VOCATIONAL EDUCATION IN SCIENCE TECHNOLOGY, ENGINEERING AND MATHS (STEM): CURRICULUM INNOVATION THROUGH INDUSTRY SCHOOL PARTNERSHIPS

James J Watters and Clare Christensen
Faculty of Education, Queensland University of Technology
Brisbane, Australia

Abstract: Governments have recognised that the technological trades rely on knowledge embedded traditionally in science, technology, engineering and mathematics (STEM) disciplines. In this paper, we report preliminary findings on the development of two curricula that attempt to integrate science and mathematics with workplace knowledge and practices. We argue that these curricula provide educational opportunities for students to pursue their preferred career pathways. These curricula were co-developed by industry and educational personnel across two industry sectors, namely, mining and aerospace. The aim was to provide knowledge appropriate for students moving from school to the workplace in the respective industries. The analysis of curriculum and associated policy documents reveals that the curricula adopt applied learning orientations through teaching strategies and assessment practices which focus on practical skills. However, although key theoretical science and maths concepts have been well incorporated, the extent to which knowledge deriving from workplace practices is included varies across the curricula. Our findings highlight the importance of teachers having substantial practical industry experience and the role that whole school policies play in attempts to align the range of learning experiences with the needs of industry.

Keywords: vocational education, industry school partnership, work transition, workplace education, STEM

INTRODUCTION
It is widely recognised that student interest in science and mathematics and related subjects (e.g., STEM) is low (e.g., Osborne, Simon, & Tytler, 2009; Osborne & Dillon, 2008). Osborne and Dillon acknowledged that while there are shortcomings in curriculum, pedagogy and assessment, a significant problem has been that school education in STEM has never provided a satisfactory education for the majority and has failed to cultivate the interests of those who might proceed to become scientists, engineers, technologists and trade-related workers. In this paper we document the design of two industry-developed curricula and analyse the alignment of content with the skills and knowledge necessary to appropriately equip students for the school to work transition across two industry sectors.

CONTEXTUAL BACKGROUND
Curriculum development in Queensland is managed by the Queensland Studies Authority (QSA) a statutory body of the Queensland Government. The QSA prepares syllabus documents which are then adopted and implemented in State, Catholic and Independent schools to suit local school needs. School administrators make decisions about which syllabuses to adopt. Implementation relies on teacher judgement in the shaping of curriculum.
work programs, pedagogical approaches and classroom assessment. These principles allow and enable individuals and cohorts to take different routes through the curriculum terrain particularly in the senior years. For a detailed description of these principles see Luke, Weir and Woods (2008). Curriculum development in this jurisdiction adopts a "low-definition" approach to syllabus design based on informed prescription and informed professionalism. The QSA also registers schools as registered training organisations (RTOs), and accredits and recognises vocational education and training courses as a part of the overall school curriculum. Three levels of subjects are available to students in the senior years 11 and 12: Authority subjects (for university entrance), registered subjects and vocational subjects (both for non-university pathways). All subjects contribute credit to the state’s school leaving certificate – Queensland Certificate of Education (QCE). Vocational school subjects contribute towards Certificates which may lead beyond school years to formal trade qualifications which are the responsibility of TAFE (Technical and Further Education) colleges and private RTOs. A recent innovation, however, has been the introduction of School-Based Apprenticeships and Traineeships, which run alongside other QCE subjects. These involve a contract between student, parents, principal and the employer and the student is considered to be both a fulltime student and an apprentice or trainee. Donnelly (2009), in a review of the literature focussed on the alignment of school curricula with vocational educational needs, has argued that “that the vocational aspect of the school curriculum is less well understood, and more locally conditioned, than are its traditional academic forms.” (p. 226). He asserts that there is limited research examining how students are best prepared for a vocational career. One such attempt to address vocational education centred on STEM has been developed in the state of Queensland, Australia. The Queensland Government has set in place a number of initiatives to stimulate the development of a highly skilled workforce to support the growth of Queensland’s expanding knowledge-intensive industries. One initiative was the establishment of school-industry partnerships across a number of industry sectors (Kapitzke & Hay, 2007; Watters, Hay, Pillay, Dempster, 2013).

