
ENGAGING THE MIDDLE YEARS IN MATHEMATICS



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Student engagement in mathematics in the middle years is consistently reported to be a challenging problem. Yet, as this action research study shows, it is possible to engage students in meaningful mathematical learning with the use of relevant investigations. This project with 14 Year 8 and Year 9 mathematics teachers was structured around an action research model with teachers supported to refine capabilities and pedagogical processes to implement mathematical investigations that ‘make sense’. Following implementation, teachers reported that students were more engaged compared to traditional mathematics lessons and that students recognised the value and application of mathematics, which in turn leads to greater engagement in mathematics.

Introduction

The formulation of a problem is often more essential than its solution, which may be merely a matter of mathematical or experimental skill. *Albert Einstein*

Student disengagement in mathematics is recognised to be a challenge for educators. Students continue to reject mathematics when they have a choice, particularly in the senior school years and at tertiary levels. “[M]athematics ... is perceived to be ‘hard’, ‘boring’ and ‘useless’” (Brown, Brown, & Bidy, 2008) and of little practical value and so many complete their formal mathematics education with poor mathematical identities. For instance, in 2009 only 7.5% of Queensland students studied both Mathematics B and C in Year 12 but to continue with mathematics it is necessary to study both (Queensland Studies Authority (QSA), 2010).

Making sense of mathematics

To mathematicians, mathematics is about making sense of the world and seeing the connections between mathematics and the world, and the connections between different areas of mathematics (Burton, 1995, 1998-1999). This idea of *making sense* of the world provides a possible avenue for increasing engagement in mathematics in the classroom. As Schoendfeld (1992, p18) notes, “[C]lassroom mathematics must mirror this sense of mathematics as a sense-making activity if students are to come to understand and use mathematics in meaningful ways”. Furthermore, the availability of technology (calculators, computers etc) has eliminated the need for most pen-and-paper calculations (Battista, 1994) yet this is still the focus of many classrooms – teaching

children to do things machines are good at which does not make sense to students. If computers and calculators were used to do the things they are good at, it would leave students with the tasks of problem formulation and interpretation of the calculative work of machines.

By providing students with investigations and problems we give them the opportunity to ‘do’ mathematics and to *make sense* of their world. The goal of these tasks is “for students to make sense of a real-world use of mathematics, to get them involved in ‘problem formulation, problem solving, and mathematical reasoning’” (Battista, 1994, p463). As students solve complex tasks they get opportunities to discuss mathematics, to “conjecture, test, and build arguments about a conjecture’s validity ... and to be encouraged to explore, guess and even make errors “(Battista, 1994, p. 463).

For students to successfully work with these tasks, they may initially need a significant amount of thought to make sense of the task and/or mathematics before they can start mathematising. According to Romberg (1994), the steps involved in doing mathematics are:

- initially one needs to formulate the problem and to think about which variables are important and which relationships between variables matter and which do not;
- a model then needs to be determined which may be mathematical or physical;
- numbers can be substituted into the variables and numerical procedures used to find a solution of a numerical model. Alternatively students may use the physical model or act out the problem to find the solution; and finally
- the validity of the solution needs to be considered – does it make sense? What if I made a minor change here or there? This may necessitate going around either the whole cycle or part of the cycle again.

For the teacher, working with investigations and making sense of the world can be much harder than teaching factual information. A focus on pedagogy rather than content is a major shift that needs to occur. As Burkhardt (1988) explains, teachers:

- need to consider the different approaches taken by the students;
- need to decide when to support students with suggestions or questions that will help whilst still allowing the students to be responsible for finding their own solution and this is for each student or group of students in the class; and
- may be put in the potentially uncomfortable position of not knowing all the answers.

Mathematical investigations

Problems in the real world are ‘ill-structured’ and so it is necessary initially to formulate them in a well-structured way (Heylighten, 1988). Problem formulation is commonly carried out by the teacher, which leaves the student with the task of applying an appropriate algorithm which may be able to be calculated by machine. Taking problem formulation from students removes a key opportunity for students to engage in sense making using mathematics (Battista, 1994).

