STEM
Science | Technology | Engineering | Mathematics

Interim review of STEM education in Queensland state schools

February 2016

Queensland Government

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Introduction

The study and practice of science, technology, engineering and mathematics is commonly known as STEM.

STEM is vital for today's society to continue to develop and meet its needs; however, student enrolment in STEM subjects at school is declining in developed countries such as Australia. With an estimated 75 per cent of the fastest growing occupations requiring STEM-related skills and knowledge,[1] the decline in enrolment impacts on students' future STEM career choices and their understanding of the influence of STEM areas when making decisions in their lives and society.

Most STEM education research has focused on science and mathematics, with technologies used to enable learning in these areas. The use of design-based learning in other areas of STEM is a relatively recent area of research that indicates students can draw on engineering thinking to develop higher levels of understanding, participation and achievement across STEM subjects and in other fields.

Improving student engagement and achievement in STEM at school and throughout their lives requires a range of strategies across all years of schooling and the elements of STEM. In particular, research and implementation of best practice approaches for building teacher capability in STEM will be integral to improving student participation and achievement.

Issues for future investigation

Student enrolment

- Student enrolment and achievement in post-compulsory STEM subjects require students to be engaged and developing their competency and literacy in STEM areas from their early schooling years. Confident primary teachers using student-centred strategies are integral to encouraging student engagement and achievement in later years.

STEM literacy

- Literacy initiatives need to be supported as language is critical for students to develop their understanding of STEM through activities such as argumentation and analysis of scientific texts.

Teacher capability

- External STEM partnerships should be expanded as these enhance teacher capability, student engagement and student participation. Partnerships also provide students with real-world examples of the role of STEM in society.

- Teacher self-efficacy, content knowledge and professional development in pedagogical strategies specific to each STEM area needs to be strengthened and nurtured.

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[1] Ernst & Young, 2015. Megatrends 2015: Making sense of a world in motion. [Online] Available at: http://emergingmarkets.ey.com/wp-content/uploads/downloads/2015/02/248.-ey-megatrends-report-2015.pdf [Accessed 2015].

Student participation

- STEM studies should be relevant to the real-world context to help engage students, including by connecting their existing knowledge with new STEM knowledge.

- Strategies to target students who are underrepresented in STEM (for example females) should be reviewed at a senior schooling level and in professional fields (for example engineering and ICT professions). Revise existing programs or develop new initiatives based on review results.

Lifting student achievement

- Inquiry-based and constructivist learning approaches are needed to support student achievement and make school STEM subjects relevant to students' real world experiences. The use of technologies, engineering thinking and design-based learning should be promoted to support student improvement.

Background

STEM is an important contributor to the Queensland and national economy. Similar to other developed countries, student enrolments in STEM subjects in Queensland have declined in the last two decades from around 90 per cent of Year 12 students studying science subjects in the early 1990s to under 50 per cent in 2011. In particular, from 1992 to 2012 participation rates for specific science subjects fell by 10 per cent for biology, 5 per cent for chemistry and 7 per cent for physics as a proportion of the total Year 12 cohort (Office of the Queensland Chief Scientist, 2014).

STEM capability will play a vital role in the future; therefore, we need to encourage our young people to explore STEM opportunities for their future careers and in their everyday lives.

In 2015 the Queensland Government commenced a review of STEM in state schools to investigate the ways in which STEM is taught and how to improve the connections between research, best practice and existing school practices. The review considered:

- best practice models of curriculum delivery

- effective approaches to build the capability of STEM teachers

- measures to increase student participation, retention and outcomes in STEM subjects

- examples of relationships and programs between schools and real-world STEM practitioners that benefit students, teachers and the community.

The STEM review is due for completion by the end of 2016. The review will highlight key areas for further investigation and action in STEM education in Queensland to support the goals of the proposed *State Schools STEM Strategy.* This strategy will focus on inspiring STEM learning through three key goals:

- building teacher capability

- increasing student participation

- lifting student achievement.

