

Chapter 13

The Successful Students STEM Project: A Medium Scale Case Study



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Abstract Schools in Australia and internationally are responding to calls to offer new and innovative learning opportunities in STEM. STEM stands for Science, Mathematics, Engineering and Mathematics, but when amalgamated into the acronym ‘STEM’ can potentially mean more than the sum of the four parts. In choosing how to respond to the STEM ‘push’, schools must first navigate through the many ‘versions’ of STEM emerging within the education community, and then face the task of upskilling teachers in content and language, teaching approaches, and new technology and equipment. Professional development of teachers plays an important part in assisting teachers and schools in this period of innovation and change. This chapter describes one such professional development project where teachers from ten schools in regional Victoria, Australia, were supported in developing new knowledge, language, pedagogy, and curriculum to support their development of a ‘STEM vision’ for their schools. The activities developed by these schools are outlined to illustrate that they each have taken a different approach to STEM, with case studies showing how these activities were developed. The factors critical to the success of the program are outlined, which have implications for a policy response, as well as challenges that may threaten the sustainability of such initiatives.

Keywords STEM · Professional development · Teacher learning · Interdisciplinarity

13.1 Introduction

The Successful Students STEM program (SSSP) is a medium scale professional development program based in a regional city in Victoria, Australia. Schools in the region have a relatively low rate of student enrolment in the senior STEM disciplines

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in comparison to the rest of the state, a fact that concerns both the schools and local industries.

Unlike many STEM case studies (e.g., English & King, 2015), this project involves a number of secondary schools, but more importantly, does not prescribe a single, ‘one size fits all’ model of STEM. Individual schools determine their own needs, and create their own perspective of what STEM can be in their school context. This has led to a range of STEM-focussed projects, ranging from Year 7 students from an all girls’ secondary school designing and building a ramp for wheel-chair access to a part of their school, to another school designing and making vehicles.

SSSP offers schools assistance in preparing teachers for such STEM activities. Professional learning (PL) and ongoing supports for teachers are high priorities, as is the induction of school administrators into the concept of STEM and the importance of their role in creating a successful STEM program in the school.

The program is developed and implemented by a team of researchers from Deakin University. Funding supports teacher professional development, staffing and administration, support for partner schools to run school programs (such as excursions), teacher support for attending professional development and curriculum development, support for schools developing links with industry, quarterly STEM teacher network meetings (open for all STEM-related teachers in the region) and a national STEM education conference (<http://stemedcon.deakin.edu.au/>) where the SSSP teachers were showcased in a number of ways.

13.2 The Program

The programme involves 3 teachers from 10 partner schools committing to professional development for two years. These teachers may be Mathematics, Science or Technology teachers, or teachers in positions of leadership who can support the change process of the teachers and within the school generally. The professional development programme includes four professional learning (PL1-4) sequences of three phases each—Immersion (2-day intensive), Implementation (10–12 weeks at their school) and Review (1 day). Each sequence builds on the learning of the earlier sequences, with the foci being: PL1—Pedagogies and Contemporary STEM practices, PL2—Assessment and up-scaling to lead change, PL3—Sustaining change, and PL4—Embedding practice and generating evidence of change. The professional learning sequences are designed to progressively build teachers’ capacity to plan, implement, evaluate and lead STEM teaching and learning in their schools.

This chapter reports on STEM initiatives from the first three PL cycles. These initiatives have thus far been units of work, learning sequences, or programming structures that incorporate some of the STEM practices and pedagogies that are promoted through the PL intensives. In addition, a Project Officer works with schools to support their developing practice. These PL sequences and the continuing support are key to supporting each school’s approach to STEM innovation.

13.3 Negotiating the University-School Partnerships

The focus and structure of the professional learning was negotiated between the SSSP team and schools, and then re-negotiated to ensure the programme continues to meet the schools' needs. These negotiations are fundamental to the success of the programme as they ensure the Deakin team is sensitive to the ongoing and changing needs of the school. There is opportunity for feedback of data (particularly student attitude and aspiration survey data) to support school decision-making, and relationships are strengthened to support ongoing trust and reciprocity between the SSSP team, the teachers and school leaders.

13.4 The “STEM Vision Framework”

A framework called the “STEM Vision framework” (reported in Hobbs, Cripps-Clark, & Plant, 2018) was introduced in PL2 to provide a common language and direction for teacher decision-making about: conceptualization of STEM for the school; STEM pedagogies and practices; curriculum structure and teacher collaboration models; teacher learning and up-skilling; and using industry links. Development of a common language around these aspects of the STEM vision has been shown through an independent evaluation to be empowering for teachers for describing and guiding their practice.

