STEM Professional Learning: Evaluating Secondary School Teachers’ and Students’ Experiences

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The four papers presented in this symposium report on the evaluation strategies and feedback from teachers as they embarked on designing and implementing STEM approaches to learning in secondary school contexts. The STEM professional learning program was designed to provide time and expert support so that cross-disciplinary school teams of up to six teachers from science, mathematics and technology/engineering could develop new school-based initiatives. A range of evaluation strategies were used in the first two STEM Academy programs to identify factors and approaches that supported teachers’ and students’ needs, and to further enhance the STEM Academy program. This symposium addresses ways in which the progressive evaluations have informed this change process.

Paper 1: Judy Anderson, The University of Sydney. *The STEM Teacher Enrichment Academy Approach*

Paper 2: Kathryn Holmes, Western Sydney University. *Evaluation of the First STEM Teacher Enrichment Academy*

Paper 3: Gaye Williams, Deakin University. *The Second STEM Teacher Enrichment Academy Evaluation: Teachers’ and Students’ Perspectives*

Paper 4: Debbie Tully, The University of Sydney. *Developing an Evaluation Framework for Future STEM Academies*

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The STEM Teacher Enrichment Academy Approach

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The STEM Teacher Enrichment Academy was developed to promote the STEM subjects in schools so that more students engage with, and consider pursuing a STEM-based career. Since teachers are key to student engagement and interest, a professional learning program for multi-disciplinary school teams was developed to support teachers in identifying and designing the most appropriate STEM approach for their students. Offered for the first time in 2014, the Academy has been implemented four times, reaching 260 secondary teachers from 47 schools. Feedback using a range of data collection tools has enabled the evolution of the program to better address school, teacher and student needs.

With a global decline in students enrolling in mathematics and science subjects at the senior secondary and tertiary levels (Kennedy, Lyons, & Quinn, 2014), and predictions that we will need many more mathematicians and scientists to meet workplace demands of STEM (Science, Technology, Engineering, and Mathematics) related professionals into the future (Office of the Chief Scientist, 2016), school systems and other stakeholders have embarked on developing new approaches to promoting STEM. To build on, and coordinate the range of reforms, a STEM Education Forum was held in Sydney in 2015 to develop a National STEM School Education Strategy, 2016-2026 (National Council, 2015). Driven by the two key goals of wanting all students to finish school with strong foundational STEM skills and capabilities, and ensuring all students want to embark on more challenging STEM subjects, the Strategy identified five key areas for national action:

1. increasing student STEM ability, engagement, participation and aspiration;
2. increasing teacher capacity and STEM teaching quality;
3. supporting STEM education opportunities within school systems;
4. facilitating effective partnerships with tertiary education providers, business and industry; and
5. building a strong evidence base.

It is noted in the Strategy that these key actions relate to both the individual STEM subjects as well as to any integrated approaches to STEM education.

While many factors influence student participation as measured through subject choice and subject engagement in secondary schooling, McPhan, Morony, Pegg, Cooksey and Lynch (2008) determined the lower participation of students in senior mathematics was particularly influenced by poor pedagogical practices, perceived level of difficulty, and irrelevance. Traditional approaches to teaching mathematics and science do not capture the multi-disciplinary nature of contemporary mathematics and science practices (Tytler, Symington, & Smith, 2011) and their connections to the systems thinking, design thinking, or computational thinking of engineering and technology (Bybee, 2013; English, 2016). Proponents of integrated STEM curriculum argue for its potential to increase student motivation and engagement (Beane, 1993); to enable students to transfer knowledge, make connections and see the relevance of the STEM subjects (English, 2016); to develop students' "STEM literacy" and their understanding of local and global challenges (Bybee, 2013); and to provide an impetus towards the further study of STEM subjects in senior schooling and STEM degrees at university (Freeman, Marginson, & Tytler, 2015).

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To date, there has been little research conducted into the efficacy of STEM subject integration in secondary classrooms (Bruder & Prescott, 2013), but there is some evidence to suggest that STEM integration is successful in increasing student engagement within mathematics classrooms (Venville, Wallace, Rennie, & Malone, 1998). Based on the assumption that students benefit from opportunities to connect knowledge across the curriculum, a professional learning approach was developed to support teachers in planning and implementing connected approaches in secondary schools. The design of the Academy program was informed by research into effective professional learning practices but with little research available about the best approaches to integrated STEM learning more generally, the program has evolved based on feedback from teachers' experiences.

The Initial Academy Design

In 2014, the Faculty of Education and Social Work collaborated with the Faculties of Science, and Engineering and Information Technology, to develop the initial program of teacher enrichment and professional development. The multi-day on campus program for up to 75 teachers (from 12 schools) of Year 7-10 mathematics, science and technology/engineering was designed to be foundational in enhancing teachers' knowledge of content and pedagogy, inspiring them to reinvigorate their classroom practice and improve student engagement in STEM subjects. The overall Academy aims were to:

- introduce and support exciting and effective approaches to learning, enhance teachers' knowledge of content and approaches to teaching mathematics, science and digital technologies in Years 7-10;
- develop a community of practice for participating STEM teachers, with ongoing support and engagement through mentoring, online forums, newsletters, seminars and events; and
- develop teachers' knowledge of STEM-related research and industry as well as knowledge of STEM programs at university and career pathways.

