Full Paper

Introduction

To reverse the current trend of declining numbers of mathematical professionals in Australia, a change of thinking needs to occur in regards to the curriculum in primary education. The question is; how can we engage young students in mathematics?
Part of the solution is scaffolding the natural curiosity in children; this sees them question mathematics in a way that forms deep connections and understandings. If we can reform curriculum programs in such a way that students are motivated to be involved with the mathematics, we can begin to foster a love of mathematics, which in turn could support students to persist with mathematical learning throughout their entire lives.

The Program

In Australia, we are facing a decline of mathematics professionals. Australian's disconnect with mathematics can be seen as early as primary school and by year 12, only 9.4% of students are enrolled in Advanced Mathematics, a statistic that has dropped by 22% from 2000 to 2012. In tertiary education, enrolments in undergraduate and postgraduate mathematics and statistics courses have remained unchanged for the last three years, and completion rate of these courses has been in decline for the last ten years (Australian Mathematical Science Institute, 2014).
These alarming figures indicate that early intervention is critical to ensure that all students have the opportunity to be engaged with mathematics, and additionally are exposed to the countless possibilities and applications involved.

For this purpose, the 'Calculus for Kids' program was initiated. The goal is to engage students in complex mathematics through the use of digital technology. The focus is to support students to gain an understanding of integral calculus concepts and applications, thus moving away from the traditional secondary school approach of teaching how to do the mathematical calculations, without reference to the applications. To achieve this, students are provided with the mathematical software MAPLE®. Once familiar with the software, students can focus on solving and understanding real-world calculus problems, without the stress of carrying out the mathematical calculations by hand (Fluck, Chin, Ranmuthugala & Penesis, 2014).

For many primary school teachers the thought of teaching calculus is no doubt, rather daunting. Glasswell (2012) states that "...teachers, like all other learners, need to be scaffolded through the learning process." Therefore, in order for the program to be successfully undertaken in schools it is essential to provide adequate support to teachers. Teachers commencing the program are provided with a full day of training, conducted by the researchers directly involved in 'Calculus for Kids'. This provides teachers the opportunity to become familiar with the teaching material and discuss any questions or concerns before commencing the program in their school. To support the teacher in the classroom, a series of 11 PowerPoint presentations are provided to aid in delivering and explaining the concepts to students. As all students learn in different ways, these materials provide; videos, diagrams, real-life applications and worked examples to explain the concepts of calculus as well as how to use the software MAPLE to solve problems. To further assist teachers running the program for the first time, a member of the research team visits the school mid-way through the program. This enables the research team to gauge the current success of the program and to assist with any teaching or technical issues.

"By allowing students to interact with and struggle with the mathematics using their ideas and their strategies… the mathematics they learn will be connected to other mathematics and to their world" (Van de Walle, Karp, Lovin & Bay-Williams, 2006). When students are involved with the mathematics, they are more likely to retain and understand it. Therefore, each of the thirteen 'Calculus for Kids' sessions provides students with the opportunity to struggle with the mathematics, and use MAPLE to connect their strategies to solutions. After each PowerPoint presentation, where the concepts and skills are explained, students are guided through MAPLE with example and practice problems. This aids students to gain experience and confidence with the mathematics. Following this, they are provided with a worksheet, which provides real life problems (see Figure 1). Sparrow (2008) discusses the importance in providing context to mathematics, when students are provided with real and relevant mathematics, which relates to their own experiences, they are more likely to engage, understand and experience success in mathematics.

In the past, the program focused on the application of integral calculus through the use of Information and communications technology (ICT) to help students gain an understanding of the concepts (Fluck, Chin, Ranmuthugala & Penesis, 2014).
However, following feedback from the teachers involved in the delivery, the program was updated in 2014 to include the development of the relevant equations before subjecting it to the relevant mathematical processes such as integration (see Figure 1). The work presented in this paper includes the results from this work.

Q1. The Golden Gate Bridge is suspended between two towers that are 1280 metres apart. The top of each tower is 152 metres above the roadway. The cables touch the roadway at the midpoint between the towers.

Determine an equation that models the cables of the bridge. Plot this curve on Maple.

