Socially Response-able Mathematics Education: Lessons from Three Teachers

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This paper examines the experiences of three teachers who were engaged in a project designed to enhance student engagement in mathematics through the development of real-world context activities which enabled students to use mathematics as a tool for responsible citizenship and the pursuit of social justice.

In a previous publication, Atweh and Brady[1] (2009), discussed an approach to mathematics education based on ethics informed by critical mathematics education (Frankenstein, 1983; Skovsmose, 1994), ethnomathematics (D'Ambrosio, 1985; Powell& Frankenstein**,** 1997**)** and social justice pedagogy (Gutstein, 2006). As Atweh and Brady noted, ethics is generally associated with moral decisions, dogma and codes of behaviour and not seen as relevant to teaching and learning mathematics. Here we understand ethics differently. Using Levinas (1969), for us ethics is not predetermined principles or commitment that is either manifested in a particular behaviour or not; rather, ethics is an adjective that describes an existing relationship with the other that precedes our knowledge of the other. Chritchley (2002, p. 11) puts it this way: "It is the relation which is ethical, not an ethics that is instantiated in relations" (p. 12).

The construct of responsibility, on which we based this approach, is a key component of ethical discourse. Puka (2005) argues that the distinction some feminists make between responsibility and "response-ability" is a significant contribution to ethical thinking. Response-ability highlights the ability to respond to the demands of our own wellbeing and the ability to respond to the demands of the other. This is similar to what Roth (2007) points out, that responsibility "etymologically derives from a conjunction of the particles *re-*, doing again, *spondere*, to pledge, and *–ble*, a suffix meaning "to be able to."

Atweh and Brady assert that mathematics can contribute effectively to student response-ability if it engages with the world of the students. Further, this engagement should be not only with the physical world and the economic world, but also with the social world; it should aim at developing knowledge not only of mathematics but also of the world. Finally, such engagement should aim at not only *reading the world* but also, whenever possible, at *writing the world* (Gutstein, 2006). The implication here is that students can learn about their social world while they are learning mathematics and, at the same time, learn mathematics as they are engaging with the world.

A socially response-able approach to mathematics education necessarily involves concern about social justice. Questions of social justice in mathematics have often been raised in the discipline under different labels including those of equity and diversity. However, arguably, they have mainly been concerned with social justice *in* mathematics education (Burton, 2003; Secada, 1989) rather than attempts of achieving social justice *through* mathematics education (Gutstein, 2003).

[1] Brady is the previous name of the second author in this paper.

In J. Dindyal, L. P. Cheng & S. F. Ng (Eds.), Mathematics education: Expanding horizons (Proceedings of the 35th annual conference of the Mathematics Education Research Group of Australasia). Singapore: MERGA.

Response-able Teachers

In this section we discuss stories of three teachers, their backgrounds and attempts to change their teaching practices in their classroom to incorporate Socially Response-able Mathematics activities in their teaching. The three teachers volunteered for an 18 month collaborative project between university staff and six Western Australian schools. The Project commenced by a professional development workshop, incorporating theory and practical exemplars of approaches to develop students' responsibility through mathematics. Several workshops and school visits by university staff and teacher-consultants were planned to support the teachers in their design and implementation of their school-based projects. Teachers were provided with a few opportunities to be critical friends for each other through comments on each other's projects. The Project culminated in teachers presenting their findings at the AAMT conference.

The Story of Alex[2].

Alex commenced his 25 years of teaching experience as a primary school teacher, shifting to middle school mathematics teaching when he moved with his young family to a small tourist town, a considerable distance from the capital. The school caters for fewer than 300 students from K-12, and won recognition by a leading national newspaper as one of the top ten schools in Australia in curriculum innovation and community partnerships.

While Alex showed the greatest enthusiasm for the Project, he was also believed that there was not enough flexibility in the curriculum for him to pursue this kind of pedagogy. Through the professional development workshops he encountered the theoretical justification for how he always envisaged mathematics education ought to be, but he had never had the support or opportunity to implement it. The focus on social justice matched his own personal passion in line with his role as union representative dedicated to improving the working conditions of teachers.