Modelled on commonly agreed core features, the Academy professional learning approach was developed to incorporate a content focus, active learning, coherence, duration and collective participation (Desimone, 2009). With a focus on examining content and processes from the STEM subjects, Academy sessions were facilitated by the University's academic specialists and STEM leaders, as well as teacher/peer-led sessions. The program involved a three-day on campus program at the University followed by up to two full school terms working on developing, planning and implementing STEM strategies in school-based teams. Teachers then returned for a further two-day program at the University to share their experiences, present evidence of teacher and student learning, discuss issues and challenges, and consider future initiatives. Each cross-disciplinary school team of two mathematics, two science and two technology teachers worked together to develop inquiry-based learning approaches to teaching both within their subject discipline as well as across the subject disciplines (Maaß & Artigue, 2013). Initially focusing on the individual STEM subjects was adopted because mathematics and science teachers made limited use of inquiry-based learning approaches in lessons that is recommended in curriculum documents and in research into meaningful learning (Sullivan, 2011; Tytler, 2007).

The First and Second Academies

For the first Academy, 64 teachers from 13 schools visited the University in November 2014 and returned in March 2015 (see Table 1 for sector representation) – schools were invited to participate based on engagement with the University. While most schools are Sydney based, four are clustered near Mudgee in the central West of NSW. This small country hub of schools enabled greater opportunity for collegiality, an essential ingredient given the small size of these schools with some teachers reporting feeling isolated and with limited access to quality professional learning. Like the first Academy, the second involved 70 teachers from 12 schools with a country hub of two larger schools from Wagga Wagga (see Table 1) and took place in November 2015 with a subsequent return to the University in May 2016. When selecting each group of schools, we sought diversity in school systems, socio-economic status, gender composition, and size to further expose teachers to the range of issues involved in curriculum redesign and promote community engagement.

Table 1
School Sector Representation for the First Two STEM Academies Including School Gender Composition

	Department of Education	Catholic	Independent	Total
2014/15	8 (1 all girls)	1	4 (2 all boys, 2 all girls)	13
2015/16	7 (1 all boys)	2 (1 all girls)	3 (1 all boys, 1 all girls)	12

While overall the feedback from teachers has been positive, the key challenges to be addressed based on the first two academies included implementing inquiry-based learning approaches in regular classrooms, understanding the connections between the separate STEM subjects, working effectively in school teams, designing a STEM strategy most suitable for school contexts, and building the community of practice. Further detail about the evaluations of each of these first two academies is presented in the second and third papers in this symposium.

Our experiences from both academies revealed some schools move more quickly to developing integrated STEM approaches because of experiences prior to academy participation of writing integrated units of work, and/or working together as a team. This highlighted the diversity of teachers' knowledge and experiences of integrated STEM before coming to the Academy and the influence this had on their progress within the Academy. Some teams were cohesive while others were dominated by one or two teachers who already had a plan which would be implemented regardless, while others had never worked together on creative programming and curriculum design. It became clear that we needed to conduct school audits of their STEM work as well as to consider teachers' experiences of working together before they arrived to participate in the program.

Team building and effective whole school planning have now become critical components of the Academy and these begin with each school before they attend the first session at the University. On site, preliminary planning meetings include the school principal and other school leaders who need to play a key role in supporting the development of STEM initiatives which frequently have implications for timetabling, teacher allocation to classes, alignment of STEM subjects on timetable lines, and resourcing. Schools have adopted a wide variety of approaches to implementing STEM education – frequently these decisions have been based on available personnel, teacher interest and resources but school structures can act as impediments to innovative practices.

Because the schools were so diverse, particularly in relation to teachers from different subjects working together, the approaches they initially adopted were equally disparate. From embedding more cross-curriculum applications within regular lessons to conducting cross-disciplinary investigations in several STEM subject lessons, schools adapted and designed their approaches around perceived student needs sometimes finding lateral ways to overcome constraints from school structures and resources. Our purposeful tolerance for such diversity acknowledges that schools need to consider the needs of their students, the competence and interest of teachers, the overwhelming influence of siloed assessment in many schools, and that real change takes time.

Building the community of practice has been a challenge. While on campus at the university, teachers willingly discussed ideas with teachers from other schools, and engaged in worthwhile sharing of ideas but the busyness of school life frequently meant little ongoing sharing in the online community. In some schools, finding time to meet as a school team was enough of a challenge and proved to be an inhibiting factor in moving plans forward. To alleviate some of these challenges, for schools to become STEM Academy participants, we had requested principals provide time for teachers to work on their projects. Unfortunately, this was not always achieved and some academy teachers have admitted this is as much they themselves not wanting to take time away from something else. Teachers being provided with school time to work on their projects, and accepting to do so remains another challenge to be addressed.

