

Getting on Board with the STEM Revolution: Two Christian schools' experiences

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Abstract

This paper reports on an initial investigation into teachers' perceptions of the process of introducing the integrated teaching of science, technology, engineering and mathematics (STEM) using a cooperative and problem solving approach. The study was conducted at two independent schools in New South Wales and will be ongoing. The initial results indicate that while there has been a positive attitude to the introduction of STEM into the two schools, there is perceived to be a need for additional professional development that will lead to greater teacher confidence, improved attitudes, wider knowledge of the importance of STEM, and more extensive teamwork. There was also found to be a discrepancy in the perceptions of primary and secondary teachers largely due to the structure of the timetable and the disjointed nature of the key learning areas.

Introduction

STEM is an acronym for Science, Technology, Engineering and Mathematics. The push for the teaching of these subjects in schools in an integrated fashion in Australia is following an international

trend in education. The future of employment in the western world is predicted to be 'technology heavy', with many of the current employment opportunities for school leavers disappearing, it is therefore becoming vital that from the earliest of ages, students are learning to apply their newly acquired mathematics, science and technology skills in an integrated and cooperative approach.

In this study, the implementation of STEM in two independent K-12 schools is being tracked in order to report on the perceptions teachers have of STEM, and the implementation processes in their teaching milieu.

Background

In synthesising and then organising the research literature dealing with STEM education, this review has been constructed around the American National Research Council's (Shavelson & Towne, 2002, p. 99) recommendations that in regard to the nexus between science education and the overall research process in the STEM area, three key questions need to be addressed: What is happening? Is there a systematic effect? And why or how is it happening? These questions continue to frame American National Research Council's publications, both in the United States and its Australian counterpart, the Australian Research Council. However, in our review of the literature we came to realize, and perhaps

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not unsurprisingly, that the three previous questions and the entire current STEM movement arose out of, and is still embedded in a “consequence of history” (Charlton 2009, p. 70) which has “come to shape the modern world” (Chesky and Wolfmeyer 2015, p. 5). Hence, this review begins with the historical context of the STEM movement followed by the three critical questions cited previously. It should be noted that our first two references, although dealing with STEM components are actually embedded in discreet discussions on individual aspects. As will be discussed later, the pedagogic connectivity between the STEM components is still an ideal and not a reality, which surfaces in the current debates underpinning the implementation of STEM in schools.

A potted history

Coined in 1990 as a marketing tool in the United States (Sanders, 2015), STEM education wherever adopted as terminology by politicians and their educational agencies, represents the supposed melding of science, technology, engineering and mathematics subjects under the one acronym. STEM, and the axiological metaphor of importance and progress it has come to represent (Bowers, 1990), has seemingly not only become a hot topic of debate and research, but a top educational priority in all levels of educational curricula internationally. Indeed, for many governments across the globe STEM “has become a national priority” (Chen 2014, p. 1). The Australian government has made this very clear in a recent consultation paper.

The Australian Government is developing a comprehensive science policy that will be underpinned by a strategy for a science nation in which scientific thinking and applied science can be found in all sectors of our economy.

This policy will be made up of several components. One important element of this broad policy will be the development of our capacity in science, technology, engineering and mathematics – STEM.

(Commonwealth Government, 2015, p. 8)

In reality this is not a new agenda in Australia or the rest of the world, as numerous early twentieth century publications, technological innovations throughout the industrial revolution, and two world wars most certainly provided kick-starts to the supposed integration of STEM disciplines and ensuing educational reforms. However, while perhaps Americo-centric in outlook, it would appear that the general remarks amongst some researchers and commentators is that the current view of STEM education became a concentrated central integrative focus, far more than previously, subsequent to the

Russian-American competitive shift into rocket science and space exploration in the middle of the last century. As Woodruff (2013) states, STEM is actually a “60-year-long runway of educational reform.” The foundations of this still incomplete ‘runway’ arguably began with the Russian launching of Sputnik in 1957, and the ensuing realisation by the American government that the United States was behind in technological understanding and application.

While Meadows (2012) argues that the argument for STEM education actually commenced with Benjamin Franklin’s proposed “Education of Youth Reforms” in the colonial era of the United States, certainly it would appear that the space race, that began in the late 1950s and gained increased momentum in the 1960s, catapulted the need for STEM education into both public and government consciousness “across the globe” (Edge in Jasanoff, Markle, Petersen and Pinch 2001, p. 7). Ensuing Apollo missions and space shuttle launches have been termed the Golden Age of science, or rather the amalgamation of technology, engineering and computer science. The instigator of this STEM emphasis, in reality an economic and political shift, was John Fitzgerald Kennedy who has been attributed with the catch cry of “a rising tide raises all boats” (Kelly, Baek, Lesh & Bannan-Ritland 2008, p. 3). While at the highest echelons of this integration the ‘STEM boats’ have risen to the highest imaginative challenges of humankind, at the grass roots level of schools and classrooms, the boats are taking water as there are issues still to be overcome. As Clem and Junco (2015, p. 514) bluntly state, “we have barely begun to scratch the surface of understanding how we can use new technologies to best support student learning, engagement, and motivation.”

