Community Partnerships for Fostering Student Interest and Engagement in STEM

James J Watters and Carmel M Diezmann
Queensland University of Technology

Abstract

The foundations of Science, Technology, Engineering and Mathematics (STEM) education begins in the early years of schooling when students encounter formal learning experiences primarily in mathematics and science. Politicians, economists and industrialists recognise the importance of STEM in society, and therefore a number of strategies have been implemented to foster interest. Similarly, most students see the importance of science and mathematics in their lives, but school science and mathematics is usually seen as irrelevant, particularly by students in developed countries. This paper reports on the establishment and implementation of partnerships with industry experts from one jurisdiction which have, over a decade, attempted to reconcile the interests of youth and the contemporary world of science. Four case studies are presented and qualitative findings analyzed in terms of program outcomes and student engagement. The key finding is that the formation of relationships and partnerships, in which students have high degree of autonomy and sense of responsibility, is paramount to positive dispositions towards STEM. Those features of successful partnerships are also discussed. The findings raise some hope that innovative schools and partnerships can foster innovation and connect youth with the real world.

Keywords: STEM education; Innovative schools, leadership in STEM, contemporary youth, Science education, Technology education, Engineering education, Mathematics education, partnerships.

Introduction

Keeping pace with social, economic and changes in knowledge over the past half century has challenged educational systems worldwide. The demands of globalization, sustainability and knowledge growth in the health sciences threaten the relevance of existing education practices, but at the same time provide resources to enhance education. With such a rapidly changing world, the educational needs of contemporary youth are much different to those of previous generations. It is claimed in multiple industry reports that science, technology, engineering and mathematics (STEM) will play a greater role on our day-to-day lives more than ever before.

Although the significance of STEM to contemporary society is acknowledged, there exists major skills shortages in STEM-based industries (Eisen, Jasinowski, & Kleinert, 2005; Dept. Business, Innovation and Skills, [DfBIS], 2009; Nathan & Bolton, 2010; National Science Board, 2010). Contributing to this situation is the declining interest in science in western countries. The large-scale international Relevance of Science Education (ROSE) study indicated that science is less popular than most other subjects (Jenkins & Nelson, 2005).
Acknowledging ongoing issues with adolescent engagement, Wallace, Venville and Rennie (2005) suggest reforms to curricula underpinned by thematic, integrated project-based, and community-focused approaches. Taking this argument a step further, Dowden (2007) advocates a student-centered integrated curriculum in which students have opportunities to engage with the community in which they live, rather than specific subject areas, as the locus of educational interest. Evidence that supports the importance of authentic experiences acquired through community engagement with professional scientists has been reported by Rahm, Miller, Hartley and Moore (2003). These researchers described successful school-community partnerships that enabled students to work with professional scientists over time to ask and solve questions, and to recognize the attributes of a scientific and technological community of practice. The benefits of community engagement extend from the students to industry. Caldwell and Keating (2004), in examining public-private partnerships for education, highlighted the benefits of engagement with community and industry in the provision of more flexible educational experiences that value innovation and creativity. Other evidence in support of the effectiveness of partnership strategies on learning can be gleaned from studies in higher education (Gamble, Patrick, & Peach, 2010).

To confront these issues of student engagement and to align schools with the knowledge demands of the 21st century, there is a growing recognition that education needs to engage in partnerships with the community and industry. The aim of this paper is to explore the establishment of such partnership.

Background

This paper presents a set of four case studies of partnerships designed to enhance student interest in STEM. First, the paper presents a brief discussion of the context in which these partnerships occurred. Second, a theoretical framework is provided to analyse the structure and purpose of these partnerships. Finally, following a brief outline of the methodology, the cases are profiled. The study draws on experiences in one educational jurisdiction, but has significance for planning and implementing effective strategies to engage students in the foundations of STEM education.

Contextual Background

The school curriculum in this state jurisdiction is developed by a central state-based curriculum planning body and highlights eight key learning areas including mathematics, science and technology. Given broad syllabus outlines, individual schools develop school-based work programs which enable schools to cater to the interests of students in different locales and backgrounds. Most students would study mathematics through the final year of schooling but in most instances students are only required to study science through their 10th year. Although students experience learning opportunities in Information and Communication Technology (ICT), there is limited exposure to design technology or engineering in the formal curriculum until the final years of schooling where, in some schools, options exist for the study of engineering subjects.

Analysing Australian data, Anlezark, Lim, Semo and Nguyen (2008) reported that between 11 percent and 14 percent of school students will pursue careers in STEM. This figure includes those who work in professional areas accredited through university courses, but also other careers such as building and engineering associate professionals, or medical and science laboratory technicians, who acquire professional qualifications through further education institutions. In addition to these are vocational education for students, required for skilled trades such as electricians, machinery operators or systems control managers.

