

“Maths Inside”: A Project to Raise Interest in Mathematics

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In this paper, we provide an overview of the “Maths Inside” project, funded by the Australian Maths and Science Partnership Program (AMSPP). The overall aim of the AMSPP is to improve uptake and participation of students in mathematics and science at secondary and tertiary levels. In this research project, we aim to improve student interest in mathematics and support mathematics teachers in their professional learning, through provision of rich and investigative learning resources, including video case studies of CSIRO scientists and mathematicians. Data collection on the outcomes of the project is ongoing and will be reported in subsequent papers.

The need for investment in Science, Technology, Engineering, and Mathematics (STEM) education in Australia was a principal part of the former Chief Scientist’s call for investment in STEM (Office of the Chief Scientist, 2013). In that paper, the case was made for the urgent need to strengthen science and innovation as the drivers of productivity, creating jobs and growing the economy in an increasingly competitive international environment. As part of this investment, the Australian Maths and Science Partnerships Program (AMSPP) was announced in the 2012-13 budget as part of a range of initiatives to improve outcomes in the learning and teaching of mathematics and science (Australian Government Department of Education and Training, 2017). Twenty-two projects were funded to the total of \$21.6 million. The projects involve partnerships of organisations, in each case led by a university. The “Maths Inside” project is funded through the AMSPP, and partners are the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the federal government agency for scientific research in Australia, the Australian Association of Mathematics Teachers (AAMT), and The University of Technology Sydney (UTS).

The projects funded under the AMSPP aim to build the confidence, capacity, knowledge base, and pedagogical skill of classroom teachers in mathematics and science, and increase the number of school students undertaking mathematics and science subjects to Year 12. A further aim is to improve outcomes for students in mathematics and science.

We developed a project to address these points, the “Maths Inside” project, so-called because the aim of the project is to help teachers and students understand how mathematics is used “inside” science and other areas. The primary aim of the project is to highlight how mathematics underpins many endeavours. “Maths Inside” uses a variety of resources to make visible the mathematics in these endeavours and aims to assist teachers in answering questions posed by their students about the value of the mathematics they are learning.

The research questions of the project are:

1. What is the role of rich and authentic learning tasks in raising student awareness of the importance of mathematics in society and in their own careers?
2. How do we improve student participation in, and attitudes to, mathematics?
3. How do we best prepare teachers to engage their students in mathematical endeavours?

In this paper, we discuss the problems that we aim to address with the project, examine relevant literature, and then provide an outline of the methodology being used to address our research questions.

The Current Context

The first issue that is concerning governments, educators, and other stakeholders is the declining participation in higher-level mathematics at senior secondary school levels (Barrington & Brown, 2014). This is suggested to be a result of a number of factors. One concerns the ATAR “gaming” that occurs: Students make subject choices that will maximize their ATAR score, often choosing a lower level of mathematics than they are capable of mastering, or avoiding mathematics entirely (Forgasz, 2006; Kennedy, Lyons, & Quinn, 2014; Mathematical Association of NSW, 2013; Pitt, 2015). A second factor is the removal of mathematics as a prerequisite to study particular courses at a tertiary level (Wilson, Mack, & Walsh, 2013). Many students feel that they will be able to “catch up” on those requirements through bridging courses. It is only when they fail subjects in their first year that they realise the problems with this belief.

The second issue is an apparent lack of motivation and negative attitudes towards the study of mathematics. Many students perceive mathematics as being difficult and unengaging, requiring a lot of time and effort to gain mathematical knowledge and skills (McPhan, Morony, Pegg, Cooksey, & Lynch, 2008). Given that students can choose their own pathways in subject selections, there is evidence that this factor is an influence in a significant number of students choosing to avoid mathematics when it is not necessary to achieve their overall academic goals (McPhan et al., 2008). This negative perception of mathematics often has roots in primary school mathematics lessons, which can lead to the phenomenon of mathematics anxiety. Furthermore, some features of mathematics learning that can cause disengagement are suggested to be rote learning and calculations, memory dependence, unrealistic exercises, mathematics tests, and authoritarianism in mathematics education (Frankenstein, 1989). The “Maths? Why Not?” report supports this picture of mathematics being perceived as an uncreative subject (McPhan et al., 2008).