The proposed strategy supports the *Advance Queensland* agenda to create knowledge-based jobs of the future through *Advancing education: An action plan for education in Queensland*, which aims to deliver the best education system and prepare young people to become lifelong

learners. The proposed *State Schools STEM Strategy* will also align with initiatives in *#codingcounts: A discussion paper on coding and robotics in Queensland schools.*

This interim report is based on a review of international research by Griffith University into STEM education and survey responses from around 900 Queensland state schools (primary, special, P–10 and P–12, and secondary schools) about STEM practices in Queensland classrooms. It connects initial research and survey findings with actions and responses that can be undertaken as part of the proposed STEM strategy.

The research findings, current approaches and issues highlighted in this report will guide the direction of the 2016 STEM review and its projects.

STEM Review priority areas

Crossover issues

1. Student enrolment and achievement in post-compulsory STEM subjects requires students to be engaged and developing their competency and literacy in STEM areas from their early schooling years. Confident primary teachers using student-centred strategies are integral to encouraging student engagement and achievement in later years.

2. Literacy initiatives need to be supported as language is critical for students to develop their understanding of STEM through activities such as argumentation and analysis of scientific texts.

3. External STEM partnerships should be expanded as these enhance teacher capability, student engagement and student participation. Partnerships also provide students with real-world examples of the role of STEM in society.

Building teacher capability

4. Build teacher self-efficacy, content knowledge and professional development in pedagogical strategies specific to each STEM area.

5. Ensure STEM studies are relevant to the real world context to help engage students, including connecting their existing knowledge with new STEM knowledge.

Increasing student participation

6. Review strategies to target students underrepresented in STEM (for example females) at a senior schooling level and in professional fields (for example engineering and ICT professions). Revise existing programs or develop new initiatives based on review results.

Lifting student achievement

7. Inquiry-based and constructivist learning approaches support student achievement and make school STEM subjects relevant to students' real world experiences. Promoting the use of technologies, engineering thinking and design-based learning support student improvement.

Key findings across STEM

Crossover issues

Student enrolment and achievement in post-compulsory STEM subjects requires students to be engaged and developing their competency and literacy in STEM areas from their early schooling years. Confident primary teachers using student-centred strategies are integral to encouraging student engagement and achievement in later years.

Current state and research findings

A review of STEM education literature highlights that reform efforts in science education advocate student-centred constructivist learning and teaching approaches to engage students in meaningful science experiences to foster scientific literacy and improve student achievement (McDonald, 2015, p. 16).

Authentic, student-centred, inquiry-based approaches across all STEM areas (for example, game-based learning) are recognised as engaging and motivating for students. Research indicates that students in Prep and early years of schooling can develop computational thinking through the use of computer programming and robotics (McDonald, 2015, p. 8). For mathematics, students can develop their reasoning skills from Prep, while upper primary is a critical time for developing algebraic reasoning and influencing student engagement in mathematics into junior secondary years (McDonald, 2015, pp. 5, 11). Consequently, active, student-centred learning of STEM in primary school is essential for lifelong learning and STEM careers.

However, primary teacher approaches and time spent teaching STEM in the classroom vary from best practice approaches.

Science

Science classroom practices in Prep–Year 2 are most often a mix of teacher-led, active learning and investigating practices (Figure 1), with teacher-led instruction ranked the most frequent practice. Inquiry-based learning and to a lesser extent event-based learning are also common classroom practices.