Schools have been innovative in planning, implementing and sharing a range of initiatives that are at the forefront of thinking about new directions for STEM education. A survey of teachers after PL3 has shown that there has been substantial change from the teachers' perspectives: 50% reported evidence of embedded classroom innovations at 18 months and 75% at 24 months; 79% reported improved knowledge and understanding at 6 months; and 100% reported improved capability at 12 months. Evidence from the reporting days show that teachers are continuing to build their language around STEM, and the ‘STEM practices’ promoted through the programme is becoming part of their natural discourse around STEM. The STEM pedagogies and practices that have been introduced to teachers are listed in Table 13.1.

Tables 13.2 and 13.3 show the variety of projects that are emerging after three of the four professional learning sequences and the teacher collaborations, that is, how teachers work together to incorporate the different STEM subjects. Table 13.2 shows the teaching teams that are largely single subject-oriented in how they were implementing STEM, while Table 13.3 shows where subject integration was a key focus. In both tables, column 2 indicates the variety of curriculum areas that are being recruited to STEM; the majority are the Mathematics and Science teachers, but also included in some schools are the Information Technology and Materials Technology teachers, as well as the Arts teacher in School G in the third iteration.

Table 13.2 shows that Schools B, C and E were predominantly focused on improving the activities and learning outcomes in single subjects. In the absence of the

Table 13.1 STEM practices and teaching and learning practices

Interconnecting STEM skills/proficiencies ^a	STEM teaching and learning practices, where students...
Flexible reasoning skills	Problem solve Create Generate own questions Inquire
Effective and adaptable use of tools, processes and ideas (artefacts)	Use conceptual, digital, physical tools Explore and investigate artefacts Use a range of modern tools Use artefacts of the discipline in a flexible way Apply constructed artefacts to new contexts
Proficiency in professional/technical discourse	Understand and engage with the disciplinary representations Know the language Share and communicate Work in teams
Understanding of the nature of evidence in different settings	Collect real data in a variety of situations Use evidence to validate a solution to a problem or justify a decision Make judgements about the accuracy and reliability of information

^aAdapted from Clarke (2015)

imperative to attend to the curriculum standards in multiple subjects, their projects were considered STEM-like because of their explicit link to the STEM practices through assessment that foregrounded these practices.

The other two schools, A and J, were delivered by teachers from one subject, but there were attempts to draw other subjects into the learning. School A projects were delivered by the Technology teacher who used the Science context as a way to engage students in the design process. School J involved the Science teachers (who also taught Mathematics) bringing the Engineering principles into Science classes. Similarly, the projects of School B involved some of the concepts from Science, but the projects were largely focused on re-designing the Mathematics curriculum.

In Table 13.3, there were different types of integration present. At School G a multi-disciplinary teaching team meant that parts of one project were delivered by different teachers in different subjects. In Schools F, H and I, the integration of subjects was done by each teacher, where one teacher makes explicit links or draws in ideas and learning outcomes associated with more than one subject, usually Science and Mathematics, but also Science and Technology, or all three in the case of School F.

While some teacher teams are predominantly Science (such as School E) or Mathematics (School B), the majority are inter-disciplinary; however, by the third iteration, even the subject-oriented teams were making links to their other subject teaching as most of the teachers teach both Mathematics and Science.

Table 13.2 SSSP projects per school in professional learning sequences 1–3 (PL1-3)—single subject-oriented teaching teams

Sch'l	PL#: year level (curriculum content)	Teacher collaboration	In these projects, students...
A	PL1 and PL2: year 8 technology (design processes and simple machines)	Tech teacher complements Science programme	Investigate types and uses of simple machines Design a machine that lifts 250 g weight
B	PL1: year 7 mathematics (angles, generating and using data), science (gravity and ramp slope)	Maths teacher makes connections to science and STEM practices	Investigate ramps for people in wheel chairs, the big question <i>Are all ramps the same?</i> : explore ramps in the community, test effects of angles on ramps, and design a school ramp
	PL2: year 8 mathematics (area, volumes, measurement and managing data), Science (transpiration and evaporation)	Maths teachers makes connections to science and STEM practices	Investigate <i>Are our garden water storage tanks large enough?</i> : analyse rainfall data, garden bed water losses, and size of water tanks in relation to the area of collection roofs
	PL3: year 7 mathematics (using data), science (ourselves)	Maths teacher makes connections to science and STEM practices	Investigate <i>When during my schooling do my parents spend most money on clothes?</i> : collect height data from the entire school study body and from local primary school children, and use secondary data to examine height changes with age
C	PL1 and PL2: year 7 info technology (developing coding skills)	Info Tech teacher makes connections to STEM practices	Complete online coding skill-building activities, leading to control of robotic lego devices
	PL3: year 7 and 8 info technology within science (coding and robotic control)	Science teacher makes connections to STEM practices	Continue to build coding skills online, then undertake a technology task, such as designing and building a Mars explorer

