadvantaging many students. Some views regarding the ability grouping and high ability students were expressed within this

clustering of comments. Teachers expressed the view that technology did not have a place in the curriculum and that it hindered teaching and learning. Assessment was also seen as problematic in that it became far more subjective and more assignment based, thus reducing the demands and rigour of mathematics.

> The diversity in student products made assessment difficult and labour intensive. The outcome – product – was open to subjective marking. There was also the danger that parents may be helping students too much so it was difficult to know how to assess.
> There is a need to ensure that mathematics is covered and all topics are covered – including algebra.
> The overall status of the document in terms of preparing students mathematically for Year 11 and 12 reduces demands.
> The approach will dummy down the real, true maths.
> The value of the unit in terms of learning 'real' mathematics – was this more about literacy, it did it support the learning of proper mathematics, i.e. the mathematics needed for senior maths.
> The assessment was not rigorous and too open to interpretation. It was too language based and not really about maths.

The comments within this clustering suggested that teachers wanted to preserve the status quo in mathematics whereby tried-and-true methods of teaching and assessment would remain in place.

Within this cohort, comments regarding student "ability" were very common. Teachers' language suggested that there was an acceptance of a reified and unproblematic notion of ability and that the task of good teachers was to ensure that "high ability" students' needs were met through the mathematics curriculum.

> This approach is too watered down. My bright students need to have a good grounding and be challenged. This does not do that, it is too simple and they will be bored.
> This might be OK for the low stream kids, but it would not be good for the smart kids, they will not get to cover what they need for Year 12 and will be bored. It is too practical and not mathematical.

As these two comments indicate, many assumptions about the desires of high achieving students are inherent in the comments. A division between practical and mathematical is seen to be hierarchical with the mathematical assuming a dominant position. Similarly, the divide between making mathematics realistic and transdisciplinary ran the risk of "watering down" substantive content.

Finally, technology was not seen to be a part of the repertoires for students in mathematics:

> There is no need for technology in the maths classroom. There is too much to cover and the students need to work mathematically, not with technology.

These views tends to support a position that "old maths" has a stronger and more credible basis for school mathematics.

The Pragmatist

A clustering of teachers, while supportive of reforms in terms of the intentions of the program, held reservations about them due to the practical implications of the reforms. Seeing the reforms as creating a change in work patterns, creating more demands on teacher, pragmatists raised concerns with the impact of the reforms on their work. Also in this category were comments directed at the work environments and how these could constrain their work

> Considerably more time is needed for planning – in terms of developing the units, develop units that teachers can use where they know that there will be consistency in terms of content and assessment.
> The need for more resources for teachers and the high demands placed on teachers for planning.
> There is a need to ensure that assessment among teachers is objective. Time is needed for teachers to work together to moderate assessment.

Teachers also commented on access to technology.

> Technology was difficult to access thus making it difficult for teachers and students to undertake some aspects of the unit. The school needs to make sure that the computers can handle the work we need to do. The ones we have are so antiquated.

While seeing the value in the reforms, pragmatists were concerned about the practical implications on their work. Time for planning and assessment were primary concerns. As the reforms had the potential to deviate considerably from the traditional modes of teaching (textbooks or worksheets), the pragmatists recognised that they would need to undertake considerably more work in collecting resources and developing activities to support learning. While some suggested that the teachers may not need to take this responsibility, more teacher aide time would be needed to support the reforms. Sometimes, practical suggestions were proposed as to how to deal with practical issues – such as taking some teachers off classes to prepare plans for the units.

Unlike their conservative peers who wanted to retain the status quo, pragmatists took a middle ground in terms of the reforms. They recognised the value of the models but recognised its limitations:

> While the approach is good and will have a positive effect, there is still a need for grounding in basic mathematics but this is a good supplement.

The Contemporary

Many of the teachers in this category taught mathematics as their second area, coming in from other discipline studies. Their experiences in other curriculum areas may have positioned them so as to be more familiar with open-ended planning, gathering their own resources, making connections between disciplines and being open to assessment techniques. This is not to say that it was only non-Mathematics specialist as a number of mathematics specialists also noted similar comments.

> Catered for different levels, allowing all students to excel due to the open-endedness of the tasks. In some cases, students who had not engaged in mathematics before, became very engaged (and had success) with this approach.
> The approach is excellent as it encouraged independent thinking and higher order thinking in all of the students.
> It moved away from an ethos of testing to working on realistic tasks. Because it was a change from normal practice, students were very motivated
> Allowing greater flexibility in teaching by moving away from textbooks.
> This approach is really good as it is not geared towards old boring textbook maths. The majority of students hate maths, this new approach changes that perception.
> I have been using this approach to teaching in [other curriculum area] so this is not new to me. I have been used to seeking out resources and developing unit plans like this and I know that they work really well. It is great not to have to be constrained by a textbook.

Teachers in this cohort also commented on the role of technology in the units. This cohort tended to be more in favour of the use of technology. Unlike the pragmatists, this could be due to their ability to have accessed in teaching time.

> Using technology, particularly spreadsheets, has been great. The students have really got into it. It has let all range of achievers get engaged at their various levels. I don
> The work with computers was really good for individuals. It did not require constant monitoring of work.