The establishment of partnerships between educational providers and industry is argued to be an important strategy for optimising and sharing new knowledge. In 2004, the Queensland Government established the Gateway to Industry Schools program. This program is a key policy strategy aimed at knowledge transfer and features 1) a public system-wide approach, 2) multiple sectors (i.e., state, Catholic and Independent schools) and global as well as local industry partners, and 3) an inclusive focus on student learning, including both students transitioning into higher education and those moving directly to skilled employment. Around 25% of Queensland schools host Gateway Schools to Industry partnerships across six industry sectors: Agribusiness, Aerospace, Manufacturing and Engineering, Building and Construction, Minerals and Energy and Wine Tourism. We focus on curricula related to two partnerships: Minerals and Energy and Aerospace.

In this paper we set out to (1) document the design of curricula developed collaboratively by schools and industry to appropriately equip students for the school to work transition and (2), document the affordances and constraints in the implementation of these curricula. We explore how these curricula provide opportunities for students to select relevant individual pathways.

THEORETICAL FRAMEWORK

In our approach we focus on the concept of opportunity, drawn from an analysis of the relationship between educational opportunity and educational gains reported by Houang and
Schmidt (2008). The word opportunity is defined as a favourable set of conditions that afford chances for individuals to achieve personal goals. It also refers to the chance that educational policies are provided with conditions whereby they can gain traction. Schmidt and colleagues (e.g., Schmidt & McKnight, 1995; Schmidt et al, 2001), in a series of studies of the Third International Mathematics and Science Study (TIMSS), have argued that education policies directly manipulated through curricular resources shape schooling in ways that align with national priorities. Thus students exposed to particular curricular implementations should learn about particular topics emphasised in those curricula. However, the curriculum experienced by the student is often at odds with the planned curricula and the opportunities to achieve intended outcomes are thwarted (Fullan & Pomfret, 1977; Hume & Coll, 2010; Keys, 2007). To investigate the alignment of curricular intentions and outcomes of the Gateway project, we focus below on four dimensions of opportunity: the nature of the curriculum, what teaching practices are employed, what knowledge is valued and to what extent the intended goals are attained through the delivery and assessment of appropriate content.

**Appropriate curricula**

In its broadest interpretation *curriculum* defines all the learning which is planned and guided by the school, whether it is carried on in groups or individually, inside or outside the school (Kelly, 2009). We use the term *appropriate* to emphasise the extent to which the formal course structures and resources attempt to achieve the intentions of the Gateway project, that is, are they suitable for achieving the Gateway goals of equipping the next generation with the skills and knowledge to make the transition from school to further education or work and fill the skilled jobs of the future.

A curriculum which is appropriate for facilitating school to work transitions would incorporate the following:

1. a clear and consistent focus on *applied learning* in terms of approaches to teaching and assessment processes
2. a clear representation of the workplace practices of the trade concerned
3. a strong focus on embodied, embedded, encultured and encoded knowledge related to the trade, alongside the required embrained knowledge

In conceptualising what knowledge is important for workplace-related curricula, and how it can be framed, we refer to the work of Blackler (1995) whose approach based in the organisational and management literature sees learning as a process of knowledge management. Blackler described five knowledge dimensions represented in workplaces and organisations, which we adopt here: embrained, embodied encultured, embedded and encoded (Table 1).