Figure 1 Science classroom practices in Prep–Year 2, Queensland (by number of schools)
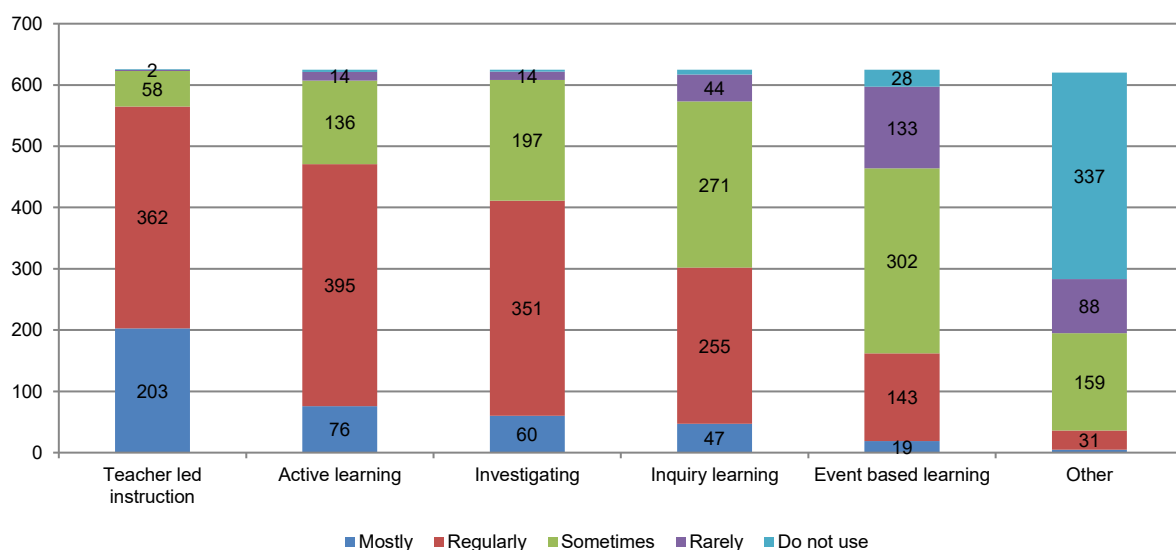
Teacher-centred instruction remains the most frequent practice in science classrooms in Years 3–6, as with Prep–Year 2, along with Australian Curriculum Science Inquiry Skills (Figure 2). Students working in small groups and the predict-observe-explain approach are also regularly used practices. Project-based learning and the 5E instruction model[2] are less used practices in the classroom.

While teacher-centred instruction ranks the highest in primary school science classroom practices, the other practices surveyed collectively support the progression of a constructivist approach to science from early years to upper primary school.

McDonald (2015, p.12) identified a general lack of science content knowledge, low confidence in teaching science, limited science teaching pedagogy, a lack of science-specific qualifications and time limitations as constraints on primary science teachers. These constraints result in teachers less prepared to teach science, less willing to devote classroom time to science and the use of transmissive pedagogies rather than active learning experiences that will engage students. Professional development programs for primary science teachers need to build science content knowledge, science pedagogical knowledge and confidence in teaching science.

Figure 2 Science classroom practices in Years 3–6, Queensland (by number of schools)
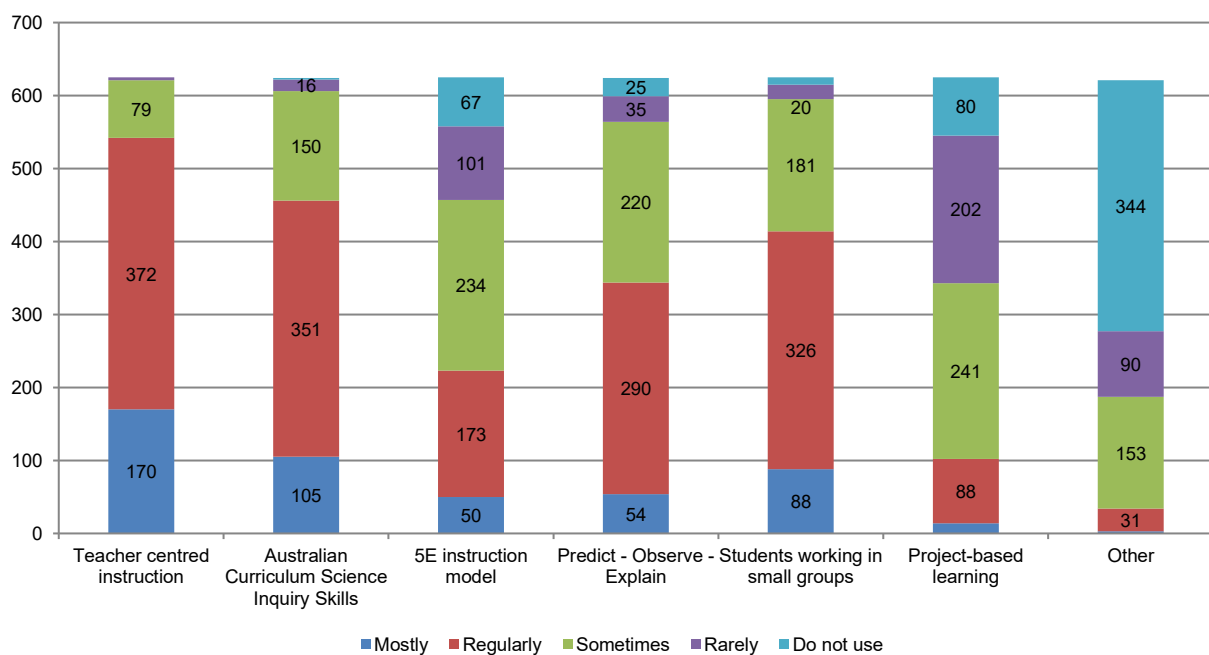
Technologies