The third issue concerns the teaching of mathematics. One factor is that teachers do not generally have the experience of working in a field that is underpinned by mathematics, and consequently are unaware of the “mathematics inside”. This makes it difficult for them to raise student awareness of the importance of mathematics. A second factor is the lack of qualified and experienced mathematics teachers, which gives rise to the need to employ out-of-area teachers, that is, teachers who may lack relevant content and pedagogical knowledge in mathematics. In a review conducted by the Australian Mathematical Sciences Institute (AMSI), and drawing on the 2011 Trends in International Mathematics and Science Study (TIMSS) survey, “Compared to the international average of 12 per cent, a staggering 34 per cent of Australian Year 8 students were being taught mathematics by a teacher without a solid mathematical background” (Wienk, 2016, p. 16). This is significant because the presence of a qualified teacher in mathematics is not only highly influential in

students' perceptions of mathematics, but also in their decisions to enrol in high-level mathematics (AMSI, 2012). This concern is evident from the responses that school principals provided in the Programme for International Student Assessment (PISA) 2012 report, stating that they have found it difficult to hire qualified mathematics teachers. (Organisation for Economic Co-operation and Development [OECD], 2014). In 2013, 8.7 percent of schools reported at least one vacancy in mathematics (Wienk, 2016).

A third factor is the type of pedagogy that is used in mathematics classes. Pedagogies that emphasise rote learning, unrealistic exercises, emphasis on algorithms, and decontextualized learning are thought to contribute to problems of uptake. Students find mathematics boring and are easily distracted, rather than engaged and motivated to take part in the lesson. Further, when students learn by repetition of abstract procedures, they "are not only learning an efficient set of procedures, but an esoteric set of practices that are not well represented outside of mathematics classrooms" (Boaler, 2000, p. 4).

These issues provided a rationale for the "Maths Inside" Project. The following literature guided the structure and content of the activities and professional development in the project.

Building Confidence, Capacity, Knowledge Base, and Pedagogical Skill of Classroom Teachers

A teacher plays a strong and influential role in students' engagement and their decisions to enrol in higher-level mathematics, as found in a study involving Year 10 students (McPhan et al., 2008). According to Sullivan and McDonough (2007), two sets of factors must align to promote student engagement in learning, and the role of the teacher is to address these factors:

The first set of factors include that the students have the requisite prior knowledge, the curriculum is relevant to them, the classroom tasks interest them, and the pedagogies and assessment regimes match their expectations. The second set of factors relate to their goals for learning, their willingness to persist, and the extent to which they see participation in schooling as creating opportunities. (p. 698)

Teachers need to know their students and what choice of classroom tasks will interest them. In order to do this, teachers must have a wide knowledge of pedagogical practice. This comes from training and experience. However, recent studies have shown that in the Sydney metropolitan area, for example, students in Year 7 have lessons taught by a qualified mathematics teacher 50% of the time, while in regional areas, 29% of Year 7 lessons and 43% of Year 9 lessons are taught by qualified mathematics teachers (MANSW, 2013). This is problematic as the "Maths? Why Not?" report (McPhan et al., 2008) indicated that a strong experience of mathematics teaching in junior school (Year 7 to Year 10) increases the chance of a student enrolling in mathematics for senior school in all geographical areas. Without qualified mathematics teachers, there is a stronger chance that students will become disengaged in the junior school years, potentially leading to increased disengagement in mathematics learning and lower rates of participation in higher mathematics in high school (McPhan et al., 2008). Teachers teaching out of area require ongoing professional support, mentoring, and exposure to examples of sound pedagogical practice.

Increasing Participation in Mathematics and Science to Year 12 and Beyond

The PISA 2012 report found that there was a strong link between active classroom interaction and better student engagement, fostering learning environments where students interrogate concepts and problems critically (OECD, 2014).

There is strong evidence that the geographical location of a school has a significant effect on the number of students enrolled in high-level mathematics (McPhan et al., 2008). Rural schools are often disadvantaged as they find it difficult to provide essential resources such as qualified mathematics teachers and quality educational resources (Jones, 2000). Results from the “Maths? Why Not?” report (McPhan et al., 2008) show that a positive junior school experience for a rural student plays a significantly high influence on enrolment in senior school. For the relatively low number of students who do continue on to senior school in rural areas, students are more likely to enrol into subjects that have a more practical focus, instead of theory-based subjects, such as higher mathematics, for senior study (Jones, 2000). This often leads to higher-level mathematics not being offered as a subject choice in rural schools (AMSI, 2012).