<table>
<thead>
<tr>
<th>Knowledge type</th>
<th>Manifestation</th>
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<tbody>
<tr>
<td>Embrained</td>
<td>Conceptual knowledge – inert, declarative, “knowledge about”.</td>
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<tr>
<td>Embodied</td>
<td>Practical skills dependent on context – functional, “knowledge how”</td>
</tr>
<tr>
<td>Embedded</td>
<td>Understanding the routines and systems of operation or workflow “conditions”</td>
</tr>
<tr>
<td>Encultured</td>
<td>Discourses of the field – knowledge of the context “culture”</td>
</tr>
<tr>
<td>Encoded</td>
<td>Knowledge captured in code – books, signs, manuals.</td>
</tr>
</tbody>
</table>
**Appropriate teaching practices**

The way that planned curricula are adopted by schools and implemented depends on many factors not least the history (Goodlad, 1995), beliefs (Keys, 2007), and previous work experience of teachers (Diezmann & Watters, 2013) and the resources and priorities of teachers and administrators. Subject matter knowledge and knowledge of how content is applied are important contributors to effective teaching (Darling-Hammond & Youngs, 2002). Teachers with good subject matter knowledge and knowledge of the intent of the curriculum are able to go beyond the prescribed content and involve students in meaningful and experiential learning. Appropriate teaching practices for facilitating school to work transitions should include practices in which students are afforded opportunities to:

1. visit worksites
2. explore how theoretical knowledge is applied in industry and
3. acquire a sense of purpose in their learning.

For those teachers whose background has been in traditional disciplinary teaching, achieving a change in perspective when teaching courses aimed at industry or workplace related outcomes can be challenging.

**Appropriate assessment**

Traditionally teachers are guided by assessment and reporting frameworks embedded in curricula. The majority of teachers trained in teacher education institutions are familiar with the assessment strategies adopted in traditional STEM subjects. These normally are centralised examinations or even where school based assessment exists, the assessment practices rely on students’ attainment of certain knowledge with limited focus on practical applications of this knowledge. However, teachers require a different understanding of assessment practices for curricula designed to address vocational education and skill development. Most vocational training providers use competency based assessment frameworks in which authenticity is paramount. Gulikers, Bastiaens and Kirschner (2004) argue that authentic assessment requires students to demonstrate relevant competencies through meaningful tasks.

**METHODOLOGY**

A case study approach was adopted here to examine how industry partnerships impact on factors affecting student learning outcomes such as curriculum, teaching practices and forms of assessment. Our analysis explored the alignment of curriculum between the needs of the workplaces of the partner organisations and student career aspirations. Our focus was on subject offered in years 10-12, including those prescribed for academic pathway students and those not likely to progress to higher education. We probed four areas: understanding of the partnership goals, curriculum and pedagogy, knowledge transfer, and student outcomes. Typical cue questions included “How do you understand the mission of the Gateway Schools programme and the role you play in helping to attain these goals?”, “Tell us about activities in classes in the Gateway programme and how they are similar to/different from ones not in the programme.” And “What knowledge is regarded as ‘relevant’ for students entering this industry? Who has made this decision and how was this done?”

Primary data were derived from (a) observations of stakeholder meetings in each industry project, (b) interviews with key stakeholders including principals, teachers, vocational education coordinators, industry personnel and staff from the various coordinating
institutions and (c) site visits to document resources, observe classes and conduct focus group interviews with students. Secondary data were obtained from websites, policy documents, curriculum and syllabus documents and teaching materials. Observational data including participating in meetings and site visits were recorded in memos supplemented with photographs where appropriate. Interviews were audio recorded and transcribed, then coded using NVivo software to conduct a content analysis (Richards, 2009). Codes were grouped into themes which reflected the underlying theoretical framework.

**FINDINGS**

**Case 1: Minerals and Energy**

The Minerals and Energy project involves a partnership between 28 government and independent (private) schools and companies in the Minerals and Energy sector. Most of the industry partners are large international mining and electrical utility companies. A coordinating body the Queensland Minerals and Energy Academy, (QMEA) links the partnering groups Skills Queensland (a government body) and the Queensland Resources Council (an industry peak body). QMEA manages the project and funding is provided both by government and industry. Drawing on the framework of educational opportunity we now report on the three dimensions: curricula, teaching practices and assessment.