In this paper, we focus on one strategy, namely community and industry partnerships, and begin with a brief synopsis of the policy directives that emerged to address the declining interest in STEM at all levels of education. We take up the story as the 21st century dawned, with three important policy initiatives that emerged and weredesigned to: 1) confront the skills shortage in the new industries, 2) build capacity in science, mathematics and technology teaching in the school sector, and 3) foreground STEM education as a priority for economic growth. The policy and the ensuing raft of reforms were driven by an acceptance that enhancing human capital is the key driver of economic productivity through the promotion of creativity and innovation (Hanushek & Woessmann, 2008). A clear goal was to ensure that all children 15-17 years of age should be engaged in school, vocational education and training, or full-time work. In particular, a strong vocational education program led to the flexible integration of schooling and work through the provision of high-quality effective transitions between further study, training and employment.

Theoretical Framework

We now turn our attention to effective partnerships. Bailey (1994) describes partnerships as, "the mobilisation of a coalition of interests drawn from more than one sector in order to prepare and oversee an agreed strategy for regeneration of a defined area," (p. 293). The establishment and maintenance of effective partnerships relies on mutual understanding of the relative interests and purposes of each member, local leadership, a culture of innovation, and a capacity for people to act in concert on an agreed strategy even in the face of setbacks (Bagnall, 2007; Walsh 2004).

Bagnall (2007) has examined the purpose of partnerships in education and characterized them as being focused or developed "towards," "for" or "in" learning. The first model describes the structure of partnerships which learners, although the intended beneficiaries, are exogenous to the partnership. That is, arrangements are made at the system or organizational level without the explicit involvement of students. Partnerships are arrangements that facilitate opportunities for promote learning experiences without necessarily defining what those experiences might be. Second, partnerships for learning work to promote desirable learning on the part of students who are seen as objects in the partnership. These partnerships would operate at a school level and more often through curriculum innovations. Third, with partnerships in learning, all the learners are integral to the partnership itself and the partnership is essentially collaboration between or among the learners. This form of partnership assumes a community of practice where all partners are beneficiaries (Wenger, 1998).

Partnerships can also be examined from the perspective and effectiveness of their establishment and management. Walsh (2004) proposes three key principles for examining effective partnerships: 1) the principle of subsidiarity whereby responsibility for implementation is devolved to personnel at the local level, 2) the implementation of strategic planning as a methodology, and 3) animation, facilitation and capacity building as processes for implementation (p. 8).

In a geographically and socially diverse jurisdiction, local priorities are of significant concern. The expectations, needs and opportunities of students in the affluent suburbs of the capital city are substantially different from those of the remote mining communities more than 1,000 kilometers awayor the tourist and retiree dominated coastal strips. Bailey (1994) argued that partnerships are normally created through a catalytic process of either a "top-down or bottom-up nature" (p. 294). In the first case, they are established as a response to a policy initiative by the central government as a mechanism for achieving some policy strategy. However, local circumstances are critically important. The key drivers for educational partnerships are the local school principals, community leaders or industry field managers. How well these individuals collaborate will seal the fate of any partnership. With well established relationships, strategic planning can progress. Strategic planning requires consultation and widespread community participation in the planning process. This participation would include mechanisms to achieve consensus on the goals and broad commitment among teachers within a school or cluster of schools, and community partners. Hence, the principle of subsidiarity assumes an important role in the mobilization and maintenance of effective partnerships.

The second principle identified by Walsh (2004) relates to a strategic approach to planning. Walsh argues that successful strategic planning has five essential requirements and, "must be:

- unified in the sense of tying all the components together,
- comprehensive in relation to all sectors,
- focused on target groups and areas,
- innovative rather than imitative, and
- integrated so that all parts of the plan are compatible with each other" (p. 11)

These requirements align with strategic planning for organizational change (Berry, 2007). Such planning typically involves the leadership and management of an organization taking the initiative for change and, after consultation with stakeholders, assuming responsibility for implementing and evaluating the change. An advantage of using this approach is that the organizational leader essentially directs the change. Planning for organizational change is common in industry, and hence, organizational leaders often assume the role of change agents (Berry, 2007). However, Eacott (2008) argues that school leaders are ill-prepared to be change agents because the focus of their leadership is instructional rather than organizational. In schools, the lack of preparation for, or orientation towards, organizational change can be addressed if school leaders employ community-based strategic planning, which is an alternative to strategic planning for organizational change (Berry, 2007). The process in a community-based approach is similar to the organizational approach in that both proceed through steps of problem identification, team selection, environmental scanning, and development of a mission and action plan. However, in the community-based approach, community members assume greater ownership of the problem, namely identifying and resolving the problem (Berry, 2007):

> "Community-based strategic planning aims to build a broad consensus among citizens, businesses and organisations in the community to develop collective responses to the community's problems. Communities often find they must develop effective networks of policy understanding and shared resources to be effective in dealing with their complex problems" (p. 340).