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Evaluation of the First STEM Teacher Enrichment Academy

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The initial STEM Teacher Enrichment Academy was held in 2014/2015 involving 64 teachers from 13 schools. The teachers attended two on-campus sessions which bookended their STEM work in schools supported by Academy mentors and online interactions using Edmodo. In survey responses, the teachers reported that the Academy had extended their pedagogical knowledge for engaging students in STEM and to a lesser extent their STEM content knowledge, however they all valued the networking opportunities afforded by the Academy. Despite their enthusiasm for implementing new STEM activities in their schools, teachers were significantly challenged by a lack of time to plan adequately.

The initial STEM Teacher Enrichment Academy (2014/2015) was designed to improve STEM teachers' capacity to plan and implement engaging STEM lessons for Years 7 to 10, provide opportunities for within and cross-school collaboration and to improve teachers' knowledge of STEM industries and tertiary STEM study options. The Academy pre-empted the National STEM School Education Strategy, 2016-2026 (National Council, 2015) but its goals were closely aligned with the five areas for action identified later in the Strategy. In this sense, the Academy has acted as a forerunner in providing leadership and direction for STEM teacher development in recent years.

Currently teachers and school systems are grappling with forecasts for new student skill sets requiring integrated models of curriculum development (ITL Research, 2011), particularly in the STEM areas where skill shortages are predicted. The National STEM School Education Strategy identifies the need for students to develop scientific, mathematical and technological literacy along with 21st century skills such as problem solving, critical analysis and creative thinking (National Council, 2015). These 'softer skills' are also embedded in the cross-curriculum capabilities identified in the Australian Curriculum (ACARA, 2015). The initial STEM Academy was designed with these advances in mind, aiming to prepare teachers to foster inquiry approaches to the teaching of STEM subjects so that students' interest in STEM and development of '21st century skills' could flourish.

The Initial STEM Academy Evaluation Design

The evaluation of the initial STEM Academy was designed as a mixed-method, survey and interview study. All teachers (n = 64) completed surveys during the on-campus sessions and a sample of volunteer teachers (n = 22) also participated in telephone interviews after the second on-campus session. The three Academy mentors also took part in a telephone interview at the end of the Academy.

The survey instrument was designed to provide a measure of teachers' existing pedagogical practices prior and subsequent to participating in the Academy. The survey items were derived from the Innovative Teaching and Learning survey instrument (ITL Research, 2011) which provides measures of teachers' propensity to use pedagogies focussed on real world problem solving and student collaboration. The teachers also responded to open-ended questions about how best to engage students in STEM. The mathematics teachers also completed an additional survey focussed on their beliefs about

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the discipline of mathematics and pedagogical approaches. After each on-campus session the teachers completed additional surveys asking them to rate the various components of the session and to reflect on the impact of the Academy in their schools

Evaluation Results

The Academy was attended by 64 teachers from 13 schools (24 mathematics, 23 science, and 17 technology). Approximately 60% of the teachers were female and the mean number of years of teaching experience was 17.9 years (*SD* = 9.4). The schools represented a range of school systems (eight government, four non-government, and one Catholic), primarily from the Sydney metropolitan area with only three provincial schools.

A key aim of the Academy was to increase teachers' capacity to engage students in STEM subjects in school. At the beginning of the first on campus session, teachers (n = 64) were asked to respond to the following open-ended question: What are the best ways for teachers to promote student engagement? Their responses emphasised the importance of focussing on real-life examples that are relevant to students' lives (n = 20), using hands-on activities and ICT where appropriate (n = 13), building a respectful, positive classroom environment (n = 9), facilitating an inquiry based approach to learning (n = 7), and student collaboration and group work (n = 7). Although the teachers emphasised the value of using real-life examples, few of the teachers indicated that they regularly planned for real-world connections in the classroom, such as allowing students to consult with experts outside of the school setting, involve parents or community members in school activities, listen to guest speakers or produce something for use outside of the classroom. Therefore, prior to the Academy, despite many teachers acknowledging the value of real-world problem solving as a means of engaging students, it seemed that few teachers actively planned for real-word interactions in their classrooms. Teachers were more likely to plan for student collaboration in the classroom, however, the mathematics teachers were less likely to do so in comparison to the science and technology teachers.

When teachers were asked about the value of the various components of the Academy program they consistently responded that they felt that they had extended their knowledge of pedagogical approaches for teaching STEM and were excited and enthusiastic about trialling their new teaching approaches with their students back in their schools. They were less positive about the degree to which their knowledge of STEM content had increased. They greatly valued the networking opportunities with other teachers and tended to value the collaborative on-campus sessions more highly than plenary/guest speaker sessions.