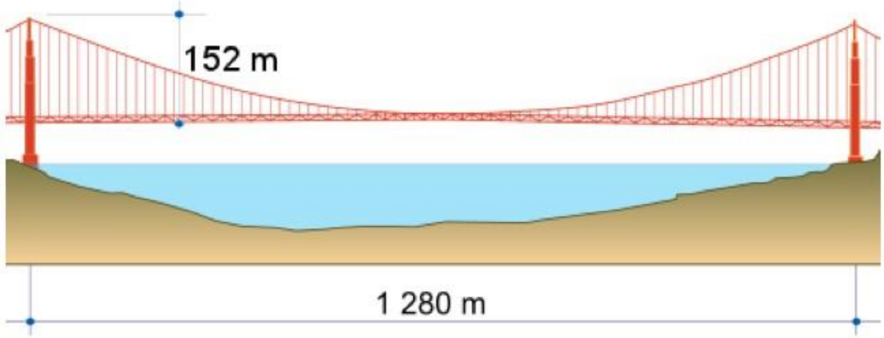

Figure 1 Example of a calculus question based on real-life applications ('Calculus for Kids' resource materials).

Previous Results

In order to monitor and draw conclusions on the success of the program, a form of summative assessment is necessary. To achieve this, students are required to complete a test using MAPLE at the end of their program. The basis for this assessment is a first year maritime engineering mathematics examination, however, university students would be required to complete the calculations by hand. The resulting test consists of thirteen questions, five of which require students to apply their understandings in order to answer the questions correctly (Chin, Fluck, Ranmuthugala & Penesis, 2011). The standard and difficulty of the assessment provides an insight into the achievement made by the students, and the success of the program. This same assessment was administered to all students at the completion of their respective programs.

The questions were based on real-life problems, enabling them to apply the relevant concepts to solve problems that they could relate to, although the solution process was assisted through the use of MAPLE. The students needed to have gained an understanding of the mathematical concepts in order to develop equations and identify the required information to enter into MAPLE (see Figures 1 and 2).

As students had not encountered integral calculus before participating in the program, there was no baseline data to compare their tests results against. Therefore, the students' understanding of the concepts is currently based on their ability to read, understand and use MAPLE to undertake the correct processes to solve the problems. The study will continue to track the students involved in the program throughout their secondary education to collect NAPLAN data and to compare their future engagement in subjects that builds on a mathematical foundation in comparison to students who have not completed the program.

All results presented in this paper are based on the final test. The benchmark for university students is a 50% pass mark. Table 1 provides the average score achieved by the students in their final test at five schools across four states published by Fluck et al. in 2014. It is seen that based on these results, students aged between 10-12 years can be exposed to university level engineering mathematics and demonstrate understanding and application to solve problems with a range of success. In 2014, St. Therese Primary School Torquay first became involved in the program and begun to observe the benefits that this program had holistically on student learning.

Table 1: School locations and average score achieved by the students in their final test in each school

State	Location	Mean Score (%)
NSW	Urban	75
QLD	Urban	88
VIC	Rural	58
TAS	Rural	63
TAS	Rural	90