So strong was his enthusiasm to the Project that he developed three school-based projects for his grade 8, 9 and 10 students – although, in this discussion here, we will concentrate on the grade 8 project. His motivation for choosing this particular project was based on his perception of grade 8 students, and in particular as youth in a small secluded town, as basically "egocentric" with very limited experience about global issues. He utilised a set of pictures from a book called the Hungry Planet (Menzel & D'Aluisio, 2007) which represented families from many nations around the world posing in front of the food that they would consume in one week. He describes his experience as "jaw dropping" and adds "I want to shake [the students' narrow views] and make students see themselves as part of a bigger more dynamic world … but also tie some good mathematical learning to it". He called the project "Feed Me".

The project required the students to keep a record of the food they ate in one week. The first class activity, costing the food consumed by each family, was a source of surprise to all students. Students learnt how to use spreadsheets to enter their results. The next phase of the project involved teaching the statistical concepts of different averages that can summarise the data including minimum and maximum values – all part of the content of the curriculum at that level. Alex believed that mathematics was only one way to examine the pictures. He used de Bono's six thinking hats strategy, which was new to the students, to look at the information depicted from a variety of perspectives. These perspectives were used to introduce additional mathematics in terms of Venn diagrams, also part of the grade 8

[2] All names used here are pseudonyms.

mathematics curriculum. This activity included a discussion as to whether happiness and wealth are necessarily related. The mathematical data generated in these activities were all incorporated in the grade 8 end of semester exams. Another session required students to collect information about their chosen countries from the internet to decide if the family represented was somewhat representative of the economy of that country. Finally, students tied in the activities to the "food pyramid" to design a healthy menu for their own family for one day and consider reasons why it may or may not be feasible for their family by considering the health, environmental and economic implications of their choices. The project concluded with reflections such as:

Give some definition of what rich and poor mean.
How do you feel about the lives of people from less wealthy countries?
How would youth of other nations comment about your lifestyle?
What does the comment 'with privilege comes responsibility' mean?
What impact has this maths project had on your understanding of the world and how you fit in it?

The Story of Mary Lee

Mary Lee was a recent migrant to Australia and the youngest of the teachers in the Project with four years of experience as a science teacher. This was her first year teaching mathematics. Mary Lee worked in a fairly new middle school (grades 8-10) with 158 enrolments situated at the rural outskirts of Perth. In many ways, the school is an experimental school intended to develop alternative ways to assist teaching and learning to young adolescents most of whom are considered to be disengaged in traditional education. The school has a significant number of Aboriginal and non-English background students.

The school structure and management were influenced by the Big Picture Schools approach to teaching and learning which offers "personalised curriculum" and "real world connections". However, class teaching was not totally abandoned – often they were single gender classes.

Mary Lee described her all-girl grade 9 students: "they don't place education as a high priority and will mostly enter a trade-based occupation or apprenticeship. Very few go to university". Mary Lee was very quick to decide on a school based project at the conclusion of the professional development workshop. As with many young people around the world, McDonald's is a significant part of the daily life of students at this school – both as consumers and employees. Mary Lee envisaged that this project may contribute to the students' perceptions that mathematics is not disjointed from decisions in daily life. The discussion around the project by the other teachers and facilitators of the Project was very enthusiastic about the possibility of the project to both provide important social issues that may interest the students as well as give rise to significant mathematics teaching and learning. We discussed the potential of considering the economic implications to society, and the world, of the expansion of the McDonald's chain of restaurants balanced with their contribution to training young people and community charity work. In addition, the health related issues of McDonald's food would provide significant ties to other aspects of the curriculum and would assist students to become more informed about in their dietary decisions.