(continued)

Table 13.2 (continued)

Sch'l	PL#: year level (curriculum content)	Teacher collaboration	In these projects, students...
E	PL1: year 8 science (plant and animal cells)	Science teacher makes connections to STEM practices	Represent the function of Plant and animal cells as two challenges: (1) different objects to represent the different organelles, and (2) bucket of cells
	PL2: year 8 science (particle theory of matter)	Science teacher makes connections to STEM practices	Use representations to (1) physically show temperature effects during chemical changes, and (2) design a communication that shows relationships between reactions, equations, and the particle theory
	PL3: year 8 science (body systems, and movement)	Science teacher makes connections to STEM practices	Use representations to explain the operation of a body system and connections to survival, then present to a younger audience at an expo
J	PL1: year 7 science (simple machines and forces)	Science teachers connect science and engineering	Design a Rube Goldberg machine focussing on forces
	PL2: year 8 science (forces and simple machines)	Science teachers connect science and engineering	Design, construct, evaluate and communicate to others about small design challenges: build a bridge, an make a water rocket
	PL3: year 8 science (forces and energy)	Science teachers connect science and engineering	Design, construct, evaluate and communicate to others about two design challenges: balsa wood bridge, and a water rocket, culminating in a STEM challenge day

Table 13.3 SSSP projects per school in professional learning sequences 1–3 (PL1-3)—integrated teaching teams

Sch'l	PL#: year level (curriculum content)	Teacher collaboration	In these projects, students...
D	PL1 and PL2: year 8 mathematics (generating and using data), science (experimental design)	Maths/science teacher co-ordinates maths and science activities	Design, test, evaluate and re-test a “Barbie bungee” in order to build up problem solving and inquiry skills
	PL3: year 9 mathematics (across a range of topics)	Maths teacher co-ordinates STEM themed extension tasks	Work with a mentor, drawn mainly from tertiary student volunteers, on problem solving tasks
F	PL1, PL2 and PL3 year 7 and 8 science (human senses), mathematics (measurement and variables), technology (robotics and coding)	Science teacher make connections to mathematics and information technology	Develop and apply programming skills to lego EV3 robotics concurrent to doing coding in technology classes. Students compare and contrast human senses and robotic sensors, and link to the electromagnetic spectrum
G	PL1: year 8 mathematics (scale, circles and measurement), science (properties of materials), technology (design and construction)	Co-ordinated approach to design challenge by science, maths and tech teachers	Investigate, design, create and evaluate a vehicle that will travel furthest down a ramp, and represent learning in a portfolio that was assessed in the three subjects
	PL2 and PL3: year 8 mathematics (scale, circles and measurement), science (properties of materials), technology (design and construction), and art and design (graphic design)	Co-ordinated approach to design challenge by science, maths and tech teachers	Investigate, design, create and evaluate a vehicle that will travel furthest down a ramp, and represent learning in a portfolio that was assessed in the three subjects. Includes industry visits where they are informed about modern design and construction practices relevant to the challenge

(continued)

Table 13.3 (continued)

Sch'l	PL#: year level (curriculum content)	Teacher collaboration	In these projects, students...
H	PL1: year 7/8 mathematics (generating and using data), science (experimental design)	Sciences and maths teacher makes connections to science and engineering	Design and construct a number of small projects—parachutes, cranes, bridge building—in order to build up problem solving and inquiry skills
	PL2: year 7/8 mathematics (indices, powers and exponential change), science (acids and bases,	Science and maths teacher makes connections between science and maths	Link three diverse topics from real life (pH levels, radioactivity and the Zika virus). In mini-workshops, students share and communicate as peer tutors
	PL3: year 7/8 mathematics (fractions, decimals and percentage)	Science and maths teacher makes connections between science and maths	Undertake a series of tasks related to real life that gradually build up transferrable cross-curricular skills: paper plane design, construction and testing; transport logistics; and 3-dimensional cube nets. Students then communicate to others through a STEM Expo
I	PL1: year 8 science (forces), technology (design process)	Maths/science teacher makes connections to science and engineering	Design and construct a small self-propelled vehicle to carry water over a set distance, after completing immersion experiences and team building activities
	PL2: year 8 science (investigating), mathematics (basic operations, data and statistics)	Maths/science teacher makes connections between science and maths	Inquire into links between mathematics and science through a series of questions: <i>How long would it take to watch all the episodes of a number of seasons of a television series?</i> and design and build a box that has the largest volume from an A3 piece of paper

