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The First Year of STEM at an Australian Primary School: Promise and Uncertainty

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Abstract

The Australian Government has called on a transformation of STEM teaching in primary schools. At the start of 2016, St Mary's Primary School in Sydney launched a program to recognise the importance of igniting students' passion for STEM at an early age. Children in Grades 1-6 spend 60-90 minutes per week with the program which is designed to: promote scientific enquiry and technological thinking; encourage collaboration; provide engaging hands-on experiences; foster effective communication; nourish curiosity and a sense of wonder. Approaching the end of the year, the strengths of the program are: exceptionally high engagement of students; regular hands-on, collaborative activities; clear communication with school staff and parents; support from the Catholic Schools Office for the program as an example of innovation and "authentic learning". While the program has had a successful first year, several issues have become increasingly salient. First, there is a risk that the creativity and excitement of the program may be diminished by exposure to the dominant standards-driven paradigm. Second, in a crowded curriculum and school timetable, there are questions about how the components of STEM should be weighted and integrated with each other and with other syllabus areas. Third, planned efforts to raise the STEM capacity of non-specialist teachers at the school may be hindered by competing demands and interests. To provide a culture in which STEM might continue to thrive, staff at the school is being invited to consider the two-sided model of teacher professionalism developed by Crowther (2016). He believes that the "standards" approach to education needs to be balanced by one which recognises the initiative and ingenuity of individual teachers.

PISA has featured in the Australian news lately and it has nothing to do with Galileo's birthplace. The nation's recent lackluster educational performance in international tests like PISA has generated consternation and debate [1]. Although Australia's score in scientific literacy is above the OECD average, it is one of the country's which showed a decline in performance between 2006 and 2015; in my home state of NSW, the decline was largest [2]. The Australian Government has recognized that the task of turning around the nation's performance begins in primary schools [3].

Several reasons help explain why STEM has not reached its potential in primary schools, among them: few primary school teachers have strong qualifications in STEM subjects; English and mathematics receive the lion's share of academic focus while science can languish as an occasional extra; the primary curriculum is incredibly crowded so easily filled with subjects teachers feel most confident teaching -- seldom science [4].

Adam Spencer, media personality, self-proclaimed geek, and promoter of science and mathematics, is often asked what it would take to revolutionise science in Australia. He writes:

"I'd equip every[1] primary school in Australia with a dedicated science teacher, who taught across the entire school, in a laboratory that was hers or his alone. In every school where I have seen this model the results are sensational" [5].

Spencer's opinion is clear and reassuring. It's a model we have introduced to St Mary's school. The children *have* become enthusiasts: they keenly wait for their next STEM class to start and are very disappointed if, for whatever reason, they cannot attend a session.

STEM at St Mary's

St Mary's is a Catholic systemic primary school in North Sydney in a high socio-economic status catchment. It currently has 374 pupils enrolled from Kindergarten to Year 6. Children in Grades 1-6 spend 60-90 minutes per week with the STEM program. Classes average 17 students which allow one teacher to provide a satisfactory level of supervision. The Science Curriculum [6] details in broad terms the outcomes and content of science and technology with engineering and mathematics featuring as stand-alone or integrated components. A summary of content for the current school term

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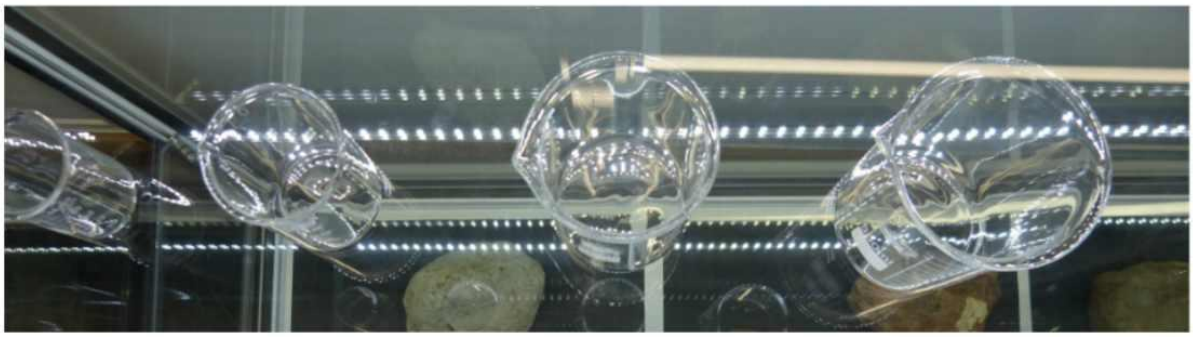
is provided to parents and staff as part of regular communications about STEM (Figure 1)

Figure 1 Summary of term program from www.handsupnow.com



Stage 1 (Grades 1 and 2)

We learn about some everyday materials and how they can be changed or combined in useful ways. These materials will be already familiar to many of us because they are used in building our homes or for cooking in our kitchens (for example, sand and sugar).