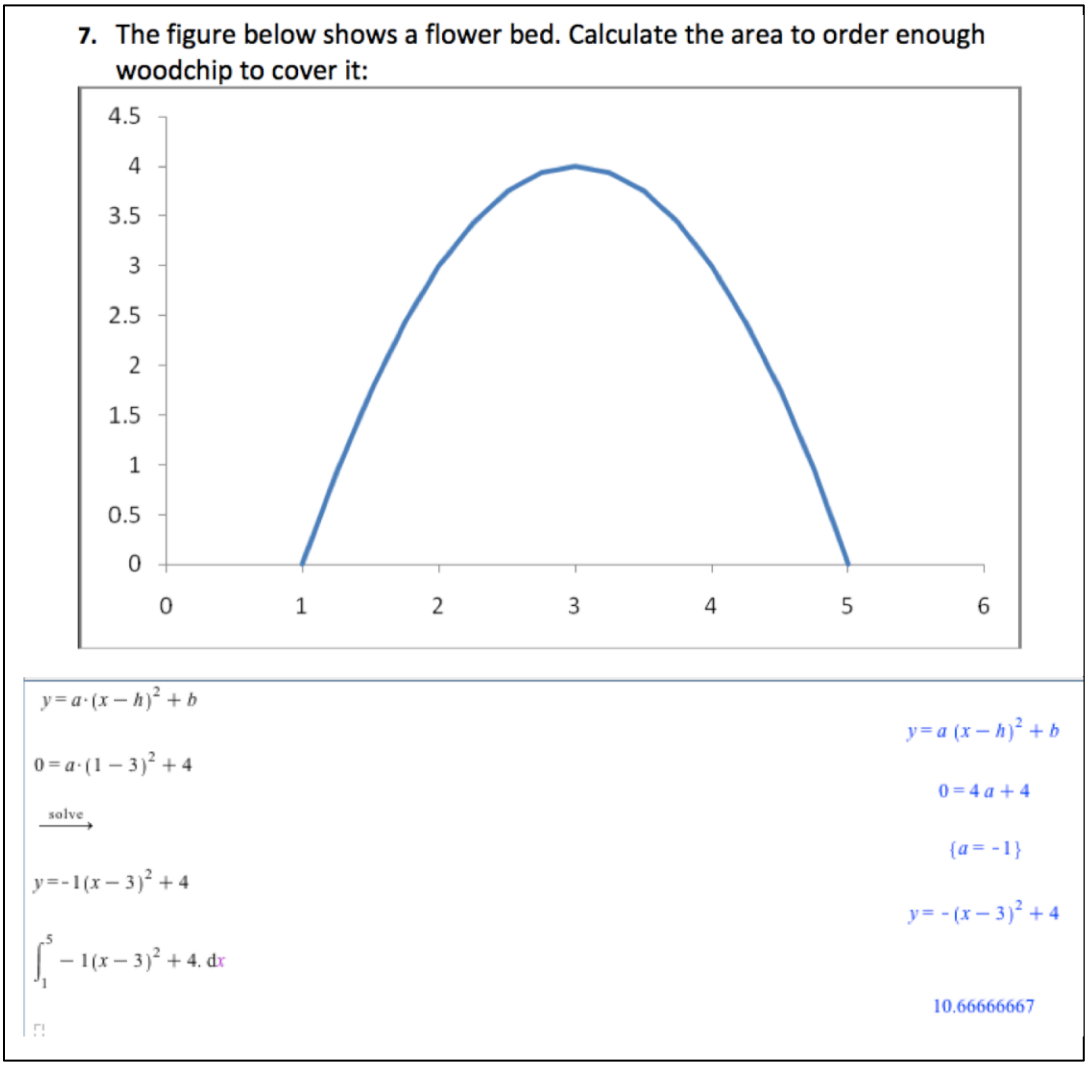

Figure 2 Example of a calculus question based on real-life application and student solution in MAPLE (‘Calculus for Kids’ resource materials).

St. Therese Primary School Torquay Context

St. Therese Catholic Primary School is set in the coastal township of Torquay in Victoria, Australia. The school comprises of 462 students and had an Index of Community Socio-Educational Advantage (ICSEA) value of 1092 in 2014, indicating slight advantage (Australian Curriculum Assessment and Reporting Authority, 2014). The school’s vision focuses on supporting students to become independent lifelong learners. In mathematics, a self-directed approach has been undertaken, which has seen students take control of their learning and in turn improved students’ motivation and engagement in mathematics sessions. Furthermore, teachers have high expectations of students, which is why the ‘Calculus for Kids’ program was adopted in 2014. This program has been successfully undertaken with three groups of students since commencement, with the fourth group set to start in Term 3 2015.

Initially the program was offered to students who demonstrated strong mathematical capabilities. The results from the summative assessment spoke for themselves, see Table 2, which were supplemented by observations throughout the program, class exercises, discussions, and interviews with students and teachers. This group of students exhibited not only that they had gained an understanding of integral calculus, but also an increase in; mathematical language, confidence, engagement and motivation to question and understand relevant areas of mathematics. These observed improvements prompted the school to offer the program to all students, of all abilities and the results so far have been equally as promising, with final results to be made available in 2016.

Table 2: Class average score for ‘Calculus for Kids’ in the final test for students at St. Therese Torquay School over three terms.

Year	Term	Mean Score (%)
2014	3	72.27
2014	4	81.97
2015	2	77.6
		77.28

Observed Benefits

A common concern raised by the teachers involved in the delivery of the program was that the ‘Calculus for Kids’ program was not directly linked to the school curriculum relevant to the proposed age level. Further discussions with the teachers reveled that this was due to their focus on the key concepts, software, and the applications. Thus, the induction sessions were improved to include and highlight the aspects within the program and related activities that enhanced various elements of the curriculum. These elements are not limited to; graphs, co-ordinates, geometry, algebraic thinking, fractions and exponents. What the program achieves, which many curriculum focused teaching does not; is scaffolding students to make real connections between mathematical areas through the use of real world problem solving. Additionally, students are exposed to a large vocabulary of mathematical language. The significance of students learning correct mathematical terminology was outlined in the National Numeracy Review Report (2008):

> *That language and literacies of mathematics be explicitly taught by all teachers of mathematics in recognition that language can provide a formidable barrier to both the understanding of mathematics concepts and to providing students access to assessment items aimed at eliciting mathematical understandings (Council of Australian Governments, 2008).*

Students participating in the program were observed to be using correct terminology to explain their understandings. The mathematical language supported students to articulate their learning, and in the process make connections between mathematical concepts and consolidate their understandings. The MAPLE software provides a range of equation templates from which conventional mathematics expressions can be easily constructed (see Figure 3).