**Appropriate curricula**

The partnership provides a wide range of formal and informal opportunities for students to engage with the mining industry involving work experience, trade qualifications, camps and scholarships. These activities collectively meet the criteria for appropriateness outlined earlier and are listed here:

- Certificate I and II in Resource Infrastructure Operations
- Certificate I and II in Process Plant Operations
- Certificate II in Engineering
- Context based modules on power generation in Senior Physics
- QSmart Year 11 and 12 subjects
- Annual Engineering camps in mining locations
- Tours and excursions to mines, power stations, skills centres, TAFEs and universities
- Work experience and training in jobs, trades and professions on sites across the State
- Access to industry mentors to address classes and conduct industry standard training in short courses, traineeships and apprenticeships
- Engagement with tertiary students in a range of workshops related to the industry
- Apprenticeship aptitude test training for those aiming to gain apprenticeships in the resources sector
- Engagement through robotic and Arduino programming activities and teacher professional development
- Scholarships and awards for students to encourage further engagement in the resources sector.

Although the schools offer a range of subjects that provide a pathway to trade careers, we focus our analysis here on one subject that is distinctive in that it was developed in collaboration with industry. The subject, titled *Science, Maths and Related Technologies for Engineering and Electrical School-based Apprentices* (or QSMART), and developed by QMEA (QMEA, 2010) is delivered over two years. The content is aimed at providing a pre-vocational grounding in topics relevant to electrical and related trades by integrating a range
of topics drawn from mathematics and science. Each subject contributes two credit points out of a minimum of 20 credit points towards a student’s senior school Certificate of Education but not for tertiary entrance consideration.

The development process involved a team of industry consultants including engineers, trade apprentice trainers in the electrical trades and school teachers consulting on an initial draft. Industry was concerned that a sufficiently rigorous subject was needed that provided both theoretical and practical content as well as providing opportunities for the development of employability skills, which must be explicitly taught (QMEA, 2011). Such skills included communication, planning, organising, problem solving, technology, initiative, enterprise, self-management independent learning capacity and team working. The course was implemented at Dragline and Black Mountain State High Schools. The consulting industry groups made a commitment to QMEA schools and their students that they would recognise the results of QSMART for entry into Engineering and Electrical apprenticeships, as equal to the results of existing senior QSA Mathematics and Science programs in their recruitment procedures. The scope of the course is outlined in Table 2. It has a strong emphasis on key theoretical understandings (embrained knowledge) with opportunities and expectations that this knowledge will be further developed through practical tasks (embodied knowledge).

Table 2

*QSMART course objectives and content*

<table>
<thead>
<tr>
<th>General objectives</th>
<th>Conceptual content organisers</th>
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<tbody>
<tr>
<td>Year 11 Course</td>
<td>The Mathematical Toolbox</td>
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<td></td>
<td>• Numeracy</td>
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<tr>
<td></td>
<td>• Measurement</td>
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<td></td>
<td>• Algebra for Engineering and</td>
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<td>Electrical trades</td>
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<td></td>
<td>• Finance</td>
</tr>
<tr>
<td></td>
<td>The Scientific Toolbox</td>
</tr>
<tr>
<td></td>
<td>• Dynamics</td>
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<td></td>
<td>• Materials</td>
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<td></td>
<td>• Electricity</td>
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<td></td>
<td>• Electrolysis and Corrosive</td>
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<td>Environments</td>
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<td></td>
<td>Year 12 Course</td>
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<tr>
<td></td>
<td>The Mathematical Toolbox</td>
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<tr>
<td></td>
<td>• Numeracy</td>
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<td>• Measurement</td>
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<td>• Algebra for Engineering and</td>
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<td>Electrical trades</td>
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<td></td>
<td>• Finance</td>
</tr>
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<td></td>
<td>The Scientific Toolbox</td>
</tr>
</tbody>
</table>

Appendix 1: QSMART course objectives and content
students can use a broader range of more sophisticated every day and trade-specific language, symbols, diagrams and conventions of mathematics and science to communicate responses to Engineering and Electrical trade-related tasks.

- students can demonstrate skills in communication, planning and organising, problem solving, using technology and self-management; and demonstrate initiative and enterprise, the capacity to learn independently and the ability to work effectively in a team at an Industry standard.