Technology use in classrooms can be used as a simple tool in other activities or as an enabler of more complex learning and thinking such as modelling scenarios and simulations. Computer programming is shown to benefit student thinking, attitudes and motivation, particularly in younger students (McDonald, 2015, p. 8).

Most surveyed primary schools teach students technologies as a combination of stand-alone and embedded approaches with a mix of higher and lower level practices. However, in the majority of the responding primary schools coding is not offered in Prep–Year 2 (around 65 per cent) and Years 3–6 (over 80 per cent) (Department of Education and Training, 2015, pp. 292–293). For those surveyed primary schools that do offer coding, it is more frequently

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[2] Teaching and learning progresses through five phases: Engage, Explore, Explain, Elaborate and Evaluate.

undertaken as an extra-curricular activity in Years 3–6, with only a limited number of schools embedding coding or programming into the curriculum.

Mathematics

The classroom practices in primary school mathematics of solving procedural problems, memorising rules, procedures and facts are the prominent practices in the majority of lessons along with the active practice of hands-on investigation of mathematics.

Working independently or working in groups on everyday open-ended problems are also common strategies used in mathematics lessons in Prep–Year 2 but slightly less represented in lessons in Years 3–6 (Figure 3).

Reforms in other countries advocate shifting classroom practices from transmissive teaching approaches, such as memorising rules and procedures (one of the prominent practices in Queensland primary schools according to the survey responses), to more active and collaborative practices to develop students' mathematical capabilities, such as working in groups and students explaining their strategies and justifying results to others (the less frequently used strategies identified in the survey responses (Figure 3)).

Engagement, competency and participation in mathematics during primary school is viewed as essential to develop mathematically competent individuals in a global workforce and participation in post-compulsory mathematics courses. Research supports the positive relationship between high-quality classroom instruction and student achievement, highlighting the importance of building the confidence and capability of mathematics teachers.

Literature provides explanations for why primary school teachers may seek transmissive teaching approaches and what support can be provided to build confidence and content knowledge for teachers of primary school mathematics.

Both mathematical content knowledge and pedagogical content knowledge are considered as essential for effective teaching of mathematics and enabling teachers to present concepts and connect student ideas more effectively (McDonald, 2015, p. 13).

Professional development programs should provide opportunities for mathematics teachers to develop their content and pedagogical knowledge.