(continued)

Table 13.3 (continued)

Sch'l	PL#: year level (curriculum content)	Teacher collaboration	In these projects, students...
	PL3: year 8 science (forces), technology (design process)	Maths/science teacher makes connections between science and maths	Design and construct a device that transfers energy (incorporating kinetic and potential energy changes) through a series of changes that eventually rings a bell, then use posters to report findings

Some schools (such as Schools C, H, I and J) are developing a dossier of activities that are embedded into their normal curriculum, while others (such as School F and G) are developing a particular programme and improving it each year. Other schools are developing and extending a pedagogical approach; for School J it is the use of representations (Tytler, Prain, Hubber, & Waldrip, 2013) in Science, and for School B it is open-ended investigations in Mathematics. School D developed a project in PL1-2, but moved towards a system of using Mathematics mentors for their year 9 students thereafter.

By PL4, many of the schools had multiple initiatives occurring at multiple year levels, and included both curricular and extra-curricular activities (School D did not continue into PL4). It is beyond the scope of this chapter to detail the breadth of initiatives emerging, however it is worth noting that over time many (but not all) of the schools were expanding their STEM programmes beyond the projects listed in Tables 13.2 and 13.3.

13.5 Case Studies

In an earlier chapter of this volume [refer to chapter Tytler et al.], we describe the STEM projects of School B. The key learnings of the three Mathematics teachers undertaking SSSP highlight the importance of paying attention to not just the initiatives and activities being produced, but how the conditions within which teachers operate shape teachers' decisions about how to incorporate STEM in a sustainable way. School B is an inner-city girls government school, where the Mathematics background of students entering Year 7 was often weak, and there tended to be low expectations, interest and enrolments in senior STEM subjects, particularly high level Mathematics. In order to respond to this impetus for change, the three teachers developed a common approach to teaching Mathematics that focused on big ideas and core principles using open ended investigations that ran for 2–3 weeks and which linked to students' lifeworlds (Table 13.2 lists the inquiry questions). Student engagement

with Mathematics was a key motivator for teachers to take on this activity-oriented approach, and to develop credible and generative assessment processes that reflected the STEM practices of creativity, problem solving, collecting real data and drawing conclusions from evidence.

In order to illustrate the relationship between the emerging projects and the rationale guiding teachers' decision making, STEM projects from three other schools are showcased below: Schools J, G and H. The approaches from these three secondary schools are described to illustrate:

- how the context of each school provides the impetus for change;
- the variety of teaching strategies that schools can use to develop and implement STEM curriculum; and
- various teacher collaboration models that are needed in different circumstances.

Each case study includes background to the school and STEM within the school, the teachers and STEM practices involved, a description of the projects, and how they evolved. In the ensuing discussion, we highlight the importance of considering school context when working with teachers to promote teacher and school change.

13.5.1 Case 1: School J

School J is a young and small private school; however, the present structure, school improvement plan and the majority of staff date from 2014. The curriculum has a traditional structure, with stand-alone, discipline based classes, that is, Science and Mathematics are separate subjects and have no involvement with the Technology faculty. The school works within the Australian Curriculum and pedagogy is predominantly textbook based and exam driven (formal exams every semester). Students often have the same teacher for Mathematics and Science.

The present Head of Science, who was employed in 2015, drove the impetus for change. Reading about, and meeting with, Canadian educators who were active in STEM education and participating in the Deakin University Science and Engineering Challenge, had inspired her. Teachers saw the potential for innovation was being constrained by the lack of a laboratory assistant and a small staff, some of whom were relatively inexperienced. The STEM Programme teachers were the Head of Science/Year 8 Science teacher, a graduate Year 7/8 Science and Mathematics teacher who had made a career change from engineering, and the Year 7 Science/Victorian Certificate of Education (VCE) Chemistry teacher.

The project aimed to change the traditional teaching pattern where theory was fore-grounded followed by illustrative activities, to a model where activities drive student learning and where theory is introduced as needed. The other aim was to introduce Engineering processes into Science, specifically identifying a problem, working in teams to solve the problem, and then testing the solution.