Thus, strategic planning involving a community-based approach is more likely to result in change because it is supportive of the school leadership team compared to planning for organizational change which occurs in relative isolation from the community.

The third principle of Walsh relates to the implementation of the partnership and the achievement of goals. Walsh describes implementation as dependent on three steps: *animation, facilitation and capacity building*. Animation can be seen as the initial step in capacity building or a holistic process. For instance, Walsh describes the process as the, "opportunity for the animators to listen to the needs and views of the community, which they can subsequently incorporate into the local Action Plan" (p. 12). Animation requires mobilizing people. It is an ongoing process of consultation supported by professionally trained animators. Facilitation involves processes of strategic planning and achievement of the partnership goals and relies on processes. This might include providing expert assistance in drafting proposals through to the mutual provision of experts who engage in practical activities aligned with partnership goals. Within Walsh's model, capacity building is a scaffolded process designed to enable the stakeholders to learn the necessary skills to achieve the goals of the partnership, as well as the implementation of structures and practices that eventually ensure self-sustaining. Walsh (2004) points out that the outcomes of capacity building might, "only emerge after intense support over a period of 10 or more years" (p. 14).

Purpose of this paper

We propose that partnerships can be successfully implemented at different levels and namely, partnerships towards learning, *for* learning and *in* learning as proposed by Bagnall (2007). So what features characterize these levels in the school sector in relation to STEM? Four examples will be discussed, each representing a different level. The first example describes a somewhat traditional relation between a high school and a community leisure industry focused on using the industry resources to help develop innovations in the teaching of mathematics and science. A second example describes a network of schools interacting with major global industries in an industrial region and reveals the strengths of partnerships. A third example is based on a provincial city in which a high school has developed strong and mutual relations with the local community and small business. The final example provides insights into a primary school that has capitalized on the establishment of broad community partnerships to enhance the teaching of science.

Methods

The descriptive multiple case study approach adopted in this paper provides a retrospective account of selected cases of interest which were identified in a series of ongoing evaluation projects. The sources of data for Cases 1-3 included departmental information collected for normal reporting processes, on site interviews with teachers and industry personnel, observations of classroom practices, and focus group discussions with students (Diezmann & Watters, 2004; Watters & Diezmann, 2006). Pseudonyms are used for teachers, industries and other stakeholders.

Level 1: A mutual benefit school - industry partnership.

Bluepoint High School is presented as an example of a partnership towards learning. The school serviced a relatively low socio-economic community with limited expectations for advanced education. The school's vision was for students to become active participants in a technologically literate society and for both staff and students to be effective users of technology in a manner that enhances learning for all. The school was initially identified through a statewide program that recognized schools that were operating at the forefront of STEM education. Key administrative staff, namely the head of the mathematics and the head of the science departments, after consulting with relevant teaching staff, expressed interest in participating in the program. The initiation exemplifies Bailey's "top-down bottom up" approach in which enthusiastic and well-positioned staff sought to capitalize on the side-wide initiative. A team approach was developed and contact made with local representatives of industry. The principle of subsidiarity (Walsh, 2004) was evident in the initiation and planning that was featured in the early establishment of the partnership.

A key emphasis in the school mathematics and science curriculum was on the use of instruments for data logging so as to provide students with the opportunity to be actively engaged in the collection of the data, to have their own unique real data sets for further investigation, and to quickly and easily repeat data collection if necessary. Data logging activities were used extensively in both junior and senior secondary science classes, with a particular emphasis on physics. Mathematics activities related to data logging were incorporated into Year 8 classes and Year 11 advanced mathematics activities.

The exploration of real data in context through the use of data logging was exemplified through "extreme" data logging activities on rides at a theme park. The school had two industry links in this project. The first link was with Texas Instruments, the manufacturer of the data loggers. The school used the Texas Instrument Data Collection System TI83-CBL2 in this project. The second link was with Fantasy Garden, a large theme park relatively close to the school which included nearly 30 adventure rides, including gravity defying thrill experiences.

Using the latest digital data logging equipment, Year 11 and 12 students from Bluepoint High School completed a detailed physics analysis of the physical phenomena of the "big five" thrill rides at Fantasy Garden. The students were highly enthusiastic and engaged in the data logging at Fantasy Garden and in making sense of the data back at school.

Since the Fantasy Garden activity was launched in 2003, Bluepoint has supported many other schools to engage in this activity and shared their equipment and expertise. As the Bluepoint Coordinator stated in response to an evaluation question, "The data logging equipment is expensive. We realize that many schools would not be able to afford the amount of gear we have put together. From the outset, this project has been viewed as something we intended to share with other schools." Staff at Bluepoint High School were proactive in supporting other schools in undertaking similar activities using data loggers. These professional development workshops have included training sessions in the use of data logging equipment and real data collection, as well as on-site practical training at Fantasy Garden. Some Bluepoint staff have also published on the initiative. The contribution of the Bluepoint coordinator was acknowledged by the receipt of a state educational award to recognize secondary classroom teachers who demonstrated leadership in teaching, and who inspired others through ongoing contributions to learning outcomes of students and colleagues.