Our work this term will be just as hands-on (if not more so) as in the last three: we'll be touching, mixing, wetting, dissolving and kneeding. Before any activity, we might be making predictions about how our actions change the properties of a substance. Now, how does it look, feel or smell?

Stage 2 (Grades 3 and 4)

What do we know about the solar system? In particular, what is the relationship between the sun and Earth? We will learn about how regular changes -- day and night, the changing seasons -- can be explained by this relationship.

Students will represent their own conception of the solar system before we look at various models of it. By taking a stroll in the park and dropping different size balls at specific intervals, the amazing scale of the solar system will make an impression on us.

To better incorporate a STEM angle, there'll be time to explore our planetary neighbour, Mars, and think about the incredible engineering mission involved in landing rovers such as Curiosity on its surface.

Stage 3 (Grades 5 and 6)

This term, we will describe the features and adaptations of some living things. We will also consider how characteristics of the physical environment may help or hinder the growth or survival of particular plants and animals

In class, there'll be an opportunity to observe and record the growth of seeds under different environmental conditions. We may also be able to examine the impact of the environment on relatively simple organisms such as yeast, worms and insects.

On a global scale, we will learn about how the activities of our own species have changed the biosphere and influenced the populations of other living things.

One of the challenges to starting a STEM class at the beginning of the year was simply the lack of a free classroom let alone a dedicated laboratory. Principal, Beverly Coffey and I felt that STEM needed its own area to emphasize its importance, provide more continuity and allow for the efficient use of resources. Two spaces were available. The first was a room with kitchen and storage facilities tucked away in a disused presbytery. The second was a large, newly-built foyer of the school which is every day traversed by children, parents and staff. While the first space may have been more functional, quiet and secure, our choice to conduct STEM in the foyer has paid off. The foyer has a physical connection with the rest of the school which allows others to see first-hand the activities. During school hours, Kindergarten classes regularly file past the STEM area which promotes science and its allied subjects to the youngest members of our community.

Barbara McAllister of Intel wrote: "We've got to make the emotional connection to STEM, or we will fail" [7]. Igniting students' passion has been our main goal. Students in their last year at St Mary's were asked to write a short reflection about STEM. Without exception, these pieces brimmed with enthusiasm and provided some insights about what had been the perceived highlights of the program (Table 1).

Table 1 Illustrative sample of Year 6 students' reflections on STEM

My favourite part of STEM was when we tried to make a tower that could hold a tennis ball. Altogether STEM has been fun and exciting the whole year and I wish I could stay next year to do STEM.
In STEM we have been doing various challenges and experiments … One of this year's highlights was the icosahedron workshop where we created an icosahedron out of straws and masking tape.

I enjoyed the experiments when we got to hold baby chickens and when we ran a [model] steam engine. I think all schools should have STEM because it is such a fantastic subject that I know all children would enjoy.
STEM is an amazing subject. I enjoy doing all the interesting experiments, from building a paper bridge that holds coins, to melting different substances.
I feel in STEM I can think more clearly as it opens up my true academic self.
STEM is unique because we always get to do an experiment or build something. My favourite STEM activity was when we got to build anything out of LEGO and then create instructions [for building it].

Features of STEM

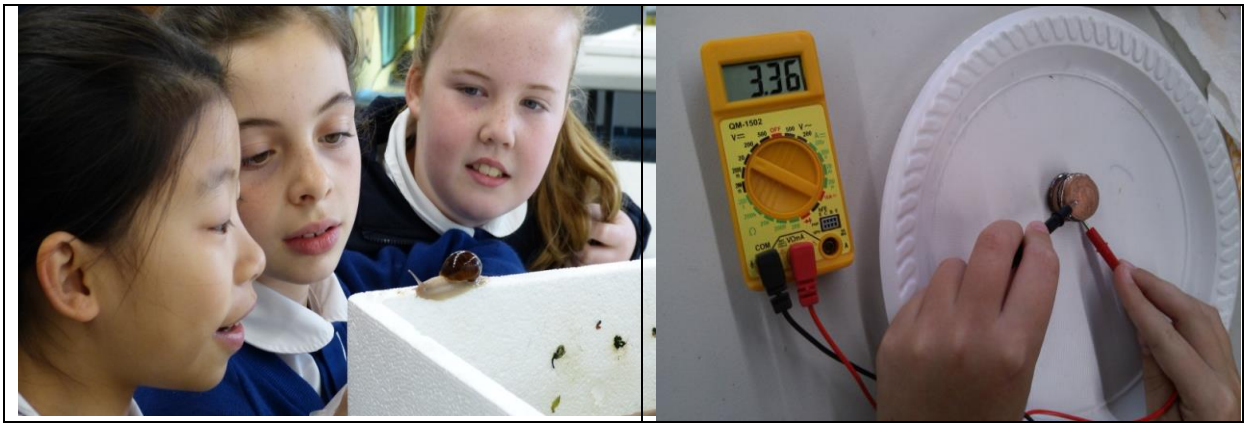
One of the keys to achieving high student engagement was to design a program where most sessions would involve students working together either to conduct an experiment or participate in a building challenge. Although STEM is often marketed in the context of high-end technology, many of the resources purchased were inexpensive, “low-tech”, and reusable.