A good investigation has multiple entry points, allowing students to start at their own level and to design their own pathway (or pathways) through it. Indeed, investigations allow students to undertake activities and thinking that resemble that of the practice of mathematicians, and so they can be viewed as authentic mathematical tasks (Burton, 1998). In this way, investigations allow for the alignment of teaching, learning and assessment.

Boaler (2008) demonstrated that it is possible to engage students in deep mathematical learning using an investigative pedagogy, particularly those students who have been alienated by traditional approaches to mathematics education. Investigations are open-ended questions or problems that are set in a range of contexts. By using investigations that are directly related to the students' lives, mathematics becomes no longer 'useless'. To achieve this, teachers need to provide a socially supportive and intellectually challenging environment in the classroom (Fredricks, Blumenfeld & Paris, 2004) so that students are able to develop strong mathematical identities. When the task is relevant and meaningful most students enjoy a challenge (The Centre for Collaborative Education, 2000, cited in Hilton & Hilton, 2005).

Encouraging students to formulate problems is not easy, as the data from this small study reported in this paper indicates. The normal routines of teaching mathematics are not easily adapted to support a pedagogy that in many instances supports a mathematical activity where there is no one right answer. In this study we will explore the journey taken by a small number of teachers as they set out to facilitate the pedagogy of investigations to enable their students to *make sense* of mathematics.

The study

The aim of this action research project was to improve middle years student engagement in mathematics by employing investigations that *make sense*. A group of Year 8 and Year 9 mathematics teachers, comprising eleven female and three male teachers, volunteered for the project. There were six state schools each represented by two teachers, with two also sending their head of department.

The project was funded by Education Queensland with an overall desire to enhance pedagogical practices leading to an improvement in numeracy results across the region. An understanding about participation in the project was that there would be a commitment to support these teachers by allowing them flexibility in their work programs to trial some of the initiatives. Teachers were encouraged to attend in pairs with their mathematics head of department to enable a continuation of the conversations back at school. The project ran during the last term of 2010 and it is important to note that because of this timing it was difficult to maintain enthusiasm as teachers had end of year pressures. Fourteen teachers from six schools completed the professional development and three schools, including Schools A and B that are the focus of this paper, chose to replace their final assessment item with an investigation that lasted at least four weeks and included in-class teaching.

Action research process

Underpinning this study was an Action Research approach. Action research is a well-accepted methodology developed by Lewin in the 1940's that has recurring cycles of action and reflection (Dickens & Watkins, 2011). The model employed in this project is adapted from Kemmis and McTaggart (1988) and is summarised as follows:

- Plan – Priorities for action
- Act and Observe – Is it working? How do we know?
- Reflect – What are the problems?
- Revise plan – Review plan
- Act and observe – How is it going? How do we know?
- Reflect – Have we got it right?

The project was devised to facilitate participants to work through the model at least once.

Fundamental to action research in the *planning phase* is the provision of information and this was achieved through two whole day professional development sessions. Discussions initially centred on the needs and interests of adolescents, given the context of this project in middle years classrooms. This focus was planned to help participants with ways of devising pedagogical approaches to meet student needs. The focus then moved to practices for differentiated learning in the classroom. Mathematical investigations were then offered as a way to stimulate the interest of the students and cater to the diversity within a class.

In this *planning phase*, data were collected in the form of teacher and student questionnaires which were adapted from the work of Beswick, Watson, and Brown (2006). The questionnaires were constructed to collect data to determine both teachers' and students' confidence with mathematical concepts, their responses about mathematics and numeracy in everyday life and mathematics and numeracy in the classroom and the types of activities that were valued. The purpose of the questionnaire was to determine if there was a correlation between what the teachers reported and what their students thought. Teachers used this information to assist their planning.