Figure 3 Strategies used in teaching mathematics in Years 3–6 (by number of schools)
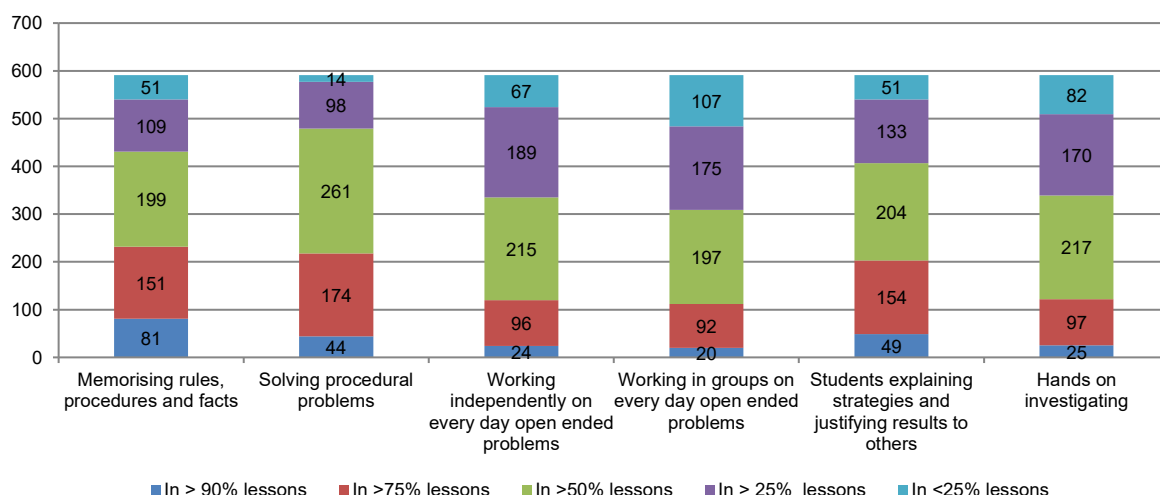
Students with negative attitudes towards mathematics identified school mathematics as lacking relevance to their lives or mathematics was taught using transmissive teaching strategies rather than active learning. A key challenge for mathematics during the transition from primary to secondary school is student disengagement during this period when algebraic reasoning and other challenging topics are taught. Negative student attitudes to mathematics at this time can influence students' decisions about their competency in mathematics and whether to pursue further mathematical study.

Enjoyable, active and engaging pedagogies are strategies shown to increase student engagement as well as relevant examples from everyday life. While research emphasises the importance of professional development to support teachers effectively engaging in student-centred approaches, it also identifies teachers' difficulties with collaborative learning environments, increased noise levels and more relaxed classroom organisation, and a tendency to return to transmissive teaching strategies such as worksheets when lacking confidence or content knowledge.

Twenty six per cent of schools with an external STEM partnership identified improving teacher capability as one of the main purposes of their partnership (see Figure 6) and as a key professional development and ongoing mentoring opportunity for teachers either at school or at the partner's site (see Figure 7). The value of external partnerships to teachers and students in all school types is discussed further, later in this report.

Potential direction and responses

Supporting students into STEM futures begins in primary school with inquiry-based learning and confident primary teachers providing engaging and relevant opportunities. Responses to support this include:

- ensuring primary teachers are confident in their own content knowledge and delivering student-centred practices by providing high-quality professional development and support to teachers at school and through partnership opportunities

- utilising the *#codingcounts* initiative to support the proposed *State Schools STEM Strategy* goals for technology, particularly with its emphasis on primary students.

Crossover issues

Literacy initiatives need to be supported as language is critical for students to develop their understanding of STEM through activities such as argumentation and analysis of scientific texts.

Current state and research findings

Improving literacy as a general capability supports students to develop a deeper understanding of STEM concepts and STEM subject content and skills in scientific argumentation, analysis and interpretation of evidence. This provides students with a parallel to real-world scientists who are required to analyse and critique texts as a core scientific practice (McDonald, 2015, p. 7), and this enables students to make topics relatable to a real-world context, effectively supporting the three strands of the Australian Curriculum: Science Understanding, Science as a Human Endeavour and Science Inquiry Skills.

Research highlights that primary science teachers have low confidence, lack general science content knowledge, have limited science teaching pedagogy, lack science-specific qualifications and have limited time available to teach science (McDonald, 2015, p. 12). This can lead to avoidance of class discussions (developing argumentation abilities, scientific language and resilience) where students communicate with each other to develop a deeper

understanding of scientific concepts related to the real world, with transmissive approaches such as textbooks and worksheets used instead (McDonald, 2015, p. 12).

Potential direction and responses

Literacy is an ongoing Department priority with a forward program of projects that:

- continue to encourage partnerships with STEM professionals to demonstrate scientific practice and incorporation of literacy in scientific practice
- support teachers in developing pedagogical practices such as student discussions and debating as scientific practice to encourage use of scientific language.

Crossover issues

External STEM partnerships should be expanded as these enhance teacher capability, student engagement and student participation. Partnerships also provide students with real-world examples of the role of STEM in society.