The success of extreme data logging was at least in part because of the strong partnerships among personnel from Bluepoint, Texas Instruments and Fantasy Garden. Though the benefits for students at Bluepoint engaged in extreme data logging are clear, there was also a return for industry partners. Texas Instruments has received widespread publicity about the educational applications of their data loggers. Similarly, Fantasy Gardens received publicity for the use of their theme park as an educational site. From the outset of the program, Bluepoint sought assistance from its industry partners, and over time these partners have benefitted directly from their 'investment' in extreme data logging. Mutual benefit was the optimal outcome of school-industry partnerships in this case.

This is a case essentially of partnerships towards learning. The partners were indirectly involved in the teaching in that they provide the resources or knowledge to support the teachers at the school. For example, the community partner (Fantasy Garden) provided a physical opportunity for students to explore physics. The Texas Instrument Company was willing to contribute equipment and advice which eventually will afford improved learning opportunities, but clearly were motivated commercially to be a partner. This partnership was negotiated at the local level with key personnel in the school driving the negotiations. In Walsh's description, the partnership was the responsibility of personnel at the local level. Strategic planning also occurred at the local level in that the roles of partners were well articulated and did not involve direct engagement with students. However, there is little evidence however of the level animation, facilitation and capacity building as processes for implementation. There was passive facilitation on the part of the Fantasy Garden partner and long term capacity building on the part of teachers, but these were flow-on effects of the partnership.

Level 2: Cluster of schools with mining and power industries

The second case study involves the Hi-Tech-Network Alliance and profiles the partnership for learning among a network of schools and local mining and energy industries, which focused on the growth in teacher professional capacity as a consequence of sustained engagement with the local industry-based professionals. This case illustrates the collaboration among teachers and industry which specifically targeted the steady decline in enrolments in science and engineering, at both the secondary and tertiary levels. The region had and continues to have a strong demand for a highly skilled workforce in STEM. Local industries employ chemists, engineers, mathematicians, skilled trade people, and a wide range of technologically-skilled personnel to support major enterprises.

Figure 1. Partnerships in the Hi-Tech-Network

A feature of this case was the level of commitment and support at the Regional Administrative level in education. Senior Administrators including the Regional Executive Director were proactive in aligning educational outcomes with community needs. This vision resulted in the establishment of a strong and enduring relation between schools and industry. Industry clearly communicated a need for skilled workers and was motivated to work with the school sector. This drive was reciprocated in the educational system though willingness of schools to work with industry in the planning of units, and access to resources and expertise. A key feature of this relationship was the stability of stakeholders, which facilitated ongoing relationships. Staff turnover was relatively low both in the school sector and among the major industry collaborators. Low staff turnover is seen as a pre-requisite for sustained viable partnerships. The stability led to the development of a culture of cooperation, which impacted new staff. There was an expectation that school administrators would work together for the benefit of the community.

The Hi-Tech-Network Alliance had consistently demonstrated leadership in the education of Queensland students in its region. The Network mobilized individuals, schools, industries and students to engage in exciting and relevant contemporary science and mathematics learning, particular at a time when student interest in these areas is at an all time low. The network demonstrated that STEM is relevant and a worthwhile career pathway for students at all levels and had mobilized the power, knowledge and skills of teachers, industries and the community in many ways to effectively introduce change for the ultimate benefit of student learning. Over many years Hi-Tech-Network had established a vision of what contemporary education should be like: a willingness to change and to reflect on change, to use intuition, influence, persuasiveness and advocacy to achieve its goals, and has shared its successes.

Five of the Alliance's many coordinated initiatives are briefly profiled here: 1) sustainable resources, 2) innovative professional development, 3) energy conservation project, 4) inquiry projects and 5) extended opportunities for indigenous students.

Sustainable resources: Through this collaborative project, teachers participated in professional development programs organized by industry, which enhanced their skills to teach science, technology, engineering and mathematics (STEM). The project was of mutual benefit as industry participants developed a greater appreciation of their local educational organizations.

Professional development: An innovative Professional Development Center was physically located at one school, but involved a cluster of schools, both primary and secondary, which worked with a partner university to deliver the professional development needs of teachers. A core activity of this project involved leading edge research scientists and science educators who provided intensive two-day workshops on contemporary science topics (e.g., polymer science, cancer biology and radiation physics). The philosophy stated by the center coordinator was based on the idea that teachers should engage in the activities to enhance familiarity and understanding of the concepts.