> I think from talking to the teachers at other schools and getting ideas and sharing ideas and just that was just really the best thing. There were things I came away with or things I could help people with that you know, it would take a lot of time of your own to be able to achieve. (Science Teacher, Non-government school)

While the teachers were in their schools in between the two on-campus sessions they were visited by an Academy mentor and invited to participate in an online community via the Edmodo platform. The mathematics (7.6/10) and technology teachers (7.4/10) valued their interactions with their mentors more highly than the science teachers (5.6/10), perhaps reflecting the degree to which a successful mentor/mentee relationship depends on the personnel involved. The teachers appreciated the outsider expertise, a sounding board, confirmation, insight and advice, although there were a noteworthy number indicating that they didn't really need a mentor, all from schools fitting a higher SES school category. In contrast, there was a substantial number who indicated that they would have appreciated more visits or contact with their mentor. Many of these schools were from the lower SES spectrum of schools. When interviewed the mentors emphasised the importance of timely visits to schools and the importance of school support for teachers as they planned and implemented their STEM activities.

> So the fact that you do have mentors is a massive plus in the program. I'm just wondering as we go forward, do we actually need more mentors so that perhaps a contact could be a little bit more consistent or a little bit more often, and whether or not it's the actual teachers who've been involved in this first round –could see how that would be a great advantage if that could happen down the track." (STEM Teacher, Catholic School)

An Edmodo site was established to facilitate communication and resource sharing amongst STEM Academy participants. Forty teachers replied in the survey that they had used the site, but of those teachers only 10 replied that they had used the site frequently. Thirteen teachers reported that they did not use the Edmodo site at all. Teachers who used the site regularly did so because of the great resources being shared. Those that didn't use the site, or who used it infrequently, said in the survey that a lack of time was the main reason for not doing so and some experienced problems navigating to the group pages within Edmodo.

> That really made me realise how important it is to keep in contact with other maths teachers and the Edmodo page that the STEM Academy came up with is great and I've actually joined other Edmodo pages for maths teachers as a way of – I guess being isolated, that's one way that I can keep in contact with other maths teachers and share ideas and things like that (Mathematics Teacher, Government school).

After the second on campus session the teachers were asked for their reflections on the Academy in terms of the impact within their schools. On the positive side, the teachers said that there was improved student engagement, more use of interdisciplinary projects (although not in mathematics), and increased enjoyment of mathematics, particularly for girls, possibly due to the use of more challenging problems. When asked about the challenges they encountered, overwhelmingly the teachers cited the lack of time that they had for planning, the difficulty in involving other staff in their schools, lack of resourcing for new equipment and in some cases, a perceived lack of support from senior staff in their schools.

> The students were engaged before, but I think that they are engaged in a slightly different way because I'm asking the questions, the students are wanting to find the answers. Instead of just wanting to be successful, they want to find an answer, so I think there is a slight difference there in just that whole thing. I think that enquiry process is starting to take hold, if you know what I mean (Science Teacher, Non-government school).

Conclusion

Overall, the first STEM Teacher Enrichment Academy was positively received by the participant teachers. However, based on the evaluation conducted several recommendations were made:

1. to plan for more time in interdisciplinary groups working on real world problem tasks;
2. to include more planning time within the residential schedule so that teachers would be more prepared to implement STEM activities in their schools;
3. to reconsider the use of Edmodo to encourage teachers to use the site more frequently and to view the site as a rich source of resources for sharing;
4. to expand the use of mentors within the Academy to ensure that teachers can access this expertise in a timely manner;

5. to provide teachers with strategies for including and enthusing other staff in their schools to use the STEM activities; and
6. to target disadvantaged and/or isolated schools, where possible, as these teachers appeared to gain the most benefit from the Academy.

On the basis of the recommendations from the evaluation, several changes were implemented to better support teachers learning and to enhance the learning experiences of students. The Expression of Interest template for the second Academy required schools to nominate a STEM Leader who would manage team meetings, encourage teachers to use Edmodo for sharing experiences, support teachers to consider using the Academy experience for accreditation requirements, and to coordinate the STEM school team's presentation and final report to the Academy. In addition, after schools were selected, each school site was visited by a member of the Academy team to meet members of the STEM team as well as school Executive members to ensure all were clear about Academy requirements before the program began. They were encouraged to pre-plan before coming to the first on-campus session by examining each subject area's scope and sequence, identifying common content and processes, comparing assessment requirements, and considering when and how they would develop a cross-disciplinary approach to STEM teaching and learning.

During the on-campus session, schools were provided with more time to work in school teams to develop cross-disciplinary programs, mentors played an active role in working with the school teams and then visiting each school during the two on-campus sessions. Some schools from the first Academy were also invited to attend the second Academy to share their experiences and provide feedback on early plans. This approach extended the network of STEM schools and helped to build the community of practice. One of the challenges remaining in the Academy program is to consider ways to sustain the early STEM work in each school and to scale the approach to more teachers in each of the subject areas.

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The Second STEM Teacher Enrichment Academy Evaluation: Teachers' and Students' Perspectives

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This paper briefly describes the aims and research design for the 2015-2016 STEM Teacher Enrichment Academy Evaluation and gives detail about the research design for the case study reported herein. A subset of findings from the case study school, developed through analysis of student and teacher interviews, is reported to highlight STEM program strengths and how the Academy was perceived as contributing to what was achieved. Student interviews showed the development or strengthening of STEM students' career aspirations.