The comments offered by the Contemporaries are in line with the overall ethos and rationale of the New Basics reforms as outlined at the beginning of the paper. The teachers embraced the ideas of transdisciplinary knowledge, relevance, deep learning and the role of technology in teaching. Comments suggest that the elements of productive pedagogies were being implemented.

Teachers' Stories About the Units

Teachers were invited to recount stories about the implementation of the unit in their classrooms and students' reactions to it. Overwhelmingly, the stories were in support of the approach.

> Students really like this type of maths. They are here at 8am and work over lunch just on their maths.
> All students in my class have enjoyed this maths.
> It improved grades of some students as they could see the relevance of what they were doing.
> The program has had some students never interested in maths now liking it and doing it!
> I am trying alternative strategies with Year 9s and the behaviour problems have decreased.

However, the voices of the Conservatives need to be heard as the issues that are raised may need to be considered:

> Students in Year 8 have no understanding about pay rates, they are too young.
> Students talked about their goals but had to be teacher-led. Students said that they would rather be *doing* maths. It did nothing for the kids at the top level and the lower level kids did not hand in their assignments. It only benefited about half the kids. It was not real maths.

While there appears to be considerable support for this approach to teaching, it would be remiss not to consider the concerns raised. In adopting such an approach, it would be important to consider

Implications for Reform

The views of the three clusters of teachers raise a number of implications if reforms are to succeed in schools, particularly in mathematics departments. While Contemporaries were largely supportive of the reforms, this could be in part due to the beliefs about mathematics teaching, learning and assessment as well as their recognition that current practices were failing students. As one teacher commented:

> Statistically maths [at this school] is the worst in the region. 60% fail because they are not ready whereas this program will allow students to develop at their own rate.

It was information of this kind that was the catalyst for reform. But as the comments (and actions) of teachers indicate, not all teachers were prepared to embrace reform in spite of the poor outcomes and attitudes students had to mathematics.

Creating an environment where staff can begin to accept and embrace reform without feeling their values and beliefs are compromised is essential if reforms are to be successfully implemented. Some of the concerns raised by the Conservatives and Pragmatists have validity and hence need to be addressed. One of the concerns with this reform is the level of mathematics being taught and whether a focus on numeracy (as opposed to mathematics) subjugates the value of many of the mathematical concepts

and processes of formal mathematics. Similarly, workloads identified by the Pragmatists are real issues essential for consideration.

From this study, it would appear that overall, the reform is seen to offer considerable potential to enhance, engage, and motivate quality student learning. In such a context for greater success and participation, it is important that a number of issues are addressed.

Identify what are the critical learning outcomes for students in mathematics and ensure such learning outcomes are not compromised. This may mean creating electives for students who want to continue with senior levels of mathematics.

Provide sufficient time and space for planning and assessment when new regimes are implemented. Teachers need time to reconceptualise their thinking and work practices. Time and space are needed for professional dialogue in order to develop a consensus of views.

Where technology is part of reforms, adequate access to appropriate computing (or other ICT resources) need to be provided. Some professional development work may be needed to encourage teachers to recognise the value in technology to support mathematical thinking and working.

References

Andrews, C. (1996). *Teachers' work: An analysis of teachers' work in a context of change*. Unpublished PhD, Griffith, Gold Coast.

Bischoff, P. J., Hatch, D. D., & Watford, L. J. (1999). The state of readiness of initial level preservice middle grades science and mathematics teachers and its implications on teacher education programs. *School Science and Mathematics, 99*(7), 394-399.

Borko, H., Mayfield, V., Marion, S., Flexer, R., & Cumbo, K. (1997). Teachers' developing ideas and practices about mathematics performance assessment: Success, stumbling blocks and implications for professional development. *Teaching and Teacher Education, 13*(3), 259-278.

Cooney, T. J. (1994). Teacher education as an exercise in adaptation. In D. B. Aishele & A. F. Coxford (Eds.), *Professional development for teachers, 1994 Yearbook* (pp. 9-22). Reston, VA.: National Council of Teachers of Mathematics.

Education Queensland. (2001). *The Queensland school longitudinal reform study*. Brisbane: GoPrint.

Gamoran, A. (1992). Is ability grouping equitable? Educational Leadership, 50(2), 11-17.

Gutierrez, R. (1996). Practices, beliefs and cultures of high school mathematics departments: Understanding their influence on student advancement. *Journal of Curriculum Studies, 28*(5), 495-529.

Manouchehri, A. (1999). Computers and school mathematics reform: Implications for mathematics teacher education. *Journal of Computers in Mathematics and Science Teaching, 18*(1), 31-48.

Manouchehri, A., & Goodman, T. (1998). Mathematics curriculum reform and teachers: Understanding the connections. *The Journal of Educational Research, 92*(1), 27-41.

Perry, B., Howard, P., & Tracey, D. (1999). Head mathematics teachers' beliefs about the learning and teaching of mathematics. *Mathematics Education Research Journal, 11*(1), 39-53.

Wilson, M., & Llyod, G. M. (2000). Sharing mathematical authority with students: The challenge for high school teachers. *Journal of Curriculum and Supervision, 15*(2), 146-169.

Wood, T. (1999). Approaching teacher development: Practice into theory. In B. Jaworski, T. Wood & S. Dawson (Eds.), *Mathematics teacher education: Critical international perspectives.* London: Falmer Press.