Of the two possible foci identified above, Mary Lee's activities tended to concentrate on the health aspects – arguably since it was easier to obtain data on this aspect of McDonald's and reflecting her background as science teacher. It also fell within her comfort zone to deal with social issues. Mary Lee's project consisted of 9 "discrete, staged learning activities" presented as worksheets collated into a booklet. The first activity consisted of watching the movie Super-Size Me. The teacher identified a few mathematical type statements from the

movie (e.g. McDonald's spent $1.4 billion worldwide on advertising) and asked students to reflect on their implications to society and the environment. The second activity included published tables about the number of McDonald's restaurants in top ten countries as well and a table of the annual income from the 2007 Annual Report of the McDonald's Corporation. Students were given specific questions which required reading graphs and calculating percentages and fractions.

The third activity involved the energy content of McDonald's food. Published tables were provided to students and a set of questions which led to answering the bigger question of whether the higher energy content of the burger implied a heavier weight. The next two activities included studying the recommended daily intake of the energy from food and type of fats and their effect on health. Interesting to note that the data was given without a reference to its source or raising issues about its authenticity or applicability to the different social groups. This information was used to create a menu "If you had to eat breakfast, lunch and dinner at McDonald's, what will you order?" The next activity centred on "Is MacDonald value for money? Is being bigger better?" where prices and weights of hamburgers from 2008 and 2010 were compared. The last activity was graphing how often the students' families eat at McDonald's which lead to representing the data on a bar graph.

The Story of Peter

Peter is a trained geologist from the United Kingdom who migrated to a small regional centre and commenced teaching in the school in 1970s. At the time of his involvement in a project, he was the head of the middle school and the mathematics department. Peter's school was established in 1906 by an order of nuns in a town in a regional centre in Western Australia. It is a Catholic school, with a majority of lay teachers and enrolments of fewer than 300 mixed gender students from kindergarten to grade 10. The school's mission balances academic excellence and care for inclusion of disadvantaged students, in particular Aboriginal students.

Peter is a dedicated teacher who placed high value on higher level mathematics and at the same time was able to gain the respect of his students and colleagues at school. In this project, he involved his small group of "higher ability" grade 10 students in mathematics.

Peter's interest in joining the project was due to his concern about making mathematics relevant to students: "to find something that actually meant something to them". Even though he came from a school system that focused on issues of social justice, he did not feel comfortable when dealing directly with issues of social justice in mathematics. In his own words, "if [the activities] go too far [from] the mathematics curriculum - that would worry me". His concern was that such discussion of social justice and values might lead to the imposition of the teacher's values on the students.

Peter planned a school-based project in which students attempted to calculate the necessary height of a storm surge wall around the town to safeguard it from the effect of cyclones that frequent the area. Concerns about damage of cyclones were a "real community talking point" for the students and their parents. The last major cyclone hit the town about four hours before high tide. Hence, the question attempted by this activity was how high the wall should be to safeguard the town from flooding if the cyclone hit the town right at high tide what would happen to their own classroom in that case.

To shed some light on these questions, the teacher provided the students with data about the height of the normal tide every four hours, together with data from the day that the cyclone hit the town. Plotting the two graphs, they were able to learn about the trigonometric sine function as well as learn about subtraction of functions, which they were able to accomplish using a spreadsheet created by the teacher. By translating the scale of the

two functions, they determined that if the cyclone had hit during high tide, the storm surge would have been 6.5 metres. To answer the second main question about the height of their classroom above sea level, the students had to learn the use of a surveyor's levelling instrument. They found out that the height of their classroom floor was 4.6 metres. The actual height of the existing wall protecting that part of the town ranges from 1.9 to 2.7ms.

At the conclusion of the school-based project, the Shire Chairman and the Chief Engineer were invited to the school to hear the students' presentation on their findings. The Engineer congratulated the students and indicated that he had employed exactly same techniques and obtained similar results within few centimetres of the measures obtained by the students. The look on the students' faces was a testimony of the great sense of pride in what they have done. Not often are school students taken so seriously by people in authority. The Engineer went on to identify the complications associated with the decision about the height of a storm wall needed for the town. For example, he pointed out that the cost of building a 6.5 metre wall would have been astronomical. Secondly, the town prided itself in being a coastal town with easy access to the sea and scenic views, so living behind a wall 6.5 metres high was not a preferred option for this reason. Lastly, if the storm wall is too high, at the time of a cyclone, it would trap the water in town and have to be knocked down to allow water to recede. The council had adopted an alternative partial solution to the problem. Current building regulations demand that new constructions should be built on an elevation of least 6 metres.

