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Promoting Students' Self-Directed Learning Ability through Teaching Mathematics for Social Justice

Richard Voss
Deakin University, PO Box 1240, Portland, 3305, Victoria, Australia

Dr. Tony Rickards.
Science and Mathematics Education Center.
Curtin University, Kent Street, Bentley, 6102, Western Australia

Abstract
Mathematics is a subject which is often taught using abstract methods and processes. These methods by their very nature may for students alienate the relationship between Mathematics and real life situations. Further, these abstract methods and processes may disenfranchise students from becoming self-directed learners of Mathematics. A solution to this may be to teach Mathematics utilizing real world social justice issues and a social justice pedagogy promoting the use of Mathematics as a tool to further investigate, address and potentially to change issues involving social justice. This unique Australian study investigated a Western Victorian District High School year nine Mathematics class using social justice pedagogy to learn Mathematics. The class comprised of gifted students, mainstream students and students who had diagnosed learning disabilities. The learning content of the Mathematics unit required students to make comparisons between their own lifestyles and those of different families from around the world. This was socially and educationally important as Mathematics was used as a tool to investigate social inequality to improve numeracy and engagement with real world Mathematics tasks. One aim of the study was to determine if this pedagogy motivated students by allowing them to become more self-directed as learners. The findings from this study suggested that when mathematics is taught using a social justice pedagogy, both student learning and engagement improved and students became more self-directed as learners throughout the course of the study.
Keywords: social justice mathematics, mathematics education, practical mathematics, student engagement.

1. Introduction.

According to Wright (2014), Mathematics has been traditionally taught by using a combination of methods based on teaching formulae, algorithms and abstract exercises from a range of textbooks. In an investigation into using social justice pedagogies to teach mathematics, Osler (2007a) and Gutstein (2006) both asserted that these methods of teaching Mathematics do not allow students to connect the mathematical concepts being taught with their personal interests, backgrounds or real life experiences. Gutstein (2006) also argues that if students are unable to connect mathematical content with their own lives, they can obtain a false perception of the essence, value and the power of Mathematics in everyday work and life.

There are several good examples of support for the view that teaching Mathematics using traditional methods in a secondary school environment results in a decrease in student engagement, student participation rates, and student achievement (Cefaratti, 2014; Wonnacott, 2011; Gay, 2010; Appelbaum, 2008). The decrease in these factors has been shown to be associated with poor performance results in some external examinations (Wright, 2014). To address this issue, governments and educators have begun to reform the Mathematics curriculum. This is evidenced by the National Council of Teachers of Mathematics in America, the Office for Standards in Education in England and the Advisory Committee on Mathematics Education from England, who are all shifting the emphasis in Mathematics from basic computational skills, memorisation and repetition to one that emphasises reasoning, problem-solving and communication (Lubienski, 2002; Wright, 2014).

In Australia, the Federal Government's National Foundation to Year 10 curriculum model, (AusVELS), seeks to follow the position taken by other countries by incorporating elements of interdisciplinary learning and active citizenship into student learning tasks (Victorian Department of Education and Early Childhood Development, 2009).

Tanko (2012, 2014), Osler (2007a) and Gutstein (2003, 2006) discuss a framework that supports these government initiatives that involve teaching Mathematics for social justice. The framework firstly focuses on students beginning to appreciate and investigate social justice issues that are relevant to their own lives and interests, with the aim of creating a general awareness. Secondly, the framework promotes the use of Mathematics to be used as a tool to further investigate, address and potentially to change issues involving social justice for the benefit of students, their community and also the environment.

In order to effectively combine the teaching of mathematics with activities that allow students to interact with the notion of social difference and disadvantage, where in some cases participants may have been the disadvantaged ones, a Social Justice Pedagogy model was employed for use in this study. The need to

generate solutions to basic mathematical problems it was hoped, would focus student attention on social justice issues and motivate participants to engage with these authentic and real world problems. This allowed students to better understand the costs, for example, of different cultural food groups and associate this with their own perceptions of how well off they may be socially. This study used the framework for teaching Mathematics for social justice as developed by Gutstein (2003) to combine mathematical and social justice goals. A key objective was to determine whether student learning, thinking and engagement are evident when Mathematics for social justice is taught with the intent of making Mathematics education more linked to students' interests' backgrounds and abilities. The current study investigates the benefits and challenges of implementing such a framework.

2. Context of the Research

The Western Victorian District High School involved in the study is approximately four hundred kilometres to the West of the capital city of Melbourne in the state of Victoria, Australia. Census data reveals that the town has a population of 9601 residents, with forty-nine per cent being male and fifty-one per cent being female (Australian Bureau of Statistics, 2011).