What is happening?

The mid twentieth century United States push to reach the moon appears to have simultaneously dovetailed with an overall negative public perception regarding education in America. Summarising the beliefs of the early ‘back to basics’ movement in this era, Lowyck (2014, p. 4) writes that at this time “Western societies aimed at improving education quality especially in mathematics and science to compensate for the supposed failure of the progressive education movement and teachers’ deficient classroom behaviors.” The coils of history never entirely disappear in education, and the belief that all of the school board microcosms across the country had failed their students in the 1960s, is still alive and well in the United States, and resurfacing periodically in Australia as a critique of earlier

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national education. However, the successful NASA launches ending with moon landings, promoted the possibility that STEM subjects at all levels of education were the answer to this supposed educational malaise and an answer to the supposed failure of the progressive education movement. It was also mooted that STEM could begin new ways and means of managing classrooms. Unfortunately, this has still not been broadly manifested in classrooms both here and in the United States (Matthews, 2007).

In the Australian context, the American technological advances in the 1960s further reinforced the overall social hope and positive economic outlook that followed the cessation of World War Two. The progressive education viewpoints were just beginning to gain traction in the Australian milieu as state and federal education policies began to move the separate state systems as a 'whole' out of outmoded ideologies that had dominated the country for decades (Seddon and Angus, 2000). Notwithstanding the global social upheavals of the 1960s, generally within the ensuing decades, a 'social imaginary' of optimism appeared to develop globally, engendering an even more positive economic outlook. The post war 'Baby Boomer' generations, in at least those deemed to be First World countries, were born into, and came to expect economic growth and stability. This outlook was also coupled with unprecedented access to education, and possibilities previously unimagined.

It would appear that for the most part, the general belief that economic growth was coupled with industrial STEM development, was the worldwide mantra in governments and their educational systems. The main issues with this perspective was that the elements of STEM were still, by and large, stand alone research and industrial disciplines. Gradually the climate of STEM awareness and debate shifted to one of economics and the need for research in science to begin to bear fruit in order to gain returns on the money invested—making it a profitable enterprise. However, as Bijker, Hughes, and Pinch (2012) note, in the late 1980s, technology, and in particular computer technology, began to claim dominance in the sciences and science research. It should be noted however, that even at this time, these seminal researchers in this field were warning that in regard to the components of STEM, "integration of this multiple expertise in turn implies complex organisation" (Bijker, Hughes, & Pinch, 2012, p. 225). Into this milieu of educational potentiality, one that Seixas (1993) viewed as possibly becoming 'community inquiry', the STEM focus in Australia began to become somewhat realised in that computer education was introduced

into many public schools, and the research into its application and impact was born. However, in this shift and apparent conjoining of disciplines the concept of multidisciplinary or interdisciplinary involvement was far from the usual case in most school levels and, in particular, in tertiary institutions.

In the intervening decades since the late 1980s warning by Bijker et al. (2012), and Bork's (1987) comment that technology would produce an educational and cultural revolution, this conjoining of the STEM elements appears to have not reached an educational fruition. Despite all of the pervasive intrusion of STEM into all aspects of current daily lives, the means and modes of implementing and teaching STEM in education systems appears to have stalled across the globe. While there appears to be pockets of sound teaching, generally it seems this is not the norm in most educational systems. It would appear that generally teachers have the desire to embark on integrating STEM as a holistic package into their teaching, and in many cases have the actual technology hardware and software to do so. The root cause of this dilemma appears to be the lack of professional development. Indeed, Benson and Lunt's (2011) entire book is devoted to the global issues in teaching and implementing STEM, and their comments in this text appear to be typical of an international dilemma.

The teachers indicated that they were unsure as to how they could incorporate investigating and evaluating products into an Early Years curriculum – important activities to help children to look critically at the designed and made world around them.