- Dynamics
- Materials
- Electricity
- Electrolysis and Corrosive Environments

**Appropriate teaching practices**

Students valued the content of the subject and how it was taught and spoke frequently of its perceived practicality. For instance, in a focus group discussion with students, one girl who was planning on becoming a diesel fitter discussed learning about “cogs and ratios” which she recognised to be relevant to her career intentions. Another boy commented that the ratios lessons gave him insights into the operation of lathes which was part of a Certificate in Engineering he was concurrently studying.

Teaching expertise was the focus of much concern, for two reasons. First the turnover of teaching staff in remote mining locations is high. Often beginning teachers are assigned to remote schools but choose to remain for short periods. Thus there is a lack of continuity and experience. In both case study schools, over a three-year period the subjects had been taught by several teachers.

Second, a lack of industry experience and knowledge can limit a teacher’s capacity to link the classroom content to its workplace setting. For example, the teacher at Dragline SHS, although in his fifth year of teaching, was a novice in teaching QSMART. He noted that in planning, implementation and assessment, he was left to his own devices. However, this freedom created some concerns. He was a teacher who had moved from a coastal town and had limited experience of the mining context:

> I definitely feel inexperienced in that area. I’m quite comfortable with the curriculum content of the subject, but drawing those links - I’m very new to the mining town. Prior to moving to Dragline SHS I had very little knowledge about the process of mining. So I’m finding that’s where I need to put the bulk of my work in. It’s not learning the content, but learning how to link that content to the actual processes that happen in the mine. …

A third concern was that, although there was support from the mining industry for the activities (listed earlier), direct links of benefit to QSMART were absent.

**Appropriate Assessment**

Teachers in both Year 11 and 12 QSMART courses are provided with a comprehensive guide to assessment, with a strong focus on using it formatively to guide students in their learning and contextualising to industry as many as possible of the assessment tasks. These tasks should be meaningful to students in terms of contemporary workplace practices.

The formal assessment in both courses involves four components: a supervised examination, a practical project, a portfolio and a workplace learning journal. The supervised examination provides a formal assessment of key concepts and thus represents assessment primarily of
embrained knowledge but contextualised to the electrical trades (Table 3). The portfolio is concerned with proficiency in different forms of communication. The workplace journal aims to provide evidence of proficiency with workplace practices. The practical project provides scope for students to demonstrate their understanding of the concepts by application to a practical task (embodied knowledge). For example, they are asked to choose suitable materials for a particular construction task, drawing on both theoretical and practical knowledge to justify their choices.

**Case 2 Aerospace**

Aerospace is a partnership between 26 schools and aerospace industry firms, training institutions and universities. The aim of this project is to create pathways for students into Queensland’s growing aerospace industries. Industry partners include Boeing Defence Australia, Brisbane Airport Corporation, GE Aviation, the Guild of Air Pilots and Air Navigators, Qantas and Virgin Airways. Central to the partnership on the industry side is a major international aviation training organisation Aviation Australia, owned by the Queensland Government.

A key school in this partnership is an industry-dedicated state high school established in 2007. The first principal was appointed from the aviation training organisation and staff committed to aviation were employed. Its mission is, in partnership with tertiary and post school training providers, “to establish an end to end education model from the classroom to employment with the industry” (Annual report, 2011).