The underlying intentions of STEM education are to engage students in STEM subjects, so they develop deep understandings, and draw flexibly on what they know when exploring unfamiliar situations (Freeman, Marginson, & Tytler, 2015). The Melbourne Declaration of Educational Goals for Young Australians (Ministerial Council on Education, Employment, Training and Youth Affairs, 2008) shares these goals: "Successful Learners… are creative, innovative and resourceful, and are able to solve problems in ways that draw upon a range of learning areas and disciplines" (p. 8). As Anderson (Paper 1 in this symposium) states, we need to know more about effects of interdisciplinary STEM education on outcomes for students. The findings reported herein from the STEM Teacher Enrichment Academy Evaluation 2015-2016 (undertaken by Tytler and Williams, Deakin University) add to the body of knowledge on how interdisciplinary STEM Education might influence the potential for STEM career aspirations of students.

Foci of the Evaluation

The second STEM Academy Evaluation was designed to find out more about how the STEM Academy experience: (a) led to changes in pedagogical practices, (b) supported the design and implementation of interdisciplinary projects, (c) encouraged collaboration between teachers in STEM disciplines within and beyond the school, and (d) influenced student engagement with STEM subjects. This paper focuses within that evaluation on: "What influences does the model of interdisciplinary STEM education, as developed and implemented in the case study reported, have on student engagement in STEM subjects?"

Research Design Elements

Design of the evaluation. Data for the broader study included document analyses, survey and questionnaire responses, field notes including photos, and interviews with various stakeholders. Both the Component Mapping teacher survey and the Change in Teacher Practices Questionnaire (administered after each of the two workshops) informed probing in interviews and foci of attention for STEM class observation. The survey (Tytler et al., 2004) and the questionnaire (Williams, 2000) were refined from research tools previously developed by evaluation team members. The survey captures where teachers perceive they lay along various evidence based spectra of high quality pedagogical practices. The Change in Teacher Practices Questionnaire was adapted from a

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questionnaire on student learning change during problem solving employed previously by Williams (e.g., Williams, 2000)). Teachers were asked to identify what they had learnt from Academy participation, and what had influenced that learning. This questionnaire and interviews with teachers and students provided opportunities for them to identify what they attended to in STEM Ed in the school rather than only respond to researcher identified elements.

Case study design. The case study design as implemented included observations of STEM Ed activity (in STEM-Tech and STEM-Maths classes), and interviews with various school community members: a) school leaders directly involved in supporting STEM initiatives; b) Academy teachers (which included school leaders); and c) six students from STEM classes (three boys, three girls) who were identified by the teachers as demonstrating engagement with STEM subjects. Engagement was also identified through teacher and student interviews, and observed body language in interviews and classroom observations through focus of attention, body direction, lack of awareness of activity external to their focus, connecting to the ideas of others, and exclamations (EyDUPLEx Framework: Williams, 2003). The interviews included probes about what had influenced new learning that occurred. This helped identify links between engagement and creative STEM activity.

STEM-ED

The school's Year 7/8 STEM program (STEM Ed) commenced two years prior to Academy participation. It was funded by the supportive principal who had faith in the primary STEM-ED instigator (now Vice Principal: VP), who developed the program in conjunction with the heads of technology and science. The team perceived benefits from joining the Academy: feelings of increased obligation (thus motivation) to succeed because they were given this opportunity, increased confidence that the innovation was worthwhile because the Academy selected them, access to a network of schools with similar interests and challenges through the Academy, raised STEM education profile at school (which encouraged more teachers to commit to STEM), valuable PD for staff, and additional time for team planning.

Given timetable and resource constraints in this small school, STEM-ED was located in the classes of each discipline, renamed STEM-Tech, STEM-Science, and STEM-Maths. Activity undertaken in these classes was interdisciplinary. For example, during data collection for the case study, the Year 7/8 STEM-Ed group were undertaking a multi-disciplinary project on Space, and Rockets. Each of STEM-Tech, STEM-Science, and STEM-Maths focused within this topic in ways that interconnected the STEM subjects.

STEM-Tech groups of three or four built rockets to launch to test their capacity. The teacher posed questions rather than gave answers when students struggled to find ways to proceed. Student 1's (S1's) eyes lit up and his voice became animated (demonstrating engagement with STEM-Ed) as he described this program: "It's more open [than other subjects] ... you got to think out ways to do it for yourself rather than be taught a certain way by the teacher". A rocket design sketch (with design features justified), and rocket construction are shown (Figure 1, left and right, respectively). Learning included: "centre of mass and ... thrust need to align so rocket does not tip ... wings need to be down low as stabilisers" (S1).

STEM-Science students tested materials to help make decisions about what materials to use for their rocket: "We were testing how fire-resistant leather was – put leather over a Bunsen burner and it shrivelled up still intact" [S3]. They also studied the Solar System.