(Benson and Treleven 2011, p. 137)

Urban and Falvo (2016) are even more forthright in their evaluation of how STEM is being taught in schools believing the critical issue is that "too many teachers at all levels are technology phobic, poorly adept, or simply out-of-touch with the pervasiveness and essentiality of technology to the classroom environment" (2016, p. xxii). Although it is touted we all live in the era of technology, the overall consensus arising out of the research emanating from the country that gave birth to the acronym and technology focus is that STEM is viewed by educators at all levels as being difficult to understand and manage. More importantly it has been deemed inaccessible for many students, and as Langen and Dekker (2005) have come to believe, mainly viewed as being for males only.

Furthermore, in discussions arising out of educational research it has been suggested that most of the children in both primary and high school do not have a strong enough science and mathematics background for further study. The NRC

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(2011) have stated outright “there are many reasons to be concerned about the state of STEM learning in the United States, in the face of research that suggests that many students are not prepared for the demands of today’s economy and the economy of the future.”

Is there a systematic effect?

It should be clear that we agree with a belief that indeed there is some form of systemic STEM related effect, that just over three decades ago, Bowden (1995) termed ‘confusion’. While the schooling systems themselves appear not to be the key inhibitor, it would seem one of the key fault lines lie within governmental educational systems, by not planning and providing sufficient professional development resources at all levels. While there is no definitive research into the critical points, most certainly the ‘knock on effect’ into the tertiary and workplace scenarios is that in the American experience, there are critical “issues of attrition post secondary, where more than half of freshmen who declared STEM majors at the start of college, left these fields before graduation” (Chen and Soldner, 2013, p. 2). There also appears to be an ongoing issue of university preparation since “more than half of STEM bachelor’s degree recipients switched to non-STEM fields when they entered graduate school or the labor market” (Chen and Soldner, 2013, p. 2). Chen (2014) is very forthright in her criticism, as her research into college attrition clearly indicates that “many STEM leavers were actually high-performing students who might have made valuable additions to the STEM workforce had they stayed in STEM fields” (p. 6). In the Australian context, it is clear that this lack of school leavers and tertiary graduates in the STEM disciplines is also a concern. Backed by all Australian Ministers of Education, the Education Council of Australia (2015) released a national strategy for the period 2016-2026. The concern with STEM at the systemic level is blatantly clear within a statement such as:

Reversing the trends in STEM performance will take time and effort across the community. Building young people’s engagement in STEM is bigger than schools and what happens in the classroom. Education systems alone cannot overcome the pervading cultural norm that it is acceptable to be ‘bad at maths’ or ‘not a numbers person’.

The purpose of the strategy is to build on a range of reforms and activities already underway. It aims to better coordinate and target this effort and sharpen the focus on the key areas where collaborative action will deliver improvements to STEM education.

(Education Council of Australia 2015, p. 2)

As unpacked by Cavanagh (2009), the concern

that STEM has not matured in the school system in the United States has reached the highest political levels, with President Obama making it very clear that technologically speaking, the country as a whole and its underpinning educational systems have fallen dramatically from the lofty levels of innovation in previous decades. In what appears to be a parallel to the national agenda announced by President Kennedy, Obama has announced the goal of once again reaching the top international status in STEM education in the next decade. This would appear to be an extremely lofty ideal for Bowden (2001, p. 64) has likened the state of play in the entire STEM research-practice nexus to a “methodological confusion, symptomatic of adolescent identity crisis.”

It is also becoming increasingly clear that industry is very concerned about the attrition of possible STEM graduates. Machi (2009) notes that Fortune 500 leaders believe that the U.S., unlike other countries, has lost its direction in STEM education and in STEM fields as a whole. Industrial cohorts and leaders in Australia are also concerned about the deficits found in this particular educational arena. Similar to calls of dismay in the United States, the Australian Industry Group (2015) released a white paper in which Ennis Wilcox in his executive summary made it clear that:

The pipeline of STEM skills to the workforce remains perilous. In the school system participation in science and advanced mathematics is in decline and our students underperform in all the major international studies.

In the tertiary education sector, participation in STEM-related disciplines is in decline in absolute terms and in comparison with other comparable nations. Participation is also low in the VET sector in all STEM areas except engineering.

(Wilcox, 2015, p. 5)

And why or how is it happening?

It is perhaps stating the obvious to claim that there is no ‘silver bullet’ that will answer the apparent STEM issues in education and the industrial linkages.

However, what is becoming increasingly clear in the literature is that there is a perception that there are significant problems in the entire educational platforms in Australia and elsewhere. As Urban and Falvo (2016, p. xxii) state, “too many teachers at all levels are technology phobic, poorly adept, or simply out-of-touch with the pervasiveness and essentiality of technology to the classroom environment.”

Previously, Matthews, (2007) had reached a similar conclusion believing that teachers were simply not qualified.