In PL1, the Year 7 Science teachers worked closely to plan and implement a design-based challenge with their Year 7 Science classes where they combined two

units of work, Simple Machines and Forces. Then students were presented with the challenge of working in groups to design a *Rube Goldberg machine* to deliberately over-engineer a machine to complete a simple task. The design brief was to incorporate simple machines and identify the forces and chain reactions of energy transfers. The STEM practices (from Table 13.1) addressed were: creativity, problem solving, applying tools to a new context, working in teams and communicating findings.

In PL2, the two Year 8 Science teachers designed and implemented two short, self-contained and hands-on challenge tasks in their Science classes: building a bridge, and designing and measuring the distance of a water rocket. The STEM practices addressed in this sequence were again: creativity, problem solving, applying tools to a new context and working in teams. A preparatory design challenge of building a paper bridge was completed in Year 8 Mathematics classes to prepare the students for problem solving and collaboration, and to develop teachers' scaffolding strategies.

In PL3, the teachers re-developed the design challenges from PL2 so that they were undertaken over a number of weeks and formed a single assessment task. Small groups of students were required to design and construct a water bottle rocket and build and test a balsa wood bridge for strength. The learning sequence culminated in a STEM challenge day in which the devices were tested and communication reports presented and shared. The STEM practices were: creativity, problem solving, communication, working in teams, and collecting real data. A student evaluation showed that teachers' careful selection of student groups enhanced student learning and confidence.

13.5.2 Case 2: School G

School G grew out of a former technical-high school and has successfully rebadged itself with an emphasis on individual student responsibility and a carefully planned teaching and learning environment. STEM subjects were taught as stand-alone disciplines with little cross co-ordination or integration. Participation in the project sought to address both the declining numbers of students enrolling in post compulsory STEM subjects and the tendency for the more capable girls to opt into the life Sciences and avoid the physical Sciences. The SSSP teachers were an inter-disciplinary team of Mathematics, Science and Materials Technology teachers.

In PL1, the teachers were given professional learning time and support by the school. The team decided to adopt a design-based strategy in their projects because it was applicable across the three subjects. The teaching team planned an integrated Year 8 unit that was taught to two classes. The unit sought to expose students to industrial processes and problem solving. Each teacher taught a different component of the unit in their separate subjects, with clear contributions from Science, Mathematics and Technology in solving the common problem: *the Rolling Vehicle Challenge*. The unit also had the objectives of stimulating an understanding of STEM and the career opportunities of STEM related subjects and allowing students to make connections between Mathematics, Science and Technology. An excursion

to the local university engineering teaching and research facility was part of the unit and it culminated in a celebration day where the teams from the classes tested and presented their solutions in the presence of guests (internal and external) and competed in a vehicle run-off. Teachers taught in their individual disciplines but there was a conscious cross-curricular co-ordination of learning activities and a common STEM language was used which was made explicit to the students and reinforced by the use of a reflective journal across all three disciplines. Assessment was based on performance of their vehicle in the run-off, and a presentation of their journal that documented their research, their design processes and findings. The project addressed the STEM practices of problem solving, creativity, inquiry, exploring and investigating artefacts, using professional/technical language in communication and working in teams, collecting data and using evidence. Timing and co-ordination of classes remained a challenge and, despite efforts to the contrary, a survey showed that the students often failed to make connections between Mathematics and Science activities.

In PL2, the school began to make connections with a local high technology industry, and widened the scope of the unit to include the Art and Design faculty. The teaching team decided to wait to PL3 to implement the project, and the school team concentrated on setting up links with local companies, re-designing the programme and scaffolding required, and making the links between the project and the curriculum for each of the four curriculum areas involved (Science, Technology, Mathematics, and Art and Design).

In PL3, the vehicle challenge was implemented over 6 weeks and incorporated learning outcomes from the four curriculum areas. Again, the challenge was to design, construct and test a rolling vehicle. The students, within each of the four Year 8 classes involved, were organised into teams of three, with roles distributed as leader, recorder or designer. Expectations included the production of a portfolio covering the development of their vehicle, including testing and evaluation, and a multimedia presentation that summarised the production process. Excursions and incursions were organised to three local companies relevant to modern design and construction practices in the car and cycle manufacturing industries. Exposure to these companies was designed to assist and inform the students in their production of their vehicle. Each excursion had a particular focus: meeting the needs of clients, design and construction, testing, and production processes. A *jigsaw* approach was used where each student from each team attended one of the three companies, and then reported their findings back to their group to inform their vehicle design. At the end of the unit, the best performing vehicles were tested in a celebration day in front of representatives from the companies they visited.