**Appropriate curriculum**

This school embeds learning experiences focussed on the aviation industry from Years 8-12. For example, subjects Aerospace Communication and Aeroskills Technology are offered in Years 8, 9 and 10. Teachers of other subjects are encouraged to contextualise their work through aviation where possible; for example, a Year 10 English class runs a school-based radio program called ‘Wingspan Radio’. These subjects are considered important in helping students to become aware of the aviation industry before they consider pathways in the senior years, when the following subjects become available. Opportunities to learn about the aerospace industry are provided through three Year 11 and 12 subjects designed in cooperation with industry (Table 3). Aerospace Studies, a QSA Authority subject, produced in 2006 and revised in 2011 provides credit towards entrance to university. Aeroskills Studies, a QSA Registered subject provides credit towards the senior school Certificate of Education but not tertiary entrance. A Vocational Education Training subject, Certificate in Aircraft Maintenance Engineering, contributes four credit points towards the senior school Certificate of Education. Complementing these three subjects, students studying various science subjects including Biology and Physics examine aspects of disease management, quarantine issues, the environmental management of flora and fauna around airports, jet propulsion and aircraft crash reports. Business studies students explore practices of running airlines supported by industry personnel.

The development of the Aerospace studies, the flagship subject, was done in collaboration with a range of industry partners. The philosophy was that content related to the aviation industry was to permeate all subject areas from Year 8 to Year 12. Most students enrol at this school specifically because they are interested in Aviation. For some that involved substantial travel or living away from home.
Aerospace Studies and Aeroskills Studies both cover the principles of aerodynamics, but Aerospace Studies also includes topics on airline management and business practices. This subject was described by one teacher as “a quite academic subject” and is recognised as appropriate for students proceeding to university where they can extend their studies. For instance, one local university offers a qualification, Bachelor of Aviation. In contrast, Aeroskills Studies has a strongly practical focus, including designing, making and testing model aeroplanes. This subject grew out of teacher and student extra-curricular interest in model planes; these activities are ongoing and students now participate in national model plane competitions. The third subject, Aircraft Maintenance Engineering, also involves both theory and a large component of practical work, all undertaken at an industry site and contributing to an Aeroskills Certificate IV through the adult vocational training and education authority. As an economic priority area, the Course in Aircraft Maintenance Engineering has been fully funded by the Queensland Government with no fee costs to the students.

Table 3

Aerospace Curriculum offerings

<table>
<thead>
<tr>
<th>General Aims/Objectives</th>
<th>Aerospace Studies</th>
<th>Aeroskills Studies</th>
<th>Aircraft Maintenance Engineering (AME)*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General Content</strong></td>
<td>Aeronautics and astronautics including meteorology, aircraft systems and historical developments. Aviation operations including aircraft traffic management, airport and airline operations. Safety management systems including policy and legislation. The business of aviation and aerospace including organisational structure and HR management</td>
<td>Introduction to the aircraft maintenance/construction industry Safety in the aircraft industry workplace Basic aerodynamics, aeroplane aerodynamics and flight controls Selection and application of hand and power tools Maintenance practices Basic aircraft hardware Basic aeroplane structures and aircraft materials Propulsion systems Propeller fundamentals Basic electrical and electronics systems</td>
<td>To prepare senior secondary students for a career as an aircraft maintenance engineer</td>
</tr>
</tbody>
</table>

**Appropriate teaching practices**

The principal acknowledged the challenges delivering a curriculum that was so intensely focussed on a particular industry. However, he argued that there were two circumstances in his favour. First, having described the network of partners and commitment from industry he
argued that the school was developing a reputation and that second, in contrast to normal practices he had been given the authority to hire staff and exercised this authority to recruit teachers with industry experience, albeit not necessarily secondary teachers:

I think probably though, it is those personalities that are part of our school that will make those connections be maintained, that is you know from one teacher who is a Glider Pilot … I’ve got another teacher who’s training for his private Pilot’s license, I’ve got another teacher (primary) who is from the air force as an aircraft mechanic and they’re part of the teaching team. .. If staffed by ordinary teachers, dare I say it, ordinary teachers then it’ll probably still function quite well but it’ll not be as impressive as it could.