It is unfortunate that the last comment is typical

“too many teachers at all levels are technology phobic, poorly adept, or simply out-of-touch with the pervasiveness and essentiality of technology to the classroom environment”

of the comments and ensuing perceptions that frame most of the literature dealing with STEM issues and its implementation in schools and universities. Whatever the case, it is increasingly clear that there “is a need to reconstruct the theoretical framework for educational technology, and there is an associated need to conceptualize its academic scope and purpose” (Spector, Merrill and Bishop 2014, p. x)

Research Purpose

The purpose of this research is to track the introduction and development of STEM based learning at two Christian schools in NSW over an extending period. This paper contains a report on the first stage of this longitudinal study into the developing attitudes of teachers towards the introduction of STEM into their schools.

Method

This multiple case study (Yin, 2015) has involved and will continue to involve collecting a variety of data. As a qualitative study (Creswell, 2014) the investigation draws on several data sources to create a mosaic of the challenges and high points in the process of introducing STEM into the school program.

The project also aims to embark on a longitudinal approach employing action research in order to provide feed back of updated awareness to the schools involved. Thus, it is also “aiming at an increased understanding of a given social situation, primarily applicable for the understanding of change processes in social systems and undertaken within a mutually acceptable ethical framework.” (Hult & Lennung, 2007, p. 241.)

The types of data collected in this study include STEM related information derived from:

- Staff meeting and other meeting minutes.
- Anecdotal journaling, including notes and jottings of those responsible for implementation within the schools.
- Internal surveys of staff at the schools.
- Schedules of inservice courses provided over the time period.
- Summaries of in-service courses provided for staff by outsourced agencies.
- Open narrative interviews with administration, implementation team leaders and a sample of teachers.

Not all of these data sources will be reported on in this preliminary paper. Interviews will be the main source of data in this paper, but as the project continues into the future and more data types are collected, they will be reported in future articles.

All data except for the interviews will be part of the internal quality control processes of the school and so will serve a dual purpose.

For this first stage of the study, the teachers at each school charged with the responsibility of developing this program in their school were interviewed. A further three teachers were then selected from each of the primary and secondary departments in each school. The interview data was then coded (Cresswell, 2014) and themes were extracted.

Each year feedback will be given to the school in the form of a report that contains an analysis of all data with recommendations for the next ‘action research’ phase.

Findings and discussion

School 1 started their journey with STEM through the enthusiasm generated by senior administration who took it upon themselves to participate in high level professional development. It was intended that the information and skills they acquired would consequently be dissipated down through the administrative levels to the teachers. School 2 entered the STEM initiative largely through one passionate technology teacher who worked hard to generate interest and enthusiasm in both the administration and teachers. This teacher anticipated that their personal initial drive would provide modelling that would generate a pervasive impetus throughout the school.

Through the ‘coding process’ (Creswell, 2014) of teacher interviews from both schools, the same seven themes were revealed: integration of learning, passion for science as a discipline, lack of knowledge, training, teamwork, attitude and structure of the school. It is clear that even though the two schools have been introduced to STEM in different ways, the issues that they face in this process are the same.

The following paragraphs discuss each of these separated themes and associated issues.

Integration of learning

There appears to be a largely tacit feeling from both schools that integration is the approach to take and the most appropriate pedagogical trajectory. Resistance to it however revolves around issues such as the absence of curricula driven incentives from education authorities, given that the Australian Curriculum is still seen by both schools as predominantly consisting of stand-alone key learning areas. While primary teachers have the flexibility to use the curriculum documents more creatively to integrate the learning areas, secondary teachers see a mixed message coming from education authorities.

“Resistance to it [STEM integration] however revolves around issues such as the absence of curricula driven incentives from education authorities”

“There are a few distinct attitudes. One is STEM is a great idea – let’s do it, another one is this is a fad that will pass and the third is how do I cover all my outcomes in each KLA and do STEM as well.”

On one hand they are seeing grants given for STEM initiatives, but on the other hand they are held to very specific learning outcomes in individualised curricula leading to BOSTES set examinations. They are questioning as to whether education authorities are serious about STEM or whether they too are waiting to see if it is a passing fad. As stated by one teacher, “Some think that this is a fly-in/fly-out initiative – one more acronym to deal with.”

Passion for science as a discipline

There is evidence from this study of the historically recurring competition between the disciplines of science/mathematics and the humanities. Interestingly, in this instance there is data to support this perception of the situation from primary teachers where normally it is observed as professional manoeuvring at the secondary level. A primary teacher highlighted:

I’m more into the humanities side of things and think that technology can be a bit of a gimmick at times. A lot of money has been spent on technology play things that spend a lot of time on the shelf when the money could have been spent on basic literacy resources that are so badly needed.