Socioeconomically in 2012, the town rated below the average living wage of $606.40 per week when compared to individuals who work in Melbourne, Victoria, Australia. Employees who work in the town earn a median individual income of $472 per week and a median household income of $898 per week (Fair Work Australia, 2012).

The town's educational facilities consist of four primary schools, one private secondary college, a technical and further education (TAFE) campus and one public government school. The government school participating in this study employs sixty staff and has around 750 students. At the government school there were a total of 114 students undertaking year nine Mathematics. The researcher negotiated with the high school's administration be allowed access a sample size of forty-five participants from the student population to undertake the study. The choice to teaching financial mathematics, that included reading graphs and converting fractions to decimals to percentages, was made in consultation with the researcher, the college's administration and the high school mathematics department. The college's administration ensured that the financial mathematics unit outcomes from the study aligned with those from other year nine traditional mathematics classes being taught. The researchers/teacher also had a particular interest in the integration of practical mathematics focusing on society to assist students who struggle with basic numeracy skills in the classroom.

3. Methodology

The study sample consisted of twenty-nine male and sixteen female participants aged between thirteen and fifteen years of age. The class had a wide range of mixed abilities, interests and backgrounds. The class also contained four integration students who had learning disabilities, and an integration aide to assist them with learning tasks. The participants were selected using a convenience sampling technique. The Western Victorian District High School assigned the first author as a teacher researcher to teach mathematics to a specific group of year nine students for the year. Triangulation (Creswell, 2012) was achieved by cross-referencing multiple sources of data obtained from (1) a focus group sessions, (2) a folio of students work, (3) a summative mathematics test conducted at the end of the unit, (4) pre and post unit concept maps, (5) a student survey and, (6) observations recorded in the researchers' reflective journal. To analyse and interrogate the data the researcher utilised a grounded theory approach as described by Denzin and Lincoln (2011) that incorporated a qualitative based action research methodology. The study excluded traditional mathematics classes taught by other teachers as the participants could not be observed directly by the researcher and therefore risked contaminating the study's findings.

4. Experiment.

To introduce students in the sample to the idea of social justice Mathematics, the researcher chose a sample topic, 'sweatshop wages', as outlined by Gutstein (2006). The topic focused on factory workers from third world countries who were employed for sixty cents a day. This highlighted to students some of the social justice issues that involve wages, housing, poverty and human rights. In negotiating and discussing the research procedures with participants, one of the students said, "How can you live on sixty cents a day"? The researcher replied, "Well… could you use Mathematics to create a budget to see if it is possible to live on this wage and to find out how these people survive?" A second student quietly commented, "Gee… sixty cents a day, nah… it can't be done… even a bag of chips costs a dollar at the canteen." The first student again asked, "Well… how do these people survive then"? After some time discussing the topic, a third student asked, "So Mr. Voss, you mean we can choose any problem that we like and try and use maths to solve it?" The researcher said, "in a nutshell, yes, but you have to work in groups and negotiate a topic with me as the teacher." Furthermore, "Your participation in the study is totally voluntary and if you choose not to take part, you can still complete the investigations with

your classmates and will not be penalised, nor will I include your responses in the report."

To brainstorm possible topics for investigation, the researcher wrote several pre-determined social justice topics based on ones used by Gutstein (2006). These were used as possible examples on the white board and allowed the students to use their laptops to access the www.radicalmaths.org website to obtain further suggestions.

For twenty minutes the workgroups considered many different topics. These included world poverty, child labour, corporate & banking profits, and compulsory school uniforms versus casual clothes. After much deliberation and negotiation with the students, as a class, they chose to study the global food and mathematics topic.

The students dedicated three hours every week (including time researching as part of the homework program) working on the global food and Mathematics unit within their respective work groups, each of which contained between four and six students. Each work group was required to investigate and produce a portfolio of work explaining their understanding of the issues that involve world hunger and poverty and how Mathematics can be used to understand various problems.

Students were required to analyse a series of photographs presented by Lowe (2012), as shown in figure 1 below. Students were asked to compare people from different countries with Australia. Secondly, students were asked to use the Internet to determine the cost of the groceries in their own homes and calculate the average cost within the workgroup. Thirdly, students were directed to use the Australian Bureau of Statistics resource to determine the percentage of income spent by average families on food, and compare it against the other countries in the photograph. Finally, they were asked to choose a strategy from a range of options that were on offer that could assist third world countries to minimise global hunger. These included supporting online forum discussions, organising a guest speaker from an appropriate charity and/or taking part in World Vision's forty-hour famine as an active participant.