Supporting Teacher Response-ability

During the course of this Project, discussions with teachers have highlighted several challenges faced by them in their attempts to adapt mathematics classrooms to incorporate a focus on Social Response-ability. Due to time limitations in the Project, only some of these challenges were directly addressed. Similarly, the experience of the teachers in meeting these challenges varied. Here we discuss two main challenges. The first relates to the challenges to the curriculum and pedagogy practices in the classroom. The second relates to finding the balance between the focus on the mathematics and on the social issues.

Curriculum and Pedagogy

At several times in the early stages of the Project's implementation, many teachers were uneasy that using project work with their students would require a significant amount of time and may lead into difficulties in covering the expected curriculum. These concerns are not unique to these teachers and are well founded in many instances. One of the concerns behind the development of the new national Australian Curriculum: Mathematics (Atweh, et al. 2012) has been the need to unclog the curriculum to allow teachers to deal with mathematics topics in depth rather than breath. Further, the increasing role that national testing is playing in all the participating schools implies that failing to cover certain topics of the curriculum may have serious implications for the students, their schools and the teachers themselves.

Undoubtedly, direct instruction on mathematics topics and providing opportunities for students to practice the intended skills and procedures gives the teacher more control over time allocations to assure that all the curriculum topics have been covered. This, however, does not guarantee the amount and depth of student learning.

Discussion with the teachers highlighted that a Socially Response-able approach to the teaching of mathematics should not be seen as mere application of content learnt in the traditional ways; rather as an alternative way to develop the expected outcomes with the

students. As the above descriptions of the school-based projects demonstrate, all projects developed by the teachers were directly related to the content that was prescribed in the official curriculum. They were convinced that students not only had a chance to encounter the intended content, but also demonstrate deeper understanding and engagement in the class. In their presentations on their projects at the national conference, teachers showed what can be described as evangelistic commitment to this approach and a belief in its efficacy. In all cases, teachers have taken a risk in providing alternative ways of teaching mathematics based on projects that included discussion and outcomes that are seen as non-mathematical. Arguably, those calculated risks have been supported by university staff and critical friends.

However, there is room to continue to examine the nature of projects that teachers could use to develop students response-ability in terms of the level of mathematics demonstrated. While, there was some evidence that some activities involved higher level mathematics (as in the example of Peter's activities) some activities remained at low level such as simple calculations and reading information from graphs.

Atweh and Brady (2009) discussed the implication of this approach to mathematics teaching on pedagogy. There we argue that developing students' response-ability cannot be achieved merely by changing the content of the activities but by giving students more control over their learning. Similarly, dealing with real world phenomena where there is no unique answer to problems, and where mathematics is only one of the contributing factors to their solution, implies a more open environment where students are involved in decisions on what mathematics is needed and on how to develop arguments using mathematics towards a particular decision. In other words, we had the vision of using Freire's construction, a teacher sharing decision making with the students as a co-learner.

The experiences of the teachers in this Project demonstrated significant steps that these teachers have taken to open up their classrooms for student involvement. In our discussion with the students, they often talked about different relationships that they have established with their teachers. Peter's students pointed out that one of significant aspect of the project for them was that the teacher did not appear to know what the answer was and he was finding it out with them. Similarly, all three groups of students have participated in discussions about the role of mathematics in understanding or shaping the real-world and indicated their growing perception that mathematics does not always give the right answer. Peter's students, in discussion with Council personnel, learnt that measuring the height of the storm wall is only a part of what needed to be considered when making the decision on what is possible/desirable to construct. Alex's students learnt that the concepts of rich and poor are not quantitative categories. Mary Lee's students learnt that being aware of the dietary benefits or detriments of a particular food is no guarantee that people will reach right decision about its consumption.