The energy conservation project: This initiative exploited the expertise of a major power generator with a workforce of about 4,000 employees and which includes a wide range of professionals and trades. The company had the vision to be the energy employer of choice and saw a responsibility to maintain an active presence in the community. It employed an Energy Education Advisor who provided a range of services to the Network. The focus was on communicating issues around energy conservation. The support from the industry provided opportunities for students to engage with the community in ways that make their learning more public.

Inquiry projects: As a deliberate attempt to engage students in more learner-centered approaches to learning, problem based approaches to teaching were developed by the Network schools, and industry/university partners. In partnership with local industry mentors, both primary and secondary teachers developed and implemented a bank of authentic tasks with accompanying assessment, standards and outcome descriptors. These tasks presented students with real-world authentic problem scenarios and challenged them to collectively generate a solution and relate this back into the real-world context.

Extending opportunities for indigenous students: The region has a significant proportion of indigenous students whose future could be aligned with the economic demands of the region. Hence, this project focused on supporting indigenous students in STEM. The intended outcomes of the project included an increased engagement and performance in science and technology learning, an improved promotion and selection of pathways into science and technology fields, improved skills in a diverse range of areas including Information Communication Technologies (ICT), electronic media, problem solving, teamwork, communication, and an increased appreciation of cultural heritage.

The Alliance was recognized for its outstanding and innovative contribution to science and science education in Queensland and was a recipient of a significant Industry Science Education Award in 2006.

The Alliance represented a broader and more complex model than any of the previous cases. The partnership was coordinated at a regional level, driven by key personnel from a number of the partner organizations. The partnership had been in existence for over a decade before this evaluation and in that time mutually beneficial relations among stakeholders was well entrenched, enabling multidimensional school-industry innovations in education, especially around STEM. At this level, the partnership works in Bagnall's (2007) terms as a partnership for learning. Numerous opportunities for students and staff to be engaged in different learning projects, experiences and innovations were facilitated through the network. The development of the partnership was beneficial to multi-national companies, as it provided a recruitment strategy for skilled STEM workers. The proportion of able students proceeding to university courses in STEM was seen by administrators as a significant indicator of the success of the partnership.

Nevertheless, in the context of the geography and administrative structures of the state, the partnership was a regionally conceived, developed and coordinated strategy. It involved a well established network of key STEM teachers, school administrators and field managers of the local industry installations. Strategic planning was coordinated by key personnel in both the school sector and industry, but detailed planning of initiatives was left to those engaged in particular spin-off projects. Nevertheless, at the network level there was a shared vision of what was good for the community .The partnership provided opportunities for stakeholders to become actively engaged and many instances of individual teachers, students and classes were animated to engage in learning experiences. In Walsh's (2004) framework, the partnership exemplified those features of effective partnerships being locally managed, planning influenced by a shared vision of what was essential for the community and implemented though a range of initiatives that involved direct engagement with partner representatives.

Level 3: Camelot State School

Camelot State School is located in the State capital and caters to students from Preschool through to Year 7 (approximately five years to 12 years). Camelot is presented as a case of a partnership *for* learning based on community relationship. It is presented as an example of a elementary school complementary to Hi-Tech-Network Alliance which involved secondary schools. The school has some 700 students of whom about 40 percent are from multicultural backgrounds. Many of these families, however, are students or staff of local universities. Camelot State School was selected on the basis of its record of academic achievement as a special school to develop an emphasis on STEM. The school was performing above the state means on tests and parents reportedly had high expectations of students. The intent of this initiative was for the school to develop curricular approaches that would enhance STEM, to up-skill teaching staff in this area and to develop outreach programs whereby other schools could build relationships and capitalize on the school's achievements. The principal, in consultation with senior staff, considered that developing initiatives across all dimensions of STEM was an unrealistic goal and that a more focused vision should be established.

The principal initially established a steering committee, which included a program coordinator funded through the same state-wide school initiative as both Bluepoint High School and Thomas Falls High School. One of the first decisions made was to canvas the opinions of parents as to which of the priority areas, mathematics, science or technology, was to become the school's focus. A public meeting was called at which some 200 parents were addressed by key academics from local universities on the priorities and issues in mathematics, science and technology education. Following a poll of the schools' community and further staff consultations, a decision was made to enhance the learning of science and assist in the development and implementation of integrated units in which science was embedded in a range of key learning areas, especially Information and Communication Technologies (ICT).

The leadership characteristics of the principal were clearly evident as she worked with her steering committee to develop a clear vision and a strategic plan to achieve excellence in science and ICTs for learning. The achievement of this vision was facilitated by professional development on vision and mentoring/coaching. Day-to-day management was delegated to the program coordinator, whose main activities involved supporting teachers to teach science well and to utilize technology, organizing professional development for staff, providing extension activities for students, and promoting science practicums for staff from other schools. Given this consultative managerial environment, a high level of commitment from school staff to the program and the leadership for various School/Center activities spread throughout the school. The multicultural population and links to a sister school in Japan raised interest and awareness of best practice internationally.