Teacher participants were asked to provide comments about their experience in the action research study. The first data collected was purely to ascertain the reasons why the participants volunteered. The following verbatim comments provide an insight into the various reasons, which are consistent with the aims of the study:

- Engaging middle school students without working 60 hour weeks.
- Better engagement from my year 9s and teaching in a way that is less didactic / more student or interaction focussed.
- I would like to make changes to the current mathematics program to engage the lower achieving students.
- To get some ideas about investigations and reflection.
- I want to feel confident in my ability to teach maths in a way that is engaging and relevant to students.
- Better ways to engage the middle years teachers and in turn the middle years students (maths HoD).

Following the two day professional development participants devised plans for their chosen class to be implemented during the final term at school. They used the action research model described above as the basis for their planning. The researchers visited the teachers in their schools to provide support and made classroom observations of some classes. In this way, both the researchers and the teacher participants were engaged in the next phases of the action research project, that is recurrent *act and observe; reflect; revise plans* that took place. After these meetings one of the researchers wrote observations. At the end of term the teachers were encouraged to again *reflect*. Finally, they *planned* the next action cycle for implementation in 2011.

Results and discussion

The data reported in this paper came from the reflections of one of the researchers and the teachers in two of the schools, identified as School A and B. In school A the students were given the 'ill-structured problem' of designing a middle years area in the

space outside their classroom which then consisted of concrete, grass and a few bench seats. In school B the two teachers developed a structured investigation where students investigated loans for a car purchase and compared simple and compound interest for an investment.

School A – An ill-structured investigation

School A was a very large P-12 school with a middle school structure consisting of Years 7, 8 and 9. The mathematics head of department was not actively involved in this research project. One of the teachers had expressed concern during the professional development session that mathematics at her school was “impossible”. She complained that she had: no support; a low ability class who were not interested, badly behaved and couldn’t cope with the work; and that she wasn’t allowed to adapt the tests so that she could reduce the amount of content that she needed to get through. In her responses to the survey this teacher had agreed that quantitative literacy was just as necessary for efficient citizenship as being able to read and write. She decided to ask her class to design a middle years area in the space outside their classroom. The task which was to be used for assessment was left open and through class discussions she and her students planned how they would approach the task. The students were told at the beginning that the Principal would be invited to look at their final models for the middle years area and that possibly some of their ideas would be implemented, giving the project a sense of authenticity. The class initially discussed what to include in their designs and all ideas were noted.

The researchers joined the class when they went outside to measure the permanent fixtures e.g. chairs, concrete paths etc. The students were excited about the task and shared this with the researchers; telling the researchers what they were going to do and how they were going to do it. At this stage the students had formulated the problem; they knew they had to decide what they were going to include by surveying, they knew they had to measure, do a scale drawing and then could make their scale model. There were a number of students with poor measuring skills, for example not reading the metres on the tape measure only the centimetres and starting at 10cm as they thought the stiff part was something to hold onto. The teacher asked questions to enable the students to see their errors themselves. For example, when a group claimed the area was considerably wider than it was long she said, “Let’s have a look at your measurements,” pointing to a 23m length and a 57m width. “What do you think?” and then “What are you going to do about it?” when the student asked, “Do we have to do it again?” she replied, “What do you think?” With this type of questioning the teacher is forcing the students to think about what they are doing and to take responsibility for their learning.

Afterwards all of the students in the class went back into the classroom to add these extra measurements to their scale drawing. The students were talking about how to do the scale drawings, and how they had collected the measurements to remind themselves where they had measured from and to and what part of the diagram it was. Sometimes they stood up and looked out the window to check where things were outside. The students worked slowly but were interested in getting help from the teacher and researchers so that they could prepare the drawing. Students told the researchers that they had to do the basic scale drawing before they could include their own additions.

By the end of the term the students had constructed scale models of their designs. All had included extra seating, shade and bins and had included their own ideas such as handball courts, basketball rings and palm trees. The teacher's feedback was that there was much improved engagement and learning for most of the students and the hands on component was important. She observed that the task couldn't be too long as the students lost focus and that group work was difficult. In her class pairs were more successful than trios as when three students were working together one tended to sit back and let the others complete tasks. The teacher also observed that she had more opportunities to find out what the students actually did know as she moved around the room talking to the groups of students.

