The STEM Teacher Enrichment Academy: Evaluating teachers' approaches to implementing STEM education in secondary school contexts

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Abstract

Amidst calls for a greater focus on STEM education in schools, attention is inevitably drawn to the quality of teaching and to appropriate means of supporting the teaching workforce so that more young people are engaged and interested in STEM subjects. This presentation describes the development and implementation of a STEM Teacher Enrichment Academy at the University of Sydney, and presents some of the outcomes from teachers' efforts to implement STEM education across a variety of school systems. The findings draw on survey and interview data from two cohorts of participant teachers and their STEM mentors as they progressed through the Academy program. One of our goals was to establish a professional learning community for enhancing STEM teaching in schools. We had mixed success, but each new Academy program builds on findings from earlier efforts so that we develop teachers' capacity to design and implement STEM curriculum to meet the needs of their students.

Currently, there is a global decline in students enrolling in mathematics and science subjects at the senior secondary and tertiary levels (Kennedy, Lyons & Quinn, 2014). In New South Wales, there has been a 13 per cent decline since 2001 in students electing to take a calculus-based mathematics course (Mack & Walsh, 2014; MANSW, 2014). Similar patterns occur with physics and chemistry, computing science, and engineering subjects in the senior secondary years. Research suggests that students who choose not to take a calculus-based course in senior years are less likely to succeed in mathematics and science programs at the tertiary level (McPhan et al., 2008). Associated with these trends is a decline in the number of mathematicians and scientists in the workforce, and predictions that we will need many more to meet workplace demands of STEM (science, technology, engineering and mathematics) professionals into the future (Office of the Chief Scientist, 2016).

There are many factors influencing subject choice and subject engagement in secondary schooling. Of the four main factors in the lower participation of students in senior mathematics identified by McPhan et al. (2008), pedagogical practices, perceived level of difficulty, and relevance are key. One strategy to counteract these issues suggests mathematics should be taught using rich tasks that develop problem-solving skills related to real-life contexts, allowing students to see the relevance of the content they are learning. Others have identified the influence of maximising ATAR scores (MANSW, 2014), as well as a lack of understanding of the importance of 'assumed knowledge' when embarking on tertiary studies in the mathematical sciences (King & Cattlin, 2015). Some of these factors are difficult to address, but one approach to promoting relevance and engagement is through subject integration in Years 7 to 10 (Bybee, 2013).

Integrating the STEM subjects forges connections and highlights real-world applications (Vasquez, Sneider & Comer, 2013). Integrated learning can be implemented in classrooms in a multitude of ways; by drawing connections to other subject domains, or by adopting a multidisciplinary approach, where teachers from two or more of the STEM subjects design integrated tasks, lessons or units of work so that students have a synthesised, integrated approach to learning STEM content. To date, there has been little research conducted into the efficacy of STEM integration and application in secondary classrooms (Bruder & Prescott, 2013; English, 2016), but there is some evidence to suggest that STEM integration is successful in increasing student engagement within mathematics classrooms (Stohlmann, Moore & Roehrig 2012; 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. This paper presents early findings from the professional learning of two cohorts of teachers.

The STEM Teacher Enrichment Academy: Setting the context

Since 2014, the Faculty of Education and Social Work has been collaborating with the faculties of Science, and Engineering and Information Technology, to build the nation's STEM capacity through teacher enrichment and professional development with the establishment of the STEM Teacher Enrichment Academy. The academy's flagship is a multi-day residential program for up to 70 teachers of Years 7 to 10 mathematics, science and technology 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 to 10 of the Australian Curriculum for NSW
- develop a community of practice for participating STEM teachers, with ongoing support and engagement through mentoring, online forums, newsletters, seminars and events
- develop teachers' knowledge of STEM-related research and industry as well as knowledge of STEM programs at university and in career pathways.

Modelled on commonly agreed core features, the Academy professional learning approach incorporated 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 residential 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).

A unique feature of the STEM Teacher Enrichment Academy is its mentoring and support provision.

Table 1 School sector representation for the first two STEM Academies including school gender composition

	Department of Education	Catholic Systemic	Independent	Total
2014/15	8 (1 female)	1	4 (2 male, 2 female)	13
2015/16	7 (1 male)	2 (1 female)	3 (1 male, 1 female)	12

Throughout the Academy, professional mentors worked with participating teachers in their schools, providing support and assistance to plan and implement STEM strategies. Mentors visited participating teachers prior to, during, and in-between the two workshop sessions. An online platform was used to facilitate continuing discussion and sharing of resources between teachers across schools. This community of practice developed through interactions in the online community, information updates about STEM initiatives via a newsletter, and STEM one-day conferences to further facilitate sharing of approaches and resources from the wider community of schools in NSW.