There were multiple layers of community partnerships through which the school partnered with parents, the local community, other schools and universities. Community partnerships for and in learning played a major role in the implementation of the program. Partnerships *for* learning were evidenced by the way partners provided practical assistance, strategic guidance and professional support. The partnership benefits were reciprocated in that the school contributed actively in the broader community by conducting community forums on science, by showcasing students' work within the community, through involvement in competitions, and through the instigation of an annual conference on science teaching.

Partnerships in learning were also in evidence where university academics and parents played a key role in the school initiatives through an open door policy of access. Those with interest or special expertise in science or science teaching were welcomed to participate in class activities. Such initiatives included an after school program for gifted students run by a local science educator.

The school was seen by staff as a "hub" in which there was an obligation to develop their expertise and share their expertise beyond the school. Within a short span of 3 years, the school had developed a reputation for inquiry-based learning in science, modeled its activities on the best examples available, and disseminated professional development and resources throughout the state. Particularly noticeable was the extent to which teachers engaged in professional dialogue. Conversations with these teachers revealed sound understandings of contemporary approaches to teaching science and learning, as well as disciplinary knowledge.

The principles of effective partnerships are evident in this case. First, the principle of subsidiarity underpinned the success of this school. Although the initiative was mandated at the state level the mobilization of the partnership was situated at the local level. The key players included the principal and interested academics and community members who negotiated the scope of the project, were engaged in intensive consultations and eventually focussed their attention onto the implementation of science teaching as a STEM initiative.

Second, strategic planning was strongly influenced by eclectic planning processes which combined the advantages of planning for organizational change and a community planning approach. At the organizational level, planning involved high level commitment from the school leadership team and a willingness to recruit key staff and partners and negotiate with them to ensure mutual benefits. At the community level, the involvement of parents and educators in making key decisions and supporting the implementation plan paid dividends through a shared commitment to the problem and responsibility for its resolution. The distributed leadership practices of the principal and her drive, along with the enthusiasm of community partners, contributed to the effectiveness of planning by enabling the development of a clear vision for the direction of the partnership and the strategies that would be necessary to achieve the intended goals.

Third, the implementation followed a process in which *animation, facilitation and capacity building* were clearly evident. Staff were highly committed and enthusiastic and had access to high quality professional development provided by partners that enhanced their knowledge and capacity to plan and deliver exemplary science programs. The capacity building also extended to other schools that were partners in the process, as well as providing better understandings of contemporary science teaching to parents.

Level 4: Single school partnering with local businesses

Thomas Falls High School is the sole government secondary school in a provincial town dependent on agriculture and aquaculture industries. Thomas Falls is presented as a partnership in learning. The school capitalized on the same state-wide program as Bluepoint High School. However, being a small town where virtually all the communities' children attend the government school, there were close personal relationships between teachers and the community.

Turnover in teaching staff was low and cross departmental initiatives within the school were common. Again, this school exemplified Walsh's (2004) principles, especially subsidiarity. Staff capacity development was facilitated with the Head of Science being given time to teach in pre-service teacher education programs at a university some hour's drive away.

Thomas Falls is noted for the range of science subjects offered and the high proportion of students who undertake science subjects in the senior years. It has various ongoing industry and community partnerships that support its science curriculum and provide opportunities for students to engage in authentic science experiences. Thomas Falls also supports feeder primary schools by providing personnel and material resources and by hosting student visits. However, our reason for selecting Thomas Falls as a case is because science was embedded in students' thinking across the curriculum and the school's partnerships included local business. Such strategies exemplify the recommendations for engaging students and successful educational innovations. Although there were many examples from this school, we illustrate one partnership venture.

At Thomas Falls, junior secondary students in a Business Studies class expressed an interest in starting their own business to experience business skills first hand. They agreed on a worm farm business for its benefits to the school and its environment. The students obtained sponsorship for the worm farm through a federal scheme and worked on various aspects of the worm business, including developing a business plan and marketing. The students sought support for their project from teachers and local businesses, including the local hardware store owner. Local business personnel assisted with the practicalities of packaging, marketing and pricing the worm products, and provided an outlet for sales. They also assisted with the management of the worm farm which was overseen by a board comprised of students and various community members. Observations of a "board meeting" of the worm farm indicated a high commitment, by all students, to this project and sufficient scope for students to undertake diverse roles related to the farm.