The teacher of Aerospace Studies believed he had the content “in his head” (embrained knowledge) and so he could focus on student learning and providing practical and realistic experiences (embodied knowledge). This was evident in the way he explained his teaching of air flow over aerofoils: “you still get all of those misconceptions coming in, so I find that's something I really get down to hands on and using the aerofoils, using the smoke; many different ways that I can describe it and explain it to try and get through”. Students in particular acknowledged the credibility of teachers as one student commented, “Teachers who deliver will be for the most part are ex aviation … which is really really good as it gives us insight into aviation”. Another student acknowledged that because students were so motivated teachers adopted a “fluid instruction” approach suggesting that the teacher responded to the specific needs of students. Students agreed that “The teachers’ experiences come across in the stories and the way it (material) is presented”. The teachers were seen to have substantial theoretical (embrained) knowledge but it was their depth of understanding and embedded knowledge of the industry that mattered.

**Appropriate assessment**

In Aerospace Studies students do exams, research-based written assignments and an investigation project presented as a report. As an example students investigate empirically the properties of wind and aerofoil shapes using NASA designed software and wind tunnels. For some students, the course provides an opportunity for students to sit for an exam to acquire a permit to train for an aircraft flying licence. Aeroskills Studies assessment is dominated by practical activities involving manufacturing models of wings and other aircraft components. Opportunities to extend knowledge are done through extracurricular competitions. In the Aircraft Maintenance Engineering program, an assessor from industry visits to monitor teaching and undertake assessment tasks. Much of the practical assessment is done in workshops with resources including a Cessna plane, wind tunnels and other aviation engineering tools. Assessment meets criteria that are set by either the QSA or industry standards. As most students study all three subjects, there is considerable integration of knowledge with opportunities to apply information learnt in the more theoretically oriented subject (Aerospace Studies) in practical situations in Aeroskills Studies and AME.

**DISCUSSION**

The focus of this study was the substantial challenge of facilitating the sharing and transfer of knowledge from industry to schools. The two case studies are not necessarily representative of all schools participating in the respective Gateway projects. Indeed, these are the more successful examples in part because they are contiguous with the operational face of the
industries. That is, the mining schools are directly located above rich mineral deposits and the aviation school is essentially on the flight path of a major international airport. This close physical proximity to the respective industries has facilitated networking and close personal relationships among stakeholders at the local level. Although this situation is particularly the case for the aviation school, there are qualifications for the mining schools where staff turnover is substantially higher.

In principle, industry school partnerships in which curricula are co-developed provide opportunities for contemporary knowledge transfer. In both cases subject outlines revealed a clear and consistent focus on *applied learning* in terms of approaches to teaching and assessment processes. In the aviation case the curriculum was taught by a team of teachers with substantial theoretical and practical knowledge. As former employees of the defence forces and with pilots’ licences and mechanical experience these teachers brought considerable embrained, embodied, embedded and encultured knowledge to the classroom. They provided clear links between the theoretical aspects of aviation and the practice.

By contrast, in QSMART, despite industry input during design, it was difficult to identify concepts and processes which would directly represent the *workplace practices* of engineering and electrical trades. The science and mathematics concepts listed in the outlines would appear unchanged in the traditional curriculum for Years 8-10 and include some general applications of the kind that science and maths teachers often include, rather than new concepts or processes derived from engineering or electrical workplaces. Hence, the focus was clearly on the development of embrained knowledge.

Constraints to knowledge transfer may exist in the capacity of teachers to apply their pedagogical and content knowledge to specific industries. The QSMART teachers were highly competent in teaching traditional science and mathematics but lacked understanding of how and where the concepts might be applied. Thus there were shortcomings in embodied, encultured and encoded knowledge – that is the practical on-the-job knowledge that represents the application of theory. Teachers with appropriate industrial experience would appear to be critical to the success of industry school partnerships. In the aviation case this condition was well met. In the mining context this constraint was felt in the QSMART subject, but students were very well provided with industry contact by a wide range of activities; thus the impact of this limitation may have been lessened.

Assessment strategies in the practical subjects described here are strongly mandated by industry and QSA and in most instances assessment was aligned to industry requirements. This was less obvious in QSMART. The involvement of industry personnel needs to be strengthened in those instances where teachers have limited familiarity with the needs of the industry, particularly as industry approaches to assessment are usually based on an unfamiliar competency model.

**ACKNOWLEDGMENTS**

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