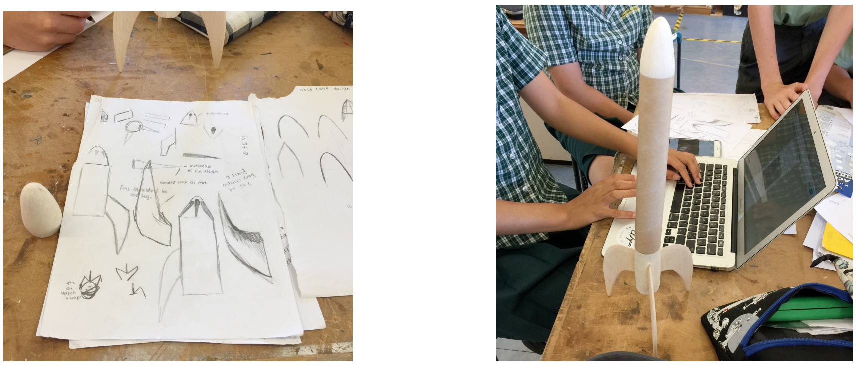

Figure 1. STEM-Tech design of one student group and rocket assembly of another group.

STEM-Maths students in groups of four, allocated group roles. They made a calendar for Mars using conversions from Earth to Mars time. The teacher stimulated class discussion by raising questions from these discussions, for students to discuss and resolve.

> The number of months were completely up for grabs for a start- we talked about that and well okay Mars has how many moons ... [and] does Mars have seasons and what are seasons and do they occur on every planet and we found that Mars does have solstices and equinoxes but they do not quarter the year as ours do ... it was a class conversation I ran and there were times where I spotted the questions to ask and they discussed and ran with that. [Teacher of Class, Vice Principal]

Group roles included a "think big" group member who selected a focus to explore beyond the core requirements of the project. S1 decided to explore Mars leap years.

Design Thinking Embedded in STEM-ED

All six students drew attention to autonomy enabled in STEM-Ed and the focus on learning for a purpose rather than just learning for assessment. Learning in STEM-ED was described in various ways: "Compared to learning in other classrooms this [STEM-ED] tries to use your brain more, it challenges you more" [S2]. 'Using what is learnt rather than just learning it' was a common comment made:

> I just like the whole STEM program because you don't just get to learn stuff in the classroom and not do anything with it- in STEM you learn information but then you get to put it into a practical use in Tech [S6]

The STEM-ED team devoted time and energy to familiarising other teachers with Design Thinking. Student comments showed Design Thinking was embedded in STEM-ED. They either made explicit references to it or described the process in activity reported:

> liked the immersion ... how you do things ... the design where you get told everything then do two designs on paper if possible a scale and then pick one of them and that usually takes most of the time ... then testing and readjusting (S4: female student)

S6 captures the cyclical nature of the process: trying to solve a problem within certain constraints, testing products to work out how to proceed in environmentally friendly ways:

> we are given like strict materials that we can use ... it helps us to think about 'how to use this in a productive way like an *effective* way so that we don't *waste* any materials but ... if it doesn't work we try not to use more materials but if we have to use more materials then we will but we are trying to make it as effective as we can

The design process appeared crucial to changed aspirations of students not previously considering STEM careers.

STEM Career Aspirations

This different way of learning shifted the career aspirations of the three girls. The boys and one girl (S6) were already interested in at least one STEM discipline at the start of secondary school. S6 was interested in Science, but her greater interest was English at the start of secondary school. The boys displayed their interest through their voices becoming more intense and their faces more animated as they discussed various STEM-ED activities. STEM-ED changed the career aspirations of all students interviewed with each of them shifting more towards pursuing STEM careers, For example, S4:

> "[In primary school, I preferred] Art [as] more creative but ... now with science not so right and wrong ... more like creativity ... I like Art still ... but Sci and Tech I like ... now and careers in that area."

S6 who wanted to be a teacher or missionary nurse included engineering as an aspiration after the excursion to the university drew her attention to engineers helping others:

> I wasn't really thinking about being an engineer in primary school but then when we had the STEM-ED camp ... visit[ed] the university and we got to see ... different engineers and what projects they do ... it really like *inspired* me because it ... showed me that we don't just learn this stuff in school- and then not use it in real life- you can ... use the information you have learnt ... to make a *difference*

Concluding Comments

This study shows that this interdisciplinary STEM education model that physically located classes in each discipline, while employing interdisciplinary projects that emphasised design thinking, achieved student outcomes consistent with the broader STEM agenda. The processes employed increased/strengthened STEM career aspirations for both boys and for girls. Creative opportunities involving design thinking (S4, S5) and raised awareness that engineering can involve helping others (S6) influenced these changes. The University of Sydney STEM Teacher Enrichment Academy contributed to team opportunities to achieve these changes by affirming the directions the team were taking, raising the STEM school profile, and resourcing the project. Preliminary outcomes for students interviewed indicate that selection by the Academy and the way teachers have used this opportunity has raised student awareness of STEM and stimulated interest in it. The team look forward to finding which senior secondary subjects STEM-ED students will select.