There was a high level of student and teacher enthusiasm for the worm farm project. Students were observed to be enthusiastic in harvesting worm casts and negotiating with the local distributor. In achieving a successful enterprise that supports ecologically friendly gardening practices, students acquired practical understandings of the science and technology of worm farming. Students also benefited by developing hands-on business skills, by taking responsibility for their own learning, and by developing confidence and team work skills. Key benefits of the students' involvement in the worm farm were the real-life learning and the transferability of skills:

> "[The benefit was] to move away from 'text book' lessons to hands-on and relevant tasks. For example, students in my Aquaculture class use their experiences from the worm farm and Convention Center to make a website to help cane and banana farmers" (Secondary Teacher)

Staff also argued that students who were disengaged in schooling became actively involved in the project and contributed to the decision making process. The worm farm, which was sustained for a couple of years, provides an excellent example of how scientific knowledge can be developed through other curriculum areas and how local business can become partners in science-related ventures. Similar partnerships existed with local fish farming industries and fruit plantations.

In reflecting on their overall experiences, students acknowledged the integration of technology and science, and the capacity to work at their own pace. These experiences are indicative of the school environment and project oriented learning:

> "Letting learn at our own pace and not giving to wait for others and being able to work independently" (Student 1)

> "We see firsthand science in real life. The aquatic center [fish farm] is a major part of the science block" (Student 2)

Thomas Falls exemplified a partnership in learning. Both students and staff were beneficiaries in an integrated curriculum where new boundaries of knowledge with STEM applications were explored. The project-based, integrated learning opportunities align with effective science teaching as advocated by Dowden, 2007; Wallace, Venville & Rennie, (2005). It also indicated the level of professional development teachers were able to benefit from. The mobilization of staff with different curricular specializations and theoretical understandings to establish a worm farm was an enlightening and significant professional learning experience. The students clearly engaged in authentic science, technology and mathematics learning underpinning the preparation and delivery of a product to the community. The flow-on learning outcomes for the community were also evident through the raising of awareness of the benefits of recycling waste to produce valuable resources for agriculture. The partnership also provided a source of material for the hardware store owner who sold the worm casts at a profit to the community. Given the geographic remoteness, but closeness of the community, the establishment of the partnership was entirely through local negotiation, involving community personnel (many of whom would have had children at the school). The evidence of strategic planning as a methodology was clearly evident in the formalization

Figure 2. Feeding and harvesting the worm farm

of a management committee involving students, teachers, support staff and community members such as the managing director of the local distributor. As indicated above, implementation was done in collaboration with the community and involved most departments within the school. The staff and students listened to the needs and views of the community, which they built into their operational plan. These features exemplify Walsh's characteristics of effective implementation of partnerships.

Discussion and Conclusions

The current article focuses on the establishment of partnerships and the range of approaches adopted. Partnerships with industry and the community have been driven by an acknowledgment and imperative that schools are not producing the graduates that industry needs, whether they be in vocational education or higher education. The US skills gap report (Eisen et al., 2005), the UK Confederation of Business (Nathan & Bolton, 2010), Canada (Sharpe, Arsenault, & Lapointe, 2008) and others have argued that educators must emphasize science, mathematics and technology-related programs in school curricula, invest more in effective teacher education focused on science and mathematics, and ensure that programs regarding career opportunities and requirements for graduation are geared for 21st century employment (Eisen et al., 2005; Nathan & Bolton, 2010; Sharpe, Arsenault, & Lapointe, 2008). However, they have also acknowledged a role for industry to work collaboratively to address the demand for STEM skilled workers (Nathan & Bolton, 2010; Eisen et al. 2005; National Science Board, 2010; Obama, 2010). Hence, numerous initiatives have been based on partnerships enabling employers to advise youth about making the right career choice and to assist young people to understand different career options through workplace experiences. The main partnership agenda has been through supporting transitions from formal education into the workforce. The four examples we have profiled above bring an alternative perspective and one that focuses on the capacity building of staff and enriching the learning experiences of students. These are representative of a limited number of successful innovations that emerged through the policy innovations around STEM and were sustained over a number of years. However, there were failures which were predictable, but a discussion of these is beyond the scope of this paper.

Bluepoint State High School was substantially funded to explore new technologies and environments to engage students in higher level mathematics and science. As Walsh (2007) has argued, strategic planning was essential and manifested through dynamic leadership within the school and a responsive industry partner. A close relationship among the mathematics teachers, science teachers, industry experts and community facility managers provided a rich context to develop and apply the pedagogical approaches supported by contemporary educational theory, namely student-centred, constructivist and inquiry-based learning. This did not happen without a unified sense of purpose focused on enhancing engagement in STEM. As Bailey (1994) argued, this coalition of interests from a range of stakeholders was foundational to the sustainability of this partnership. The flow-on effect was significant as the science and mathematics teachers developed their expertise, which they shared with colleagues through professional development initiatives and conference presentations. Dissemination of quality teaching is aligned with achieving the highest standards of professional excellence. The enhanced expertise and professionalism lifted expectations on Bluepoint students to achieve success in STEM. The industry and community partners benefited through exposure of their products (e.g., data loggers) and facilities (e.g. Fantasy World) and the capacity to draw on their experience with Bluepoint to advance their commercial interests.