13.5.3 Case 3: School H

School H is a medium sized government secondary school. It runs an integrated, Year 7 and 8 programme, with Science and Mathematics teachers sharing the teaching of

combined classes. During participation in SSSP, the teachers were mapping their courses against the new Victorian Curriculum and developing common assessment tasks. The SSSP teachers were the Year 7 and 8 Science and Mathematics team of three teachers. Different projects, mainly as a collection of learning tasks, were developed over the three PL sequences, and have been mapped and documented in keeping with the remainder of the other Science and Mathematics curriculum. In doing so, the work of the SSSP teachers was relevant to the changes already occurring at the school.

In PL1, the school-wide focus on critical thinking formed the basis of the planned learning tasks. The teachers conducted the activities in integrated classes, with the secondary goal of developing stronger links between Science and Mathematics. Emphasis was given to drawing on real life contexts, and the skills required in jobs that related to the hands-on activities. The challenge-based activities were designed to be performed in small groups, and completed in two or three class periods. The challenges, which had a competitive edge, required students to design and construct: a parachute that descends the slowest, a paper crane that lifts 50 g, and the strongest bridge. The STEM practices addressed were: problem solving, creativity, using tools, applying new concepts, working in teams, collecting real data and using evidence to validate solutions. In an evaluation, students indicated greater engagement in both Science and Mathematics, but teachers reported that more effort was required to design suitable assessment rubrics or criteria to match the tasks. As a result of this reflection and evaluation after the unit, for the next year's programme they planned to construct a template or design a common approach to these types of activities so that students could become familiar with the appropriate design processes and problem solving techniques.

In PL2, interesting pedagogies were used where the students tutored their peers in order to promote deeper engagement with the materials and improve the communication skills of the students. Representatives from each group of three or four students participated in teacher-run workshops on three seemingly unrelated Science topics: the Zika virus, radioactivity, and biological growth, but the common thread was the Mathematics topic of indices and powers. In addition to the STEM practices addressed in the PL1 problem solving activities, there was a stronger emphasis of communicating and team work. Each student reported their 'findings' back to their groups. This time, the evaluation indicated that the students had a better understanding of the concepts, had greater ownership of their learning as a result of explaining the concepts to their peers, and were beginning to see links between the subjects.

In PL3, the teachers planned a series of learning activities that were constructively aligned: a mixture of small scale design challenges (such as designing, making and testing a paper plane), Mathematics problems drawn from real life relating to fractions, decimals and percentages (such as relating recipes to a shopping list), and critical thinking exercises (such as problems based on logistics—the efficient movement of people and goods). All activities matched the learning goals for the term, and also became practice exercises for the major common assessment task. The culmination was a STEM Expo, where small groups of students presented posters and other forms of communication to each other. The evaluation was run as a peer feed-

back opportunity, with pairs of students, one from Year 7 and the other from Year 8, visiting each 'booth' at the Expo and providing peer feedback via a teacher designed reflection sheet. The same STEM practices were addressed as for PL2, as well as the application of ideas to new contexts that was promoted through the STEM expo as students gave feedback to each other.

13.5.4 Discussion

Evident in the three cases, and School B, are commonalities and differences in the teaching strategies used and how the STEM subjects were included. All schools incorporated problem solving in one form or another. Other teaching strategies used included, for example, open ended investigations (School B), design challenges (Schools J, G and H), peer teaching (School H), jigsaw approach (Schools H and G), and group work (Schools J, G, H). Schools H and J developed different activities for each PL sequence, and demonstrated increasing sophistication in the complexity of the tasks and links between the subjects. School G also found that students were more successfully able to make links between the subjects, especially in the second iteration of their vehicle challenge, partly because the teachers were more aware of the need to make the links explicit for students.

Different teacher collaboration models are also illustrated across the four schools, with a Mathematics team (School B), a Mathematics-Science team who integrated Mathematics and Science (School H), a Mathematics-Science team who taught both subjects but separately (School J), and an interdisciplinary team of teachers who taught one of the subjects (School G). This variety illustrates that there are many ways to incorporate STEM into schools: both discipline-bound and integrated approaches to STEM can lead to effective learning outcomes; STEM curriculum and the STEM practices can be taught by a single teacher or a team of teachers; or STEM curriculum can be a substantial learning sequence based around inquiry, or contained activities.

This variety in responses to the STEM 'push' is measured by the needs of the schools, and they are reflected in the reasons the schools became involved in SSSP. All schools indicated an intention to focus on improving student engagement. At School B, for example, the intention was to respond to low engagement of the girls in Mathematics, especially at the senior level, therefore, enhancement of the Mathematics curriculum was the intended focus. At Schools G and H, a desire to improve students' ability to make links between different subjects was the driver to integrate the subjects. Also important at both schools was to bring 'real life' into the classroom, where, at School H this manifested as real life problems recognisable for students, and at School G, links with local companies brought the world of work into the classroom. At School J, the potential for STEM to inspire through student directed project work was regarded as a way to engage students; also, the teacher support provided through SSSP was a motivator to participate in SSSP as it was seen to attend to the lack of resources and teaching experience at the school.