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Developing an Evaluation Framework for Future STEM Academies

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Building upon prior evaluations, a comprehensive evaluation plan for the STEM Teacher Enrichment Academy at the University of Sydney is currently being devised and will consider the multiple perspectives of teachers, students and school leaders, and the interplay between these key stakeholders as it affects program outcomes. Additionally, effects of parents and industry partners will also be examined. The evaluation will follow a mixed-methods protocol with the additional collection of pertinent school-level data of all participating schools. Evaluation results will not only prove beneficial in shaping future academies but will also add to the literature in this growing field of academic research.

The evaluations conducted as part of the first and second STEM Teacher Enrichment Academies offered key formative assessment data that proved useful in improving the structure and content of the academy as seen through the lens of the academy participants. As we move forward in developing an evaluation framework for future academies, our focus will become more outward with the aim of evaluating not only the initial objectives of the academy but also keys goals as outlined by the National STEM School Education Strategy (National Council, 2015).

The professional development offered through the STEM Teacher Enrichment Academy endeavours to increase teachers' pedagogical content expertise through guiding teams of teachers in their development and delivery of integrated STEM units of study within each of their schools. While it is anticipated that this approach would inspire teachers to expand their own personal interests in STEM, for some teachers this team-styled approach towards creating and disseminating integrated STEM content in their classrooms may be a novel experience affecting their personal beliefs towards teaching, as well as their understanding and knowledge towards their subject area. The literature is replete with examples of how teacher beliefs and self-efficacy significantly impact student learning and achievement, and we assume likewise in our evaluation (Tschannen-Moran & Barr, 2004).

As the need for an expanded STEM workforce grows, the role that teachers play towards encouraging students to pursue STEM fields of study appears critical. In building an evaluation model, emphasis will be given not only to teachers' perceptions of their own capabilities and beliefs both individually and collectively, but also towards their capacity in affecting students' interests, motivation, 21st century learning and future career choices in STEM (Betz & Hackett, 1986; Dick & Rallis, 1991; DuFour & DuFour, 2010).

One of the major outcomes envisioned of the STEM Teacher Enrichment Academy is an eventual interest and increase in student participation in STEM occupations. Accordingly, an assumed pathway towards that goal is increased student engagement with senior school mathematics, science and technology subjects. The attitudes students possess towards STEM are a significant factor in not only influencing future STEM subject choice but also in students' pursuit of STEM related careers (Maltese & Tai, 2011), and as such become an important area for examination in our evaluation plan.

Additionally, school principals are appropriately considered as drivers who may influence the effectiveness of professional development programs aimed at student success and teacher growth in STEM education (Prinseley & Johnston, 2015). Without the advocacy, vision and leadership of principals in STEM curricular efforts, the impact of the

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STEM Teacher Enrichment Academy's professional development program in any one school may be short-lived. The academy aims to provide teachers with the tools, resources and knowledge to affect positive change in their classroom teaching through encouraging collaborative hands-on STEM learning in a "real-world" context. Yet, the leadership, condition and culture within each particular school context may also influence the eventual outcomes of this STEM focused professional development program. Therefore, when evaluating the program effectiveness of the STEM Teacher Enrichment Academy it seems essential to consider and understand the multiple perspectives of teachers, students and school leaders, and the interplay between these key stakeholders as it affects program outcomes.

Designing an Evaluation Framework for the STEM Teacher Enrichment Academy

Integrated STEM teaching and learning is a new endeavour for many Australian schools, and as such their effects are under-researched. While the quality and scope of STEM education evaluation schemas varies widely (Brody, 2006), the conclusions drawn by Bryk and his fellow researchers (2010) offer a concise reflection on the multiple factors considered as pivotal in successful science and mathematics educational programs: (a) school leadership as an impetus for change, (b) professional capacity of faculty through engagement with professional development, changes in values and beliefs, and the ability for collaboration amongst faculty, (c) outreach that strengthens the ties between parents, community, academic institutions and industry, (d) student-centred learning environments, and (e) instructional guidance that advances learning. In addition to these attributes, two specific STEM evaluation models with both theoretical and systems-based approaches, offer beneficial insight as we devise our own evaluative strategies (Arshvansky et al., 2014; Saxton et al., 2013).

Our specific evaluation plan for the STEM Teacher Enrichment Academy is designed as a mixed-methods protocol, with both survey and interview components, and will measure outcomes for principals/school leaders, teachers and students based on key program objectives. Additionally, effects of parents and industry partners will also be examined (see Figure 1).