Schools in the metropolitan areas are typically larger than rural or regional schools and have more access to resources. A larger school size can have a positive influence in a student’s decision to enrol in higher-level mathematics (McPhan et al., 2008); it is argued that this is because schools in the city have more access to qualified mathematics teachers and resources. Metropolitan areas have the highest levels of enrolment in more advanced mathematics subjects (MANSW, 2013).

Improving Students’ Outcomes in Mathematics and Science

Student engagement and motivation are necessary for improving student outcomes in mathematics and science. As noted in the four yearly MERGA review, there is growing interest in the study of motivation and engagement in mathematics education research in Australia (Attard, Ingram, Forgasz, Leder, & Grootenboer, 2016). While some authors use the terms interchangeably, Attard (2012) draws on the definition of engagement as a multi-faceted construct initially offered by Fredericks, Blumenfeld, and Paris (2004). She distinguished engagement from motivation because motivation refers to “beliefs and orientations towards schoolwork and learning” (Attard, 2012, p. 10), while engagement is concerned with cognition, affect, and behaviour. A student may in general be highly motivated, but constrained by some feature of the context of the classroom such as the influence of peers, the relationship with their teacher, or the nature of a particular task, from fully participating in all three aspects of engagement with mathematics on a particular day. The intertwining of these constructs and constraints is acknowledged by Fredericks et al. (2004), who state that “definitions of engagement incorporate a wide variety of constructs. For example, behavioural engagement encompasses doing the work and following the rules; emotional engagement includes interest, values, and emotions; and cognitive engagement incorporates motivation, effort and strategy use.” (p. 65).

When teachers use active learning methods, students become more engaged and interested in mathematics. Studies (e.g., Freeman, McDonough, Smith, Okoroafor, & Jordt, 2014) have shown that active learning can also increase student performance with a lower failure rate. The PISA 2012 report found that there was a strong link between active classroom interaction and better student engagement, fostering learning environments where students interrogate concepts and problems critically (OECD, 2014).

Attard (2013) reported on a longitudinal case study of students making the transition from primary to secondary school. The same students were interviewed and observed in classroom settings and focus groups. Attard (2013) found that “those pedagogies that fostered substantive engagement with mathematics were those that promoted active participation, academic challenge, and social interaction, and highlighted the relevance of mathematics within students’ current and future lives” (p. 583).

In addition to providing tasks that involve active participation, teachers who show their enthusiasm for mathematics and their concern for their students and their learning are more likely to achieve increased engagement in mathematics (Skilling, 2014).

“Maths Inside”

The aim of “Maths Inside” is to provide teachers with classroom materials that are engaging, interesting, and provide a range of challenge. The materials include, and are inspired by, a series of videos made by the CSIRO about their scientists at work in solving problems and inventing new processes and technology to answer questions of value to the Australian community. Examples include the Zebedee device for 3D mapping, the Square Kilometre Array of telescopes, the Patient Admission Prediction Tool, and Bees with Backpacks (monitoring how, when, and where bees travel). The classroom materials to accompany the videos are prepared by the Australian Association of Mathematics Teachers (AAMT). Writers from AAMT liaise with CSIRO and the project team at UTS to ensure that the videos provide sufficient links to school mathematics. This may mean requesting the scientists to use mathematical language that school students will recognise.

Each activity is linked to the Australian Curriculum: Mathematics, making it possible for all teachers, whether trained or out-of-field, to include the “Maths Inside” activities in the school program. Teacher notes are included with the activities so that all teachers have the Knowledge at the Maths Horizon enabling them to more easily engage students (Hill, Ball, & Schilling, 2008) – see Figure 1. Out-of-field teachers often struggle with this aspect of Subject Matter Knowledge.