Current state and research findings

Positive experiences and inquiry-based approaches to STEM from early years can develop deep thinking and sustained engagement with STEM. This engagement is necessary to encourage participation throughout the transition from primary school to junior secondary school, when engagement declines and students begin making decisions about enrolment in senior STEM subjects.

To support positive experiences primary school STEM teachers in particular require support and professional development of their capabilities to deliver inquiry-based learning in STEM, as survey results indicate traditional teaching strategies rank highly as classroom practices.

Teacher confidence and professional development in effective STEM pedagogical practices can be developed through a variety of external partnerships that support inquiry-based and context-based learning approaches with STEM researchers, practitioners and industries who are seeking the next generation of STEM professionals.

The STEM survey of state schools indicates that science is the predominant focus of external partnerships, across all school types (see Table 1). Mathematics is the second highest area of focus for external partnerships with less emphasis on technologies or engineering.

Survey responses indicate that primary schools have more external STEM partnerships (70 partnerships) but at a lower rate (12 per cent) in comparison to secondary (36 per cent) and P–10 and P–12 (20 per cent) schools that completed the survey.

Table 1 Focus of external STEM partnerships in all types of state schools, Queensland (schools with a partnership/s responses)

| School type	Schools with partnership (%, no.)*	Focus of partnership — Science (%)	Focus of partnership — Technologies (%)	Focus of partnership — Engineering (%)	Focus of partnership — Mathematics (%)
Primary	12.4%, 70	70%	38%	30.4%	49.4%
Secondary	36.5%, 46	91%	57%	54%	61%
P–10 and P–12	20.3%, 15	80%	40%	40%	60%

*Multiple selections for answers

Queensland universities are the most prominent external partner across each school type, accounting for more than half of the external organisations (see Figure 4), followed by research institutions and major businesses who may be an additional partner with the school partnership program. Around 8 per cent of school STEM partnerships involve other local state schools or a Queensland Academy.

Around 36 per cent of partnerships have been established for one year or less (see Figure 5). Almost half (46 per cent) of the partnerships have been ongoing for three or more years, with a significant portion (27 per cent) established for five or more years. This signifies an investment of resources, commitment and ongoing relationship between schools and external partners.

Figure 4 External partner organisations by type for all school types, Queensland (multiple responses from schools with a partnership/s)
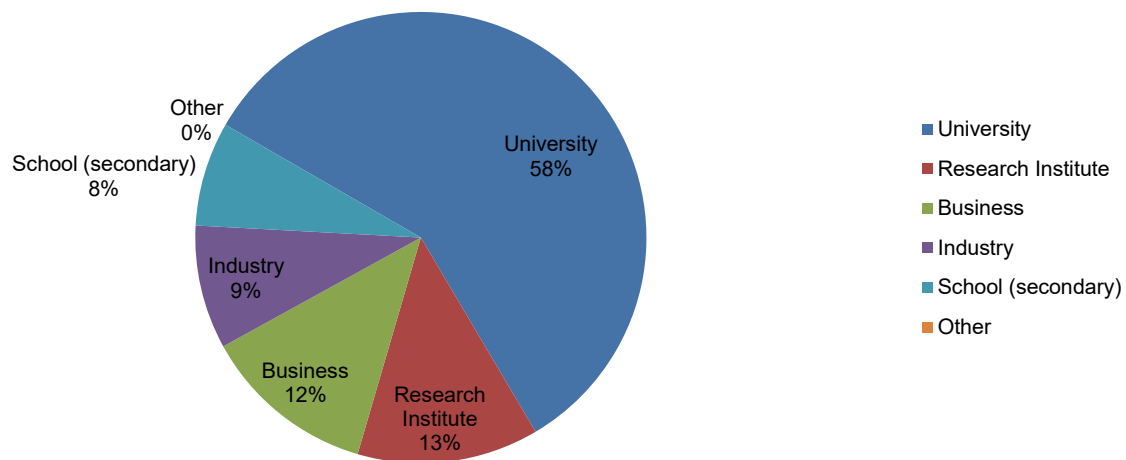
Email is the most common tool schools use to communicate with their external partner/s (indicated by 58 per cent of responses). Discussion lists are also identified as a useful communication tool between teachers at different schools (13 per cent).