A primary teacher believed that to be passionate about STEM, teachers need to be passionate about science,

(STEM) comes undone because a lot of teachers here are not driven by science.

Lack of knowledge and training

While repeated in different ways, there was a majority view amongst the teachers in this project, expressed as a concern that staff members each had a different idea of what STEM is. As a corollary, they also believed that more training was needed to make sure all teachers knew what STEM is, why it is important and how it should be implemented in each school. There was also a clear viewpoint added that administration needs to clearly spell these aspects out to the staff as a coherent and integrated framework of praxis.

While lack of knowledge was a recurring theme at both schools from teachers at primary and secondary level, one teacher was very animated with this theme stating,

It hasn’t been told to the staff exactly what STEM is and why this school needs to run with it, and the clientele haven’t been told how this will benefit the specific types of kids we have here.

Teamwork

It is interesting that teachers spoke very positively

about the impact STEM can have on teamwork. For example, one teacher said,

A shared and enunciated vision is important. People may be excited about the program but for different reasons.

It was also pointed out several times that this applied to the teamwork of students, who were learning from the earliest years of schooling the value of cooperative learning, but also applied to teamwork among the staff who were learning to work together within disciplines, but needed to also reach out across disciplines. A primary teacher asserted,

Even in kindy the kids are learning to work together when given a challenge.

Attitude

Interestingly, there was a variation in attitudes regarding the efficacy of STEM. Attitudes ranged from very positive to cynical, with negative attitudes that emanated from fear, lack of confidence, lack of time, lack of informed knowledge or suspicion of another fad. Perhaps more worrying, were the rationales underpinning this variability. A secondary teacher responded,

There are a few distinct attitudes. One is STEM is a great idea – let’s do it, another one is this is a fad that will pass, and the third is how do I cover all my outcomes in each KLA and do STEM as well.

The latter attitude of confused complexity links to earlier expressions of inadequate preparation in pedagogy.

Structure of the school

The workplace structures of the school were perceived as a significant issue, more so by secondary teachers than primary teachers. Secondary teachers who are passionate about STEM do not believe that curriculum, timetables or teaching loads need to be a major hurdle. One secondary teacher claimed,

Timetable is always said to be an issue but if there is a will it could be done.

They believed that important steps forward can be taken within existing budgets, timetables and teaching loads. There was an overall perception amongst the passionate that all that is needed is for teachers to rethink and step out of the confines of a traditional secondary structure. However the secondary teachers who are passionate about

STEM are in a minority.

Primary teachers however recognise that they have the flexibility to work STEM into their programs while meeting the outcomes for each key learning area. In general, these teachers appear to need to grow into greater confidence through systemic support and choosing to take ownership for STEM as part of their program rather than it being an 'add-on' organised by a STEM champion in their school.

Future research directions or recommendations

This research has been designed with teacher perceptions of the introduction of STEM into their schools as the focus. This is a longitudinal study that will keep collecting data as it tracks changing attitudes to STEM and changing ways of applying STEM in the schools.

The report generated from this study and provided to the schools recommends that the most vital factor in generating ownership and enthusiasm for STEM in these schools is ongoing professional development that is open and honest about the benefits and blockages to successful STEM implementation. The professional development needs to specifically emphasise:

- The importance of the integration of learning areas and its role in providing differentiation of learning for specific individuals.
- That teachers need not fear STEM or have all the answers to the challenges given to students. The idea is to challenge students to use whatever means they have at their disposal to find their own potentially unique solutions.
- That teamwork is vital at teacher/administrator level for STEM to succeed.
- That flexibility in school structure including timetabling at secondary level is necessary and possible.

Conclusion

It seems that positive and negative opinions regarding STEM within the focus of educational communities, as expressed by the respondents in this investigation emerged as equal thematic components in this initial research agenda. This outcome appears to have many contributing factors including: mixed messages from government sectors that provide funding for STEM activities but do not show full commitment through syllabus inclusions; lack of sound strategic information flowing through to teachers; consequently teachers fearing that they may not be capable of successful implementation; and persisting fear of change.

Although the two schools that participated in this study approached the introduction of STEM

from different perspectives, perhaps if both address these shared limiting factors they may move forward in a collegial and more strategic approach. Despite the hesitancy, fear and numerous roadblocks, the goodwill from the staff at both schools could be linked and enabled within a collaboration to provide a more effective pedagogical framework potentially expressed in their individual environments.

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