Capacity building and focused strategic planning targeting STEM across stakeholders from different sectors (industry, schools and government) were central principles underpinning partnerships involving both Hi-Tech Network Alliance and Camelot Primary School (Walsh, 2004; Bailey, 1994). The establishment of a large scale Hi-Tech Network Alliance of schools over a decade with substantial support from administrators, industry, community groups and universities, and driven by passionate and committed educators, has enabled major educational innovations to be developed which are, again, aligned with the local community. The alliance in partnership with industry demonstrates how schools and education can respond to contemporary economic priorities by raising awareness of the scope of careers in the mineral resource industry. It was then able to capitalize on this industry to enhance pedagogical practices in the classroom.

The Camelot Primary School represents a particularly interesting example being focused on younger children and challenging the disengagement of children from STEM at this age. If students are to achieve a lasting interest in science and retain opportunities to pursue careers in STEM, then high quality primary science is essential and a challenge to those concerned with STEM. Camelot took up this challenge and though a clear, locally based partnership with parents, university and research academics, and other schools, achieved extraordinary results in a short period. Those aspects of effective partnerships, especially the negotiation of a focus, establishment of a clear and shared vision, and the realisation of benefits for all partners, set the foundation for effective implementation.

Thomas Falls provided a further example in which an integrated and purposeful initiative engaged students of all abilities and interests in a common goal. The exploitation of waste material through the development of a large scale worm farm (the products of which were sold to the community) provided an authentic and highly motivating educational experience. The small, close knit community worked in harmony with the school in ways that reinforced the importance of community involvement in guiding education and developing shared visions for what youth could achieve. The principle of subsidiarity was highlighted in this partnership (Walsh, 2004). The geographical isolation meant that relationships between the school and the community were close, and organization thus lay within the community independent of the educational bureaucracy or large industry management. Indeed, the students themselves were seen as competent managers of the partnership.

Partnerships are only as good as the individuals involved and their willingness to change practices. The successful establishment of the four partnerships discussed could be attributed to the depth of passion of the leaders, but also the organization within schools, community and industry to support and prioritise these initiatives (Berry, 2007). In all cases, the initiatives drew on teachers who had developed trusting relationships with industry or their community and were prepared to learn from their partners. Principals were prepared to support partnerships and accept innovation (Eacott, 2008). Reciprocally, industry and the community were prepared to meet schools half way and provide real opportunities to align their goals with those of the school. Thus, partnerships appropriately managed and supported can address the need for more authentic pedagogical practices that make STEM interesting, engaging and relevant for students, thus grounding a potential career in STEM. The partnerships illustrate that adolescents can engage with STEM where the experiences are relevant to their lives. Integrating STEM into the lives of students requires visionary school leaders, authentic experiences and community partnerships. Laying a solid foundation for STEM in the early middle years of schooling is essential if students are to pursue an interest in STEM beyond the compulsory years of schooling.

Establishing the impact of the partnership on the long term outcomes was beyond the scope of this study. Neither was there an intention to compare models in terms of outcomes as each set out to achieve different purposes. For example, partnerships towards learning provide opportunities and resources whereas partnerships in learning involve close liaison at the level of teaching.

The intention of this paper was to provide examples of partnerships around STEM, and therefore raise awareness of some of the key principles drawn from the literature on effective partnerships as judged by their sustainability and capacity to engage students. Follow-up studies are needed to investigate whether partnerships such as those described help students to pursue careers in STEM and the impact on teacher capabilities. Our current research is examining some flow-on effects of such partnerships. We do know that a number of the teachers who were key participants in these partnerships have been recognized through teaching awards or have been seconded to leadership roles where their expertise has been valued.

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Dr Jim Watters is an Associate Professor in Education at the Queensland University of Technology, Brisbane, Australia. His

teaching and research interests lie in science, mathematics and technology education. A focus of his research is on how professional knowledge is acquired, practiced and disseminated. This includes the practices of teachers in schools and universities and how institutions such as schools build relationships with knowledge experts to enhance the learning of students. He has published over 70 research papers in these fields and has supervised in excess of 30 doctoral students in researching related aspects of education in STEM.

Dr Carmel Diezmann is a Professor and Assistant Dean (Research) in Education at the Queensland University of Technology, Australia.

Her professional practice and research is highly collaborative including colleagues, graduate students and teacher practioners. Carmel is a prolific publisher and has produced numerous STEM-related articles, curriculum books, DVDs and videos to support preservice and inservice teachers to plan, implement and evaluate effective mathematics and science programs in the early years and in school. Carmel is particularly interested in how researcher and teacher capacity can be fostered and the synergy between these professional partnerships.