Figure 5 Duration of partnership arrangement, all school types, Queensland (multiple responses from schools with a partnership/s)
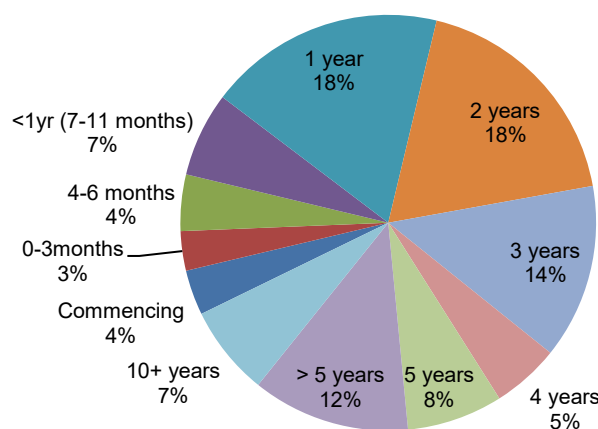

Schools were surveyed about the main purpose/s of their external partnership in line with the proposed *State Schools STEM Strategy* goals. Students are the main focus of partnerships,

with increasing student engagement (37 per cent) and lifting student achievement (32 per cent) indicated more frequently than improving teacher capability (26 per cent) (see Figure 6).

Figure 6 Main purpose of external partnership for all school types, Queensland (single responses from schools with a partnership/s)
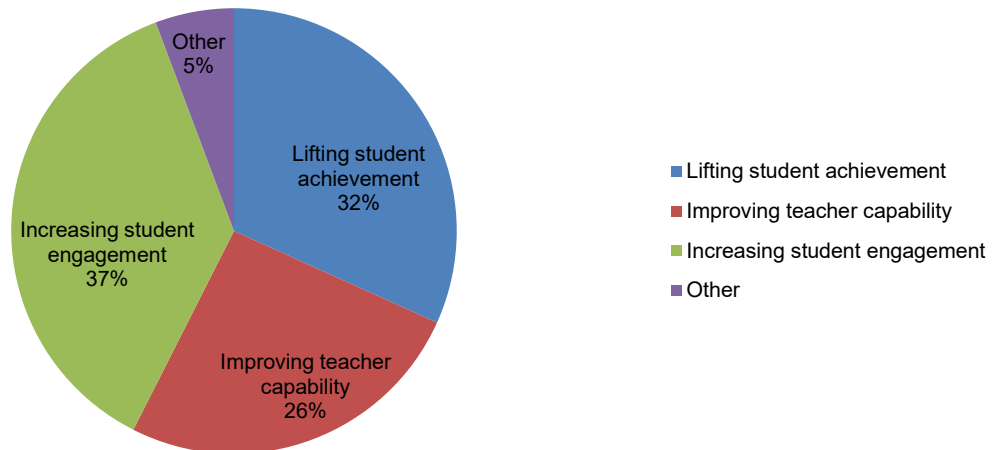
Figure 7 Description of what the partnership provides, all school types, Queensland (multiple responses from schools with a partnership/s)
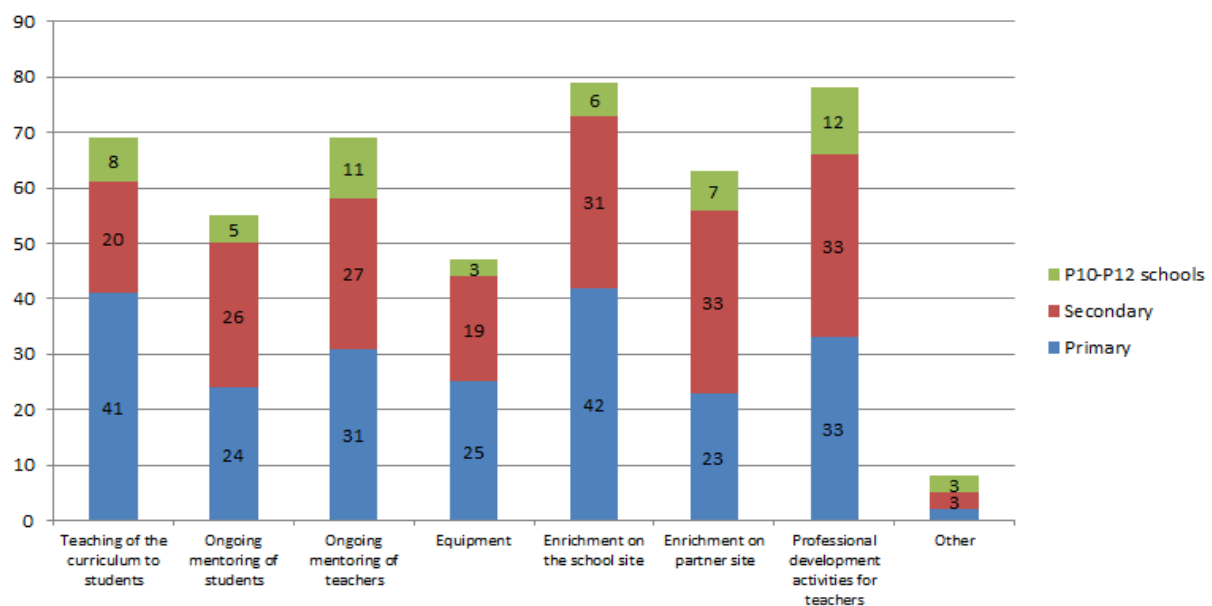
Partnerships provide a range of benefits to schools including provision of equipment and mentoring of students and teachers. Professional development opportunities for teachers and enrichment at school or at the partner's site are key services provided by partners according to secondary schools. Enrichment at school and teaching of the curriculum to students are key services provided by partners according to primary schools (see Figure 7).