Outcomes and recommendations from the STEM Academies

For the first Academy, 60 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 were based in Sydney, four were 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. Similar to 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 socio-economic status, gender composition, and size, to promote sharing and to provide a diversity of experiences.

While overall the feedback from teachers has been positive, the key issues 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 particular school contexts, and building the community of practice.

An external evaluation of the program revealed the features most supportive of teachers' STEM efforts included the provision of planning time, mentor input, and the structure and content of the program, which began with a focus on the separate subjects, allowing teachers to develop new skills and pedagogical strategies before exploring cross-disciplinary approaches. Focusing on the individual STEM subjects was adopted because mathematics and science teachers make more limited use of inquiry-based learning approaches in lessons than is recommended in curriculum documents and in research into meaningful learning (Anderson, 2005; Barron & Darling-Hammond, 2008).

However, teachers requested more examples of STEM integration, including sample tasks, projects and lessons – interestingly, when we did provide such examples, it was not always evident to teachers how they might use them and how the tasks connected with syllabus requirements. Indeed, there appears to be a need to make the connections between the STEM subjects more transparent for teachers (English, 2016), particularly when they are presented with already-prepared multidisciplinary tasks. These observations further highlighted the siloed nature of secondary school teaching, with teachers being most comfortable with their subject specialisation; to adopt a STEM curriculum perspective, teachers require horizontal expertise and they need to 'boundary cross – stepping into unfamiliar domains' (Clarke, 2014). Clarke also recommends that we need to construct STEM education around practices which could include discourse, artefacts, reasoning and evidence. Such an approach might help to address the issues associated with inconsistency in language as highlighted by English (2016), although some have addressed this by focusing on the engineering design process or systems thinking (Bybee, 2013).

Our experiences from both academies revealed some schools moved more quickly to developing integrated STEM approaches because of earlier experiences of writing integrated units of work, and working together as a team. This highlighted the diversity of teachers' knowledge and experiences of integrated STEM before coming to the Academy. It was clear that we needed to conduct school audits of their STEM work as well as take into account teachers' experiences of working

together as a team. Some teams were cohesive and had already worked on projects together; others were dominated by one or two teachers who already had a plan that would be implemented regardless, while others had never worked together on creative programming and curriculum design.

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. 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 particular 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 diverse. Some of the approaches used by Academy schools have included:

1. embedding more cross-curriculum applications within regular lessons (for example, exploring half-life in mathematics lessons and using virtual worlds in science to collect data to model and investigate real-world ecological problems)
2. conducting cross-disciplinary investigations in several STEM subject lessons to design solutions to problems (for example, improving the recycling system at the school, designing a new grandstand for the school football field)
3. undertaking an extended investigation over several weeks or school terms to design an artefact (for example, a plan for an energy efficient home for the school principal on a nearby plot of land)
4. redesigning the STEM curriculum program for a whole-year group around themes or big ideas (for example, mission to another planet, human diseases and prosthetics, better parks and gardens)
5. creating a STEM elective for Year 9 and 10 students
6. inviting STEM speakers to the school to share their experiences.

While this list may appear to be a rather eclectic set of approaches without any real cohesion, it recognises and accepts that schools are at different places in designing integrated curriculum and in embracing substantial change to curriculum design and delivery. Our acceptance of 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 the fact that real change takes time.

Building the community of practice has been a challenge. While on campus, teachers willingly discussed ideas with teachers from other schools, and engaged in worthwhile sharing of ideas, but the busyness of work back at school 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. For schools to become STEM Academy participants, we had requested principals provide time for teachers to work on their projects, but this was not always achieved and remains another challenge to be addressed.

Future STEM Academy programs

There has been considerable interest in the program across NSW and Australia, so there is clearly a role for such an academy in supporting schools in implementing integrated STEM approaches. Our next program will have a similar number of schools from NSW, including another regional hub, but we will also be expanding to include a country-based program. We also plan to track students as they move through their secondary school to gather data about the efficacy of the program in relation to promoting the study of the STEM disciplines in senior school and beyond.

There is also a need to consider developing a STEM program for primary school teachers, as many are not confident teaching mathematics and science in the upper grades of primary school. We have evidence that some students enter secondary school already expressing anxiety and disengagement in mathematics and science. This needs to be addressed if we are to improve engagement in the STEM disciplines across all of the secondary school years.

Finally, Williams (2009, p. 31) cautions:

> The problem for educators here is that the consequent absence of a sound educational rationale for this combination of subjects inhibits its development. There needs to be a reason for integrating these subjects which relates to quality learning outcomes for students. As an educator, it is not difficult to be attracted by the logic and research that an integrated curriculum approach would be more appropriate for secondary schooling than a discipline silo approach in that it is more reflective of the society for which students are being prepared.

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