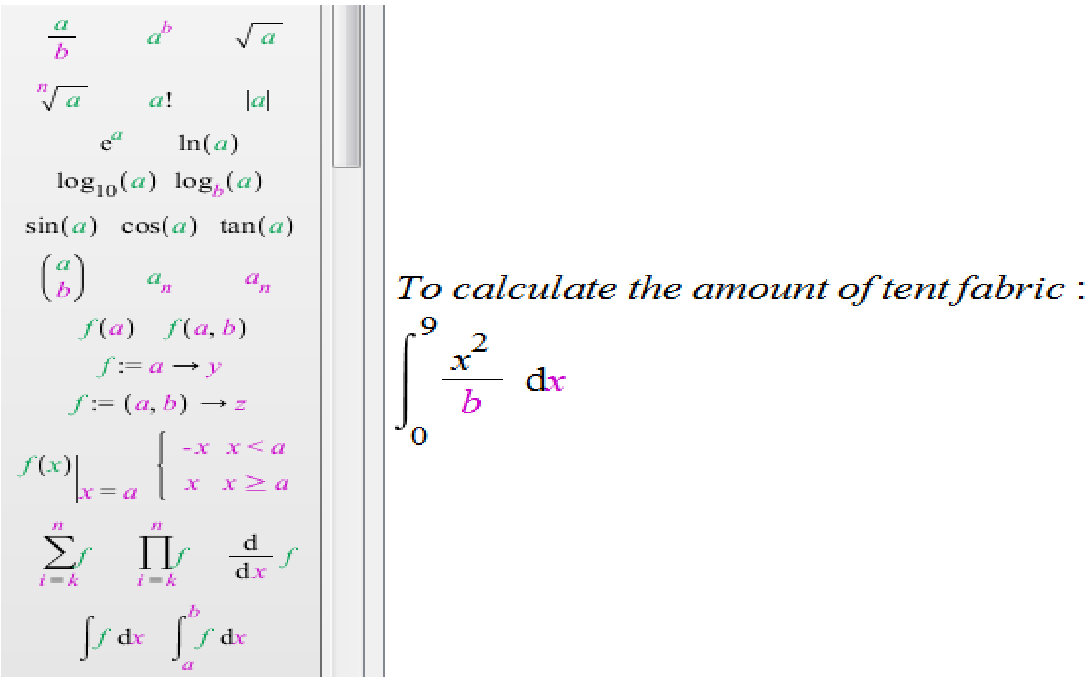

Figure 3: The MAPLE control screen provides templates (on the left) from which equations can be constructed using conventional mathematics symbols (on right).

Fullan & Langworthy (2014) list that digital learning tools and resources as a core component of new pedagogies. Additionally, Fullan & Donnelly (2013) stated that "...technology used without powerful teaching strategies (and deep learning tasks) does not get us very far." The support material provided to teachers in the 'Calculus for Kids' program provides the opportunity to pair technology with meaningful real-life problem solving to engage students in mathematics. Furthermore, students are provided with the opportunity to engage in the technology through the use of the mathematical software MAPLE. A high level of student involvement has been observed, as they are actively involved in the technology, rather than using it passively as a source of information. Hattie's (2009) study of the influences on student achievement found computer assisted instruction and acceleration had an effect size of 0.37 and 0.88 respectively. This is based on his theory that an effect size of 1.0 demonstrates an improvement of one standard deviation; depending on the case this is equivalent to the normal achievement gain in a year of study. This supports the program, which combines technology with challenging mathematics to engage and motivate students in their mathematical learning. Since an annual learning gain equates to an effect size of 1.0, 'Calculus for Kids' has a significant effect size of 5.0+ for these Year 6 students, since these mathematical ideas are not normally encountered until Year 11.