How technology is used in classrooms varies from students as end users to technology activities such as computer programming and robotics that develop student competencies in problem-solving and higher-order thinking skills (McDonald, 2015, pp. 3–4).

Partnerships that provide opportunities for students to develop their digital literacy and interact with STEM professionals using technologies support a student-centred learning approach. Such partnerships also provide teachers with the opportunity to build their content knowledge and pedagogical capability in new fields. Similarly, partnerships in the engineering field would support both student participation and developing teacher content knowledge and capability.

Potential direction and responses
Schools should continue to build partnerships that promote all three goals of the proposed *State Schools STEM Strategy,* including:

- continuing science partnerships that provide students with real-world learning contexts and teachers with opportunities to promote and practise student-centred learning

- investigating opportunities to expand external partnerships to increase the number of technology, engineering and mathematics opportunities, particularly in primary schools

- researching and evaluating case studies of successful partnerships and encouraging additional schools to engage in partnerships. Case studies should include partnerships with universities, industry and other local schools (school clusters)

- continuing to promote partnerships to teachers through communication channels such as discussion lists and OneChannel

- undertaking an analysis of partnerships targeted at primary schools to provide insight into developing external partnerships in all STEM areas but particularly engineering and technology at a primary level

- utilising STEM champions to support research and partnerships included in the *Advancing Education* and *#codingcounts* initiatives.

Building teacher capability

Build teacher self-efficacy, content knowledge and professional development in pedagogical strategies specific to each STEM area.

Current state and research findings
Schools were surveyed about the processes used to increase STEM teacher capability in science, technology and mathematics at the school (see Figure 8, Figure 9 and Figure 10).

Teachers in primary schools and those teaching out-of-field face the challenge of developing their self-efficacy and subject content knowledge in specific STEM areas as well as developing pedagogical strategies to suit student needs.

The influence of STEM teacher content knowledge on student achievement and classroom practice is an area of research that requires further investigation (McDonald, 2015, p. 12). Most sources acknowledge that content knowledge and confidence influences whether a teacher uses active student-centred approaches that support students' higher-level thinking or transmissive pedagogies and traditional techniques that may not engage students in the subject.

Figure 8 Processes used to improve teacher capability in science by school type, Queensland (multiple responses by schools)