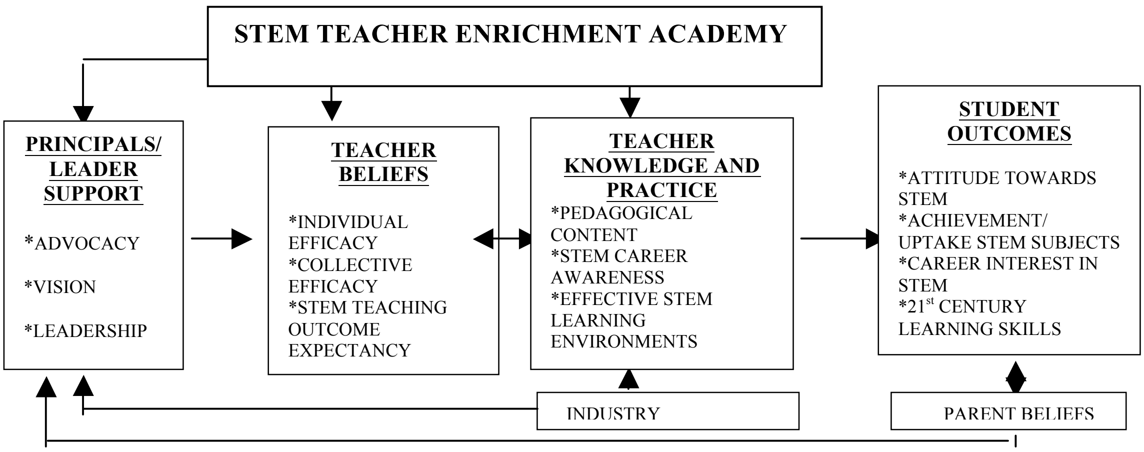

Figure 1. STEM Teacher Enrichment Academy comprehensive evaluation model.

Principals/School Leaders. The survey items designed to measure the advocacy, vision and leadership of school principals are derived from the P-STEM survey instrument which specifically measures the leadership offered by school principals towards STEM education within their specific school contexts (Friday Institute for Educational Innovation, 2014). Using a 5-point Likert scale, principals indicate their response to items such as, "Regarding the STEM work at my school, I… enable collaboration of teachers across content areas…. ensure technical support/other resources are available for STEM teaching…maintain strategic partnerships with STEM industries". Reliability testing has produced a Cronbach's alpha above 0.90 for this instrument. The 37-item survey will be administered to principals prior to their school's enrolment in the Academy and one year after their school's participation, and will also serve as a formative reflection for principals. Additionally, principals will be interviewed to capture a more nuanced understanding of the specific adaptive STEM culture within their schools, and their partnerships with STEM specific industries.

Teachers. The teacher questionnaire will consist of items from the T-STEM survey instrument (Friday Institute for Educational Innovation, 2012b) and the Collective Teacher Efficacy Measure (Goddard, Hoy, & Hoy, 2000). The T-STEM survey assesses teachers' personal STEM teaching efficacy beliefs, STEM teaching outcome expectancy beliefs, reflection on STEM instruction, 21st century learning attitudes, teacher leadership attitudes and STEM career awareness. Reliability testing on each of these scales has produced Cronbach's alphas ranging from 0.814 to 0.948. The Collective Teacher Efficacy Measure is comprised of four subscales that assess group competence and task analysis. The survey will also contain four reflective open-ended prompts. The teacher questionnaire will be administered during the on-campus components of the academy and one year post-academy participation. Additionally, teachers will be interviewed at the conclusion of their school's involvement with the academy to probe the STEM initiatives in their school, their perceptions of the impact of the STEM Teacher Enrichment Academy, adjustments made to their school's curriculum to accommodate STEM teaching and learning, their involvement with communities of practice, partnerships with industry, and efforts to sustain STEM initiatives in their schools.

Students. A student questionnaire will be devised of items from the S-STEM survey (Friday Institute for Educational Innovation, 2012a) and the STEM Semantics survey (Tyler-Wood, Knezek, & Christensen, 2010). The S-STEM survey measures student attitudes in mathematics, science and technology, future career interest, self-assessment of current achievement across STEM subjects, future projected STEM subject uptake and 21st century skills. CFA Goodness of Fit Indices and Cronbach's alphas indicate a high level of validity and reliability of this instrument. The STEM Semantics survey assesses student perceptions and attitudes towards each of the separate STEM disciplines in which students indicate on a scale of 1 to 7, for example, their opinion of science as fascinating (1) to mundane (7). Surveys will be administered to students prior to and after their engagement with integrated STEM teaching and learning.

Parents. Parents are certainly influential in their children's career selection, particularly for students choosing an engineering or science pathway (Dick & Rallis, 1991). The STEM-CAT survey (White, 2015) will assess parents' beliefs about STEM education, their values towards STEM education and their perception of the resources that their child's school offers in STEM education.

School Level Data. As the numbers of schools and educators who participate in the STEM Teacher Enrichment Academy grows, so does the need to create a database in order to track the long-term impact of student and teacher engagement with integrated STEM teaching and learning. Data to be collected will include school level data such as demographics of student body, school affiliation, offerings and enrolments in STEM subjects, and faculty level data.

The data collected as part of the STEM Teacher Enrichment Academy evaluation plan will allow us to assess both short and long-term effects of the academy. Principal, teacher and student surveys will be administered both pre-test and post-test allowing for comparison through repeated measures statistical testing. Further inferential testing may reveal connections across the participant data. Interviews will further elucidate quantitative findings. The data gathered through the STEM Teacher Enrichment Academy evaluation will not only prove beneficial in shaping future academies but will also add to the literature in this growing field of academic research.

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