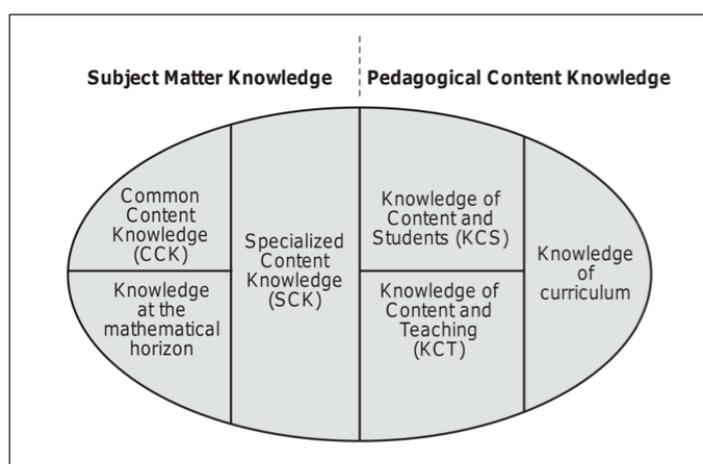


Figure 1. Domain map for mathematical knowledge (Hill, Ball, & Schilling, 2008, p. 377).

The classroom materials are designed to provide teachers with a wide choice of activities. These include group work, individual projects, and hands-on construction, using

partially-prepared spreadsheets to investigate scenarios, and some routine calculations. Where the tasks are routine, they are within a theme and context provided by the scientists. The materials are trialled with teachers in professional learning contexts including conferences, and with small groups of students.

The use of active learning methods is the basis of all the classroom materials in “Maths Inside”. For example, after viewing the video about the Square Kilometre Array and hearing from astronomers how parabolic dishes collect radio waves, students then build their own parabolic trough solar collectors to cook a sausage, boil water, and melt marshmallows (see Figure 2). The mathematical properties of the reflection of the sun’s rays through the focus of their cardboard parabolas are not only visible but also effective, in real-world terms, to provide heat for cooking. Links to the use of inexpensive and readily available technology for cooking in the developing world are made. After the practical and global applications are appreciated, the students more readily engage with the mathematics. The geometric properties of the parabola are then analysed with co-ordinate geometry, making this an unforgettable lesson.



Figure 2. Radio telescopes inspire parabolic cookers (CSIRO, Maths Inside Project Team).

The possibility of humans travelling and living on Mars is a current topic of interest. The videos on Zebedee and the Square Kilometre Array are useful starting points for discussions about communications from Earth to Mars. Speed, distance, and time calculations, based on the relative locations of the planets, are part of the considerations when planning such communications.

The Bees with Backpacks video leads into several possible investigations into the geometry of the hexagon, tessellations, and three-dimensional packing. Students also consider the way that bees communicate through the “waggle dance”, involving trigonometry and much hilarity as students perform the dance to tell their friends the direction and distance to a food source outside the hive. Many teachers struggle to find real-world contexts for teaching about ratio; however, the “capture/recapture” method for estimating the sizes of populations can be applied to the bee hive.

Plans are in progress for videos and classroom materials about pollution in the ocean and modelling demands on hospitals, examples of the wide range of real-world problems that CSIRO scientists and data analysts are addressing using mathematics as an essential tool.

Data and Methodology

The effectiveness of “Maths Inside” is being researched in parallel with the development of resources. Surveys from teachers who have viewed the videos at conferences informed the next stage; for example, the project team soon learnt that the initial videos were too long, and that certain kinds of videos would appeal to different age groups. The project team is recruiting schools to participate in ongoing research that will be conducted as a set of case studies with mixed methods for data collection: surveys, observations, and interviews. Baseline data about student attitudes to mathematics and interest in continuing to study mathematics will be collected, and the data will be compared with later survey data (Fraenkel, Wallen, & Hyun, 1993). Members of the team are aware of the limitations of the study, which include the features of case study research (Burgess, 1985) and the need to take a reflexive attitude to the relationships between researchers and participants. In addition, as the schools were self-selected to be involved, generalisations beyond those schools to other situations may be limited.

Conclusions and Looking Ahead

The literature of engagement and motivation in mathematics, especially the importance of providing challenging tasks, demonstrates the usefulness and value of mathematics to students. The value of mathematics has at least two aspects relevant to our ongoing work: the value to society (someone needs to know it to solve real problems), and the value to individual students (If I learn this, I can do...and these careers and jobs will be open to me).

The members of the “Maths Inside” team are planning resources to address those two aspects. Scientists in the videos talk directly about the mathematics that they use to address authentic problems, and the classroom materials draw on those scenarios and provide tasks that show how mathematics is useful to individual citizens. We look forward to reporting on the results of this work in the future.

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