Figure 1. *Sample of Lowes (2012) photographs used in the global food and mathematics unit.*

Ecuador: The Ayme family of Tingo
Food expenditure for one week: US$31.55
Family recipe: Potato soup with cabbage

To collect and analyse the data effectively, the project was conducted in five stages as described in MacIsaacs' (1995) research model. The stages were as follows:

***Stage one (1 week)*:** The first stage of the project consisted of a survey followed by a focus group session. The survey went for thirty minutes and consisted of a concept map and a broad range of questions to help students express their attitudes to learning Mathematics, their past learning experiences, and their interests and motivations.

Stage two (2 weeks): The second stage of the project required students to gather preliminary data for their portfolio. For instance, students were asked to collect a range of supermarket shopping dockets to determine the average class cost of groceries purchased.

Stage 3 (3 weeks): The third stage was informed by the second stage, and required students to take the initial data obtained and carry out a range of mathematical investigations.

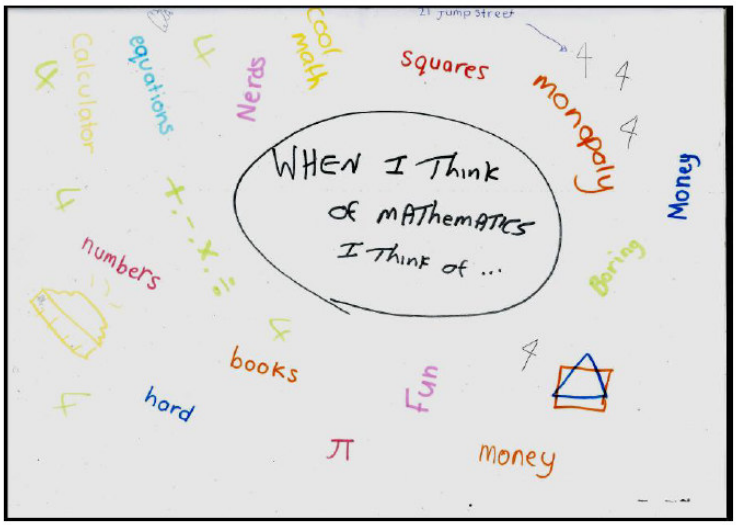
Stage 4 (2 weeks): The fourth stage integrated mathematical modeling into social justice issues. Students were required to describe the Mathematics required to support their workgroup's investigations.

Stage 5 (1 week): The fifth stage involved compiling, presenting and reflecting on all previous investigations collected as part of the student's folio of work. Students were required to submit their portfolio for assessment, undertake a Mathematics test and participate in the final focus group.

5. Result Analysis.

***Stage one*:** The initial stage of the study produced little evidence to show that students responded positively to being taught using social justice based pedagogy or becoming self-directed learners. When introducing the study for the first time, students quickly became off task and asked questions like 'Mr. Voss, why are we doing this stuff in math and not in social studies?' and 'what's this gotta' do with math?' During this stage, I spoke with the class integration aid about the student's responses and she mentioned that she felt many of the students had indicated that they felt lost and confused. In order to probe for possible reasons, I asked the students involved in the focus group sessions about their initial thoughts towards the unit of work. In response, the focus group members replied, 'this stuff [the approach to learning math] is different, really different'. They were seemingly trying to understand but not yet adapt to a changed learning environment. Observations recorded from the students' initial concept map, shown in figure 2 below, which ask students to write their thoughts about mathematics also highlights a lack of knowledge about practically based mathematics. Student responses focused on learning mathematics using textbooks and traditional teaching methods.

Figure 2. *Students initial concept map.*



Stage two: During the second stage of the study where the students were required to gather preliminary items for their portfolio, the greater majority of the students began to elicit behaviours often attributed to self-directed learning. In this stage, the researcher placed eleven photographs on a table (such as in figure 1) that showed the different amount of food families purchase in different countries around the world. However, as these photographs did not include Australia, the student's task was to compare their own lifestyles to those in the photographs. This became more of an engaging activity for students, and had more context than they usually experienced in Mathematics classes.

When introducing the social justice problem to the class, some of the student table groups began to discuss how they could solve the problem. One solution put forward by several table groups that consisted of high achieving and mainstream students was that their table groups had to collect a range of supermarket shopping dockets from their classmates to determine their own average class cost of groceries purchased. When these students gathered the shopping dockets, the students noticed that while some families purchased their groceries on a weekly basis, others purchased their groceries fortnightly or every few days. Observations showed that these table groups were able to methodically convert all dockets into weekly amounts by working as a self-directed group with little intervention from the teacher.