The 2016 report¹ by an independent evaluator highlighted a number of factors that have been critical to the success of SSSP thus far. Three of these factors are outlined below.

13.5.4.1 Teacher Time Release

Teachers found that the most valuable aspect of the project is funding for teachers to have time for guided planning, both at school and during the professional learning days where there is cross-fertilization of ideas across schools. Time is needed for teachers to plan for and implement STEM learning, generate and analyse evaluative data, reflect on their learning, then collaborate with teachers to re-develop and develop new programmes. Time is needed to up-skill and recruit new teachers to these new directions and pedagogies. Time is also needed to embed, sustainably, a STEM focus into the curriculum, strategic plans and future directions of the school. For students, time is needed for them to learn, hone their skills, and re-consider their career aspirations; longitudinal data is required to capture changes in student subject choice and destination data.

13.5.4.2 STEM Expert Support

SSSP, particularly through the Project Officer, provides invaluable STEM expert support for teachers in the schools. As a STEM enthusiast, the Project Officer worked closely with many of the teachers to develop new curriculum, supported them in running some activities, and even prepared equipment. The schools used the Project Officer in this capacity to different extents, some often, others rarely, depending on the needs of the teachers and time they were devoting to developing new curriculum. The availability of the Project Officer was noted in the evaluator's report as being a key success factor. Support through the professional learning days was also noted by the evaluator as building teacher confidence and capacity to design and implement effective STEM programmes, and develop directions for the future of STEM in their school. In a number of cases, the sharing of projects resulted in schools adopting and adapting the ideas emerging from other schools, for example, the STEM Expo at School H had been inspired by a STEM Expo at School E involving children from the feeder primary schools.

Further, a number of teachers have taken on positions of responsibility in relation to STEM since starting the programme, and a number reported that they are being called on by school leadership to help shape the future of STEM in their school.

¹Teacher and program leader interview, meeting outcomes and project outputs were used by the evaluator as evidence.

13.5.4.3 STEM Academic Leadership

Deakin's involvement has been crucial, both in providing the supportive personnel and infrastructure, but also in setting a programme focussing on and documenting teacher and school change. STEM academic leadership is important for a number of reasons.

Academic leadership enables a research informed and co-ordinated approach to providing a common language around STEM and flexibility in responding to and meeting the respective needs of each school. It became evident during the reporting days that teachers were adopting the common language relating to the STEM practices and the different STEM pedagogies. The variety in how schools approached STEM and the different processes involved in reflecting on and re-developing or diversifying their projects illustrates the need for flexibility in professional learning for STEM teachers. While many other STEM initiatives focus on providing packaged STEM learning experiences for students, or raising teachers' awareness of and access to STEM activities and programmes, the SSSP Programme takes a flexible, school-directed approach to building an expectation of sustained, school-generated, evidence-based change. The evaluator noted that this flexibility remains a key strength of the programme, both in structure and execution; the negotiation between the teachers and the academic leads and Project Officer have been critical to this flexibility and can only occur where there are ongoing and trusting relationships that are built over time.

Academic leadership can be provided to schools for generating a body of evidence of the impact of the school-based initiatives. Documenting such evidence, as promoted by the *National STEM Education Strategy* (Education Council, 2015), can, for example: mobilise future buy-in from other teachers at the school, the school parent communities and other schools; attract the attention of governments/policy makers and funding bodies; and provide evidence to support career advancement for the participating teachers.

13.5.4.4 Challenges

One of the challenges that schools are still wrestling with is developing appropriate assessment practices. Schools have used a range of activities for assessment, such as student journals/portfolios, presentations, artefacts, and worksheets. However, the method and focus of assessment are still being developed by some schools, with tensions arising between: criterion based assessment versus descriptive assessment; a focus on disciplinary content versus STEM practices or inquiry processes; and a focus on reporting versus a focus on student engagement. Decisions made in response to these tensions have depended on whether the STEM programme is part of the mainstream subjects (such as part of Science, Technology or Mathematics units) or integrated across a number of units, or whether they are stand-alone STEM experiences. For example, School B uses learning intentions focussing on students'

ability to apply Mathematics concepts to real world problems, rather than explicitly assessing mathematical skills and conceptual understanding.