This teacher was enthusiastic about her experiences with the investigation and the difference this pedagogy had made to her class. Consequently she has taken on the role of Year 7 co-ordinator for 2011 with the aim of getting all the Year 7 teachers together to plan investigations as part of the assessment and pedagogy for mathematics.

School B – A highly structured investigation

School B was a large secondary school (Years 8-12) with a similar clientele to school A. In this school teachers did not trust the students to bring their equipment to class so the students left their mathematics exercise books in the classroom to ensure they had them for every lesson. The two teachers who participated in the study wrote an investigation exploring loans and investments, with the support of their mathematics head of department who had not attended the professional development. The task included comparing two different methods of paying off a car and comparing simple and compound interest for an investment. In their response to the survey, the two teachers had disagreed with the statement that quantitative literacy was just as necessary for efficient citizenship as being able to read and write.

The students were given a choice of purchasing five cars or a motorbike. The highly structured investigation was outlined on a task sheet that included the price of each vehicle, the number of kilometres travelled and the weekly repayments if purchased through the dealer's finance company. The task sheet stepped out what needed to be done at each stage of the investigation and supplied the required formulas so that the students only had to insert the numbers into the equation and calculate the answer. This meant that this group of students missed the opportunity to formulate the problem and also make personal choices by allowing them to choose a car for themselves. When the researchers went into two different Year 9 classes with one of the teachers and a Year 9 class with the other teacher only one of the classes were actually working on their investigation the other classes were developing the mathematical skills and knowledge necessary for the next part of the investigation. The students were doing their own individual work, however there were a lot of discussions with their peers. These students couldn't really tell the researchers much about the task, and were not particularly interested but when asked did admit that it was a useful assignment as they would be buying a car once they left school.

When the two teachers from school B reflected on the task they reported that students enjoyed the buying the car task and came up with a variety of reasons for their choice of which car to purchase, with the comments "[K]ids loved the topic – very interested in cars, both the girls and boys. Surprisingly, kids came up with a variety of

reasons for buying their cars, and didn't just go for the one that looked 'cool'. The teachers reflected that the students had taken ownership of the task and that the students appeared to enjoy using the spreadsheets, stating that "[T]eaching focus on kids taking ownership of task was very positive. Kids liked making spreadsheet and learning Excel tricks". The students reportedly, were not interested in saving for a house deposit. Teachers reported being concerned about the loss of interest towards the end of the task and the need to perhaps keep the task shorter, stating that "[T]ime pressure and the fact that this was the first time using the task made it difficult to get through the last few questions with the same enthusiasm as the first half of the task. Perhaps the task is too long?" The teachers also found it difficult to allow the students to take charge due to concerns about engagement, as noted in this comment "[I]t was difficult to allow kids to take charge of the task due to fear that they would get off-task/waste time". The teachers admitted that the task hadn't allowed the students enough opportunities to demonstrate their ability to reason mathematically.

Working through the reflection phase, teachers were planning to introduce more investigations into the following year's work program but were concerned about getting the balance between allowing students the opportunity for creativity whilst still being practical to mark, stating that the "[T]ask review needs to strike a better balance between including creativity in the task and making marking practicable".

Conclusion

By using an action research approach to facilitate the inclusion of investigations as a pedagogical practice, the teachers in this study reported that the students appeared to be more engaged with the investigation tasks and the learning compared to conventional mathematics lessons. By giving the teachers the knowledge and support to implement mathematics investigations in an informed way that included reflection and revision, these teachers have provided the opportunity for students to *make sense* of the value of and applications of mathematics which in turn has encouraged the students to participate and engage with the learning.

Perhaps because their teacher values quantitative literacy, the students at school A were given an ill-structured investigation which they formulated and worked through with the teacher. By contrast at school B, where the teachers did not put such an importance on quantitative literacy, the students were given a highly structured investigation that did allow for some choice but included the algorithms to use.

The biggest increase in engagement, as reported by the teachers and observed by the researchers, was with students in school A. This may be because they had more opportunity for ownership of the task as they were not just using given algorithms but had to formulate the problem themselves. This is something that needs further investigation and has implications for engaging adolescents with mathematics.

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