However, by examining the way the teachers implemented their projects, it is evident that there is further room for experimenting with more open ended pedagogies towards increasing students' response-ability. For example, the teachers differed in the ways they provided their students with the data and information they needed to make their observations and calculations. Both Peter and Mary Lee provided students with the data they needed. Alex, on the other hand, required his students to collect their own data about their eating habits as well as searching for information from the internet about the different countries. Further, Mary Lee's McDonald's booklet consisted of tables to be filled by the students in a familiar methodological way – consistent with many text and workbooks in commonly available in schools.

It is important here to point out that these comments are not meant to evaluate the teachers' work in the project. Only the teacher is able to determine the level of support that students need/expect in order to carry out their activities. Further, a certain level of confidence of the teacher in both content and pedagogy is required before they open up their classroom for student-led explorations. The intention here is to present these as possible areas of support needed to increase the response-ability of the teachers themselves.

Balancing Mathematical and Social Learning

Jacobsen and Mistele (2010), in their investigation of the challenges preservice teachers face with teaching for social justice concluded that the major challenge was what they called the "problem of balancing" (p. 8). In other words, the problem of how to get a balance between the mathematical concepts and the social justice issues addressed in given tasks. They provided four possible manifestations of the "problem of balance" (1) the use of mathematics without mathematics instruction by the teacher (2) use of traditional methods of teaching and/or non-challenging mathematics (3) trivializing of social issues, and (4) disconnect or artificial connections between social issues and the mathematics. In this section, we make some observation on how these teachers have balanced the focus on mathematics and the focus on social justice in their projects.

First we note that this balance is subject to the personal value system of the individual teacher. From the above discussion, Peter, who developed a very successful project to teach rather abstract concepts in the mathematics curriculum was hesitant to introduce social justice discussion in his classes based on his personal fear of indoctrination of the students. His belief of what constitutes worthwhile mathematics outcomes has directly been reflected in his project. His focus was on developing high level mathematical skills in his students – and arguably he has achieved this well. Similarly, however, due to lack of confidence rather than a political stance, there was very little discussion in Mary Lee's workbook about social issues. Alex, however, highlighted social discussions in most of his activities, while it is possible that there may be room for higher order thinking mathematical problem solving activities. Nevertheless the students have had meaningful contexts to deal with several topics in the curriculum.

A related challenge is that while social studies teachers receive professional development to be able to deal with controversial issues without, to use Peter's term, "indoctrinating" students into particular lines of thinking, mathematics teachers receive no such training. As we have seen above, this deficit led Peter to avoid controversial social justice issues in his activities. Alex did not have this problem. He felt comfortable in dealing with issues of poverty and happiness in his class. Mary Lee on the other hand, may have chosen a safer discussion of diet and health than the discussion of McDonald's as a business. However, in negotiation with the English teacher, she passed on the data that she used together with the students' work in order for students to develop an essay about their conclusions. Peter also recruited the English and Religious Education teacher to coach the students in their presentations – an area where he did not feel he had much experience and expertise.

Conclusion

The stories of the three teachers above demonstrate that engaging mathematics with social response-ability depends, to a large extent on of the teachers themselves. Teachers' beliefs about the nature of mathematics, its role in the curriculum and in the real world determine their readiness to take risks in changing classroom practices. Similarly, more

confident and experienced teachers are in better position to take larger steps towards that goal. Teachers need support and scaffolding in their risk taking. In particular, mathematics teachers require further development in dealing with issues that are seen as controversial and depend on personal and social values. Mathematics teachers who are not confident in dealing with these interdisciplinary capacities may benefit from working collaboratively with teachers in other subjects in the school curriculum. Lastly, these teachers have dealt with the balance between quality mathematics and quality social justice issues differed. It is our hope that through further reflection and self-critique of their practices, with further support, all teachers would be able to negotiate this balance to their students, and their own empowerment towards making mathematics learning a socially response-able activity.

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