There are challenges, or ‘common barriers’ (Hackling, Murcia, West, & Anderson, 2014, p. 9), associated with school-industry collaborations when attempting to make links between school content and the world of work. School G’s partnerships with three local industries are a successful example of how schools can embed meaningful learning experiences in a way that connects the school project of building a vehicle with three relevant local industries—the local car testing facility, a high-end cycling manufacturer, and an aerospace manufacturer. One of the challenges that can arise, however, is that teachers and industry representatives often do not share a common language, and the language of industry may not be understandable for students. This can be alleviated when a teacher has some knowledge of the industry and can be selective in which industry practices are emphasised and inserted into the learning tasks, or if a ‘broker’ is engaged who understands both languages and can help to translate each partner’s needs and offerings. Other issues that can arise relate to the time needed for partners to undertake these negotiations, as well as carry out the activities such as through excursions or incursions. Hackling, Murcia, West, and Anderson (2014) found that submissions to their inquiry identified the following as potentially addressing barriers to establishing industry-school partnerships: ‘better co-ordination, administrative support, and working in partnership with education service providers who understand how schools work and have specialist curriculum knowledge’ (p. 9).

There are long-standing challenges around maintaining the integrity of the disciplines during curriculum integration (Rennie, Wallace, & Venville, 2012). There can be a tendency for one or two of the disciplines to be fore-fronted with Mathematics, and sometimes the Science, being used as tools instead of the disciplinary ideas being explicitly taught. Conceptual development can be compromised and sidelined in preference for other outcomes such as engagement, with creativity, design processes and construction being the focus of assessment. Key to maintaining the intellectual rigour of the STEM challenges and activities is being explicit about how the STEM practices and Science and Mathematics concepts are integrated into the unit or learning task. Mapping of curriculum (e.g., as was done by Schools H and G) can be important in explicating how the disciplines are realistically represented.

Another challenge is convincing school leadership, other teachers, students and even parents of the value of rethinking the curriculum to include STEM learning opportunities. To do this, evidence of change to student learning outcomes and student engagement can be fundamental to the ongoing acceptance and thus successful embeddedness and sustainability of STEM learning experiences in a school more accustomed to a traditional siloed approach to curriculum. Apart from the data gathered by the Deakin team, teachers are beginning to embed opportunities to gather data. While they have collected data from students during each sequence, they are developing more sophisticated tools to find out the effects of the programmes on student learning, engagement, and other variables considered important by the schools. Further support for teachers researching their practice is the focus of PL4.

13.6 Conclusion

State and federal education authorities have reacted to the STEM ‘push’ by initiating a range of policy changes culminating in the *National STEM School Education Strategy* (Education Council, 2015) that aims to: raise student STEM participation and achievement through increasing student aspirations; improve teacher capacity and quality; support within school systems; create partnerships with tertiary providers, business and industry; and build an evidence base. These aims are comprehensive and resonate with initiatives in other parts of the world, such as the European Community where attempts have been made to raise student STEM awareness, establish industry and school links, and build up STEM teaching skills (Scientix, 2014).

SSSP, too, meets these aims by supporting teacher learning through targeted intensive and ongoing support to develop inspiring and interesting STEM learning experiences, where traditional silo bound and textbook teaching approaches give way to problems from ‘real life’ and serious engagement with the world of work. Critical to the success of this programme was that it was longitudinal in nature with a combination of formal professional development with ongoing support, fostered was a community of teacher learners who were willing to share and take risks, the programme was designed from the outset to respond to teacher and school needs rather than as a ‘one-size-fits-all’ approach, and teachers were given time and space to reflect, plan and change beliefs and practice. Where previous large or medium scale interventions use professional development based on delivering specific programmes or practices, unique to SSSP has been the encouragement of schools to develop their own approach to conceptualising and implementing STEM that makes the best use of their resources. The outcome has been a wide variety of projects organised in schools in different ways. What holds the programme together has been a comprehensive discourse of STEM through the STEM Vision framework modelled during the PL intensives and by the programme team, and which over time helped the teachers to develop rich practices in their own particular ways and contexts.

The first step for any teacher or school in embracing STEM is to articulate what STEM is and needs to be for their particular context; the seemingly amorphous nature of STEM is both its power in being shaped to potentially provide a solution to some of the problems faced by schools (such as student disengagement), but also makes it difficult for teachers to navigate without guidance and support, hence the demand for professional development in this space. A common but flexible language around practices and pedagogies suitable for STEM education must be articulated and made explicit in this professional development if sustained teacher and school change is to be achieved.

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