Mathematical anxiety is linked to a lack of confidence and can lead to a drop in mathematical performance (Buckley, 2013). When students were presented with the Calculus program, they are made aware of the high level of mathematics of which they were achieving, and thus improved confidence was observed. Students who began the program without strong mathematical capabilities, saw the greatest increase in confidence as they were supported to achieve something they perceived as extremely difficult. This has had an ongoing effect in mathematics sessions as these students are more likely to see their weaknesses as challenges and are motivated to improve as they did with 'Calculus for Kids'. The students, who came into the program with stronger mathematical abilities, also saw a change. They began to question mathematical concepts, rather than accept them at a surface level, which in turn led to a deeper understanding. Furthermore, it sparked motivation to investigate other complex mathematics including algebra and trigonometry. This was demonstrated by a group of girls who were so curious about functions that they wanted to learn how to plot them manually, they would request functions that they could take home to work on. One of their parents even commented that they had to remind their daughter to take a break. Overall, a shift occurred in regards to mathematics at the school as students no longer treated it as 'boring' or 'hard-work' but saw it as a challenge that was personally rewarding to achieve. Therefore, the 'Calculus for Kids' program encourages students to develop a 'growth mindset'. Dweck's (2006) research on 'mindset' compares a fixed mindset; which involves individuals believing intelligence cannot be changed, to those of a growth mindset. Those that possess a growth mindset, have a greater chance of experiencing success, as these individuals view mistakes as a challenge they need to improve, rather than failure to achieve. Presenting students with complex mathematics such as calculus exposes them to the magnitude of the field of mathematics. This in turn plants the idea that there is always more to learn, and more to improve on.

Engaging Students in Engineering

An important benefit of this initiative is the advantage that it provides to the field of engineering. Introducing students to calculus at a young age, allows students to build an early understanding of what it means to be an engineer. The program supports students to achieve success in solving practical engineering problems, which could potentially set them up for a future career in the field. An ongoing imbalance in the profession of engineering is the under-representation of women. Engineers Australia (2011), reported that only 11% of members were female. Table 3 provides an insight into the female participation and results in the calculus program at St. Therese.

Despite the slightly lower participation rate, the girls that completed the program achieved a higher mean score than the males. Whether these girls pursue study in the field of engineering is unknown, the results demonstrate that by participating in the program they have been provided with a positive start to success.

Table 3: Gender Comparison of Students results in 'Calculus for Kids' final test at St. Therese Torquay

Gender	**2014 Participation**	**Mean Score**	**2015 Participation**	**Mean Score**
Males	59.3%	72.95%	57.2%	76%
Females	40.7%	78.32%	42.8%	81%

Implications

The logistics of delivering this program in the classroom were minor, compared to the benefits observed. As with all technology, there is a risk that it will fail at the critical moment. In the early stages of the program, this was an apparent issue, and was often disruptive to the sessions. However, with the support of the research team, MAPLE software support and the school's ICT support, these issues were quickly resolved within the first few sessions of the program. The school decided to run the program separate from regular mathematics sessions; requiring some manipulation of the timetable to ensure that the trained teacher was available to facilitate the program. This decision produced interesting results, as the program was offered as a choice to students, and continues to be non-compulsory this year. The results of this have seen the program being largely popular, as word has spread through the year 5/6 community of how enjoyable it was for students to learn mathematics in this format. Each time the program has been offered, there has been no shortage of students signing up, and even some students missing out and having to wait until the next program commences. The only possible future barrier to the program's continued success at St. Therese Primary school, is that only one teacher is trained to conduct the sessions. As a mathematics specialist, this teacher has invested professional development, time and enthusiasm into the program, which may not be transferred if they were no longer teaching in this area. As the school has seen the significant value of the program, it has been insured that another teacher would be trained in the program if need be. Additionally to this, the 'Calculus for Kids' research team has provided a range of supports to teachers and schools to aid them in undertaking the project. Most importantly, during the training days, teachers from all schools involved exchange emails. This provides a support network, where facilitators can ask questions to improve their practice. To summarise, these minor barriers, were easily overcome, and have been outweighed by the observed benefits and successes experienced by all the students involved.

The strength of this particular report is the perspective from the classroom, by an author fully engaged in the life of the students. It is written from a pedagogical point of view which provides veracity and authenticity to the narrative. Limited to a single school, it nevertheless represents activity which has been, and is being, spread through fifteen or more Australian schools. Attitudinal data is now being collected in these further trials, which will provide further evidence. Obtaining data on the effect the 'Calculus for Kids' project has on nationally standardized numeracy scores is more challenging, especially when students move to new schools from which post- test assessment data might be gathered, but this is also underway.

Conclusion

The initial aim of the program to teach primary-aged students integral calculus has seen significant success in schools thus far based on the final test. As the study is in its infancy, further results of the ongoing effects of the program will become clear through NAPLAN monitoring in the future and the engagement and achievements of these students in mathematics based units in their secondary education. More promising to the future of mathematics in Australia however, has been the observed benefits in the classroom practice of the program. When students are presented with what seems to be an impossible task - to learn mathematics far beyond their expected grade level - and given adequate support to understand and experience success, they are seen to have a renewed engagement with mathematics. This engagement sees improved motivation, confidence and positive attitudes towards mathematics. Optimistically this will support students in lifelong learning and achievement in the field of mathematics, and its applications in our world.

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