A second observation which suggested that students were able to become self-directed learners involved the integration students. For example, the integration student's table group said, 'Mr. Voss, in each of the photos I wonder how much food each person would get each day?' In response I replied, 'That would be interesting, can you find out for me.' As these students were able to pose and solve their own questions, I believe that self-directed learning in a teacher facilitated, rather than teacher directed classroom learning environment evolved and was evident at all levels.

Stage 3: The third stage required students to take the initial data obtained in the previous stage and carry out a range of mathematical calculations including converting fractions to decimals, finding percentages and basic statistical calculations. Observations were recorded in the researcher's field journal and also verified by the integration aid. These observations demonstrated that while students were acting as self-directed learners in stage 3, self-direction and group interactions were not taking place to the same extent as they had in the second stage. For instance, while the second stage produced inter-table group discussions between all students, in the third stage the majority of students chose to work either on an individual basis or within their own table group.

Stage 4: The fourth stage integrated mathematical modeling into social justice issues, and evidence showed that the students' ability to become and act as self-directed learners peaked during this stage. For example, after completing the mathematical calculations from stage 3, students were required to construct a graph of the data as shown in figure 3.

Figure 3. *Student assignment.*

Observations recorded in the researcher's journal show that when the table groups were investigating different types of graph, one student who had an interest in computer coding asked if they were allowed to use Microsoft Excel on the computer. The researcher replied 'do you know how to use the program?' The student replied, 'yep, sure do – and I can show the others how to do it as well.' For the remainder of the lesson the student provided peer tuition to the class producing several different types of graphs allowing the class as a whole to compare results.

Observations also showed that the ability of the students to become self-directed learners was not only linked to the mathematical component, but also the social justice component of the unit. In the later part of the fourth stage, students began to pose their own questions and carry out several mini-investigations as part of their homework program. For instance, one table group asked themselves 'what is a co-op and how does it work?' To answer this question, the table group priced a can of Coke from the school canteen and discovered it was cheaper to buy the item in bulk from the supermarket. These students then believed that maybe be possible for some of the poorer families to purchased food in bulk from a large supplier at a reduced rate and distribute the produce amongst themselves. Furthermore, some students also discussed the barter system and questioned if any money had to change hands at all when purchasing some items. These self-directed activity based discussions indicated that the students understood the issues well, and were relating activity and discussion to real world problems.

A second example of students becoming self-directed learners involved a different table group who investigated different relief agencies who support third world countries. Some of these students went on to participate in the World Vision Forty Hour Famine to see what it was like for those who were less fortunate than themselves and who may have less access to nutritious food than they do. Observations and other discussions with student participants in this study showed that the majority of the class supported the table groups' initiative by sponsoring their classmates in the World Vision charity event and raising the general level of awareness of these issues.

Stage 5: During the fifth stage of the activities, students worked as a community of learners to complete all set tasks. Each table group allocated tasks amongst themselves to submit their folio of work for assessment by the due date. Classroom observations showed that although each table group had set their own agendas, these table groups also worked together to benefit one another. For example, the student who taught the class how to create a graph on Excel spent a considerable amount of time assisting the integration students to correctly code and printout their graphs. Observations also showed that many table groups were comparing their folios amongst each other with the higher achieving students mentoring the other students where required in a very cooperative and collaborative way.

An observation from a teacher who was not directly involved in the study, was that students had

approached the college's Student Representative Council in an attempt to promote the World Vision Forty Hour Famine at a school level. Although the school did not support the students' request, the students went on to participate on an individual basis and later shared their experiences among their classmates.

6. Conclusions

Teaching mathematics for social justice is a relatively new approach for teaching mathematics in Victorian public schools. One limitation encountered in the study was that it only involved one mathematics class from a single Victorian Western district High School due to financial and administrative constraints. Other studies may wish to increase the sample size to encompass a wider range of school sites, but due to a lack of any budget, this was not possible in this seminal study. Future studies may include the investigation of teaching mathematics for social justice in different educational settings or undertaking longitudinal studies to compare student learning and student engagement taught in different schools.

Future studies may also wish to investigate a larger sample, to improve the generalisability of the findings and confirm the findings from this study. Future research may also engage students in the greater use of ICT to perhaps allow direct contact with other cultures, as this is not readily available in many of the Education contexts that are presented in this study.

The findings from this investigation suggest that incorporating social justice issues in Mathematics education improves student learning and engagement by promoting students to become self-directed learners. Evidence from this study also suggested that a social justice pedagogy enables students to explore real world Mathematics beyond the classroom, develop specific mathematical skills, and acquire the knowledge and motivation to become active citizens in society. Teaching mathematics using social justice is an effective pedagogy that can be used to promote the development of student social tolerance both globally and more locally between different social and cultural groups of people within Australia's modern day multi-cultural society.

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