Vasquez has characterised STEM in terms of the level of integration between disciplines [8]. Using her scheme, many activities of the past year at St Mary’s would be classified as interdisciplinary or transdisciplinary.

For example, the Year 6 children learned about electricity. They watched a video clip on the voltaic pile before being given materials they could use to make a battery: old coins, aluminium foil, vinegar and cardboard. Shown how to use a multimeter, they were challenged to generate the highest voltage and then, afterwards, tried to power a miniature electric motor with the battery they had made (one group succeeded).

The session spanned many learning areas. It included some history of the battery with Volta’s invention now more than 200 years old. There were scientific concepts and the language to express them: electrical circuit, materials which conduct and insulate, different metals (aluminium, copper, zinc), electrolyte, voltage, connecting cells in series and in parallel. There was the process of working technologically, not just learning how to measure voltage, but also how to meet the challenge of maximizing voltage. By noting readings from the multimeter (including variability at the decimal level), recording results in graphical form and calculating averages, mathematics was connected.

In another session, ten year olds began by reading about the garden snail. They were then questioned to check understanding and draw out the scientific vocabulary: mollusk, mucus, radula, tentacles, hermaphrodite. The children spent time observing snails, peering at them through magnifying glasses, holding them in their hands. For the next activity, they were instructed to write a story from the perspective of one of the snails they had watched. Early finishers were able to build a snail using LEGO. Note that, in this example, integration across disciplines extended to literacy and art.



Promise and Uncertainty

In Australian primary schools like St Mary’s, there are two important pedagogical cultures which should complement each other but which, in practice, can be rivals. Those who identify with the first tend to look to the Finnish system for inspiration. It’s a culture that emphasises the child’s ability to play and explore as a path to building inner motivation and self-directed learning. There is room for the

teacher to exercise professional judgement and an understanding that different educational approaches are necessary to cater for individual differences among the children. A warm and supportive relationship between teacher and pupils is considered fundamental along with the teacher's sensitivity to how each child experiences school. The success STEM has enjoyed in its first year owes much to an appreciation of these principles

The second pedagogical culture stresses the attainment of outcomes. Teachers operate within a cycle where they identify outcomes in the syllabus, plan and streamline activities and lessons to meet them, test students before and after units of work, collect evidence of achievement for their students and for themselves. Competition is keenly felt, between students, classes and schools. Advocates for a standards-approach to education more often look towards Singapore as a model.

Especially for a new, experimental program like STEM, these two cultures need to be finely balanced..

During the "snail session", the children's excitement and curiosity was palpable. For some, it was the first time they had held a snail; perhaps the first time they realised how something so commonplace could also seem so wonderfully alien. A program which regularly offers these kinds of experiences meets the promise of igniting students' passion for the natural world.

In a primary school where standards are the dominant consideration, a new program is likely to draw questions which ultimately leach away the students' and teachers' feelings of enjoyment and confidence. *Have the outcomes been mapped from the learning activities to the various syllabuses? Are the learning intentions clearly articulated? Is it really STEM if the children are writing a narrative? Should we include the arts and have STEAM rather than STEM? What are the children learning if they are building a snail from LEGO? Where is the evidence that learning has taken place? Has technology been properly incorporated in the lesson?* While questions of this kind raise tactical and strategic issues, given too much attention, they create uncertainty and drain energy out of the classroom.

Emeritus Professor Frank Crowther believes the standards movement has cut away the "heart and soul" of teaching [9]. He argues we need to see teacher professionalism as a two-sided coin where the standards movement, on one side, is balanced by the idea that teachers bring pedagogical gifts to their work which need to be recognized, developed and brought into play. The success of STEM in Australian primary schools will depend on attracting and retaining teachers with the right gifts. These might include: fond memories "doing science" as a child; delight in finding out how things behave and what makes them tick; admiration for the work of scientists past and present; an ability to set up enticing, age-appropriate learning activities for children. As a creative enterprise involving child, teacher and curriculum, STEM in the Australian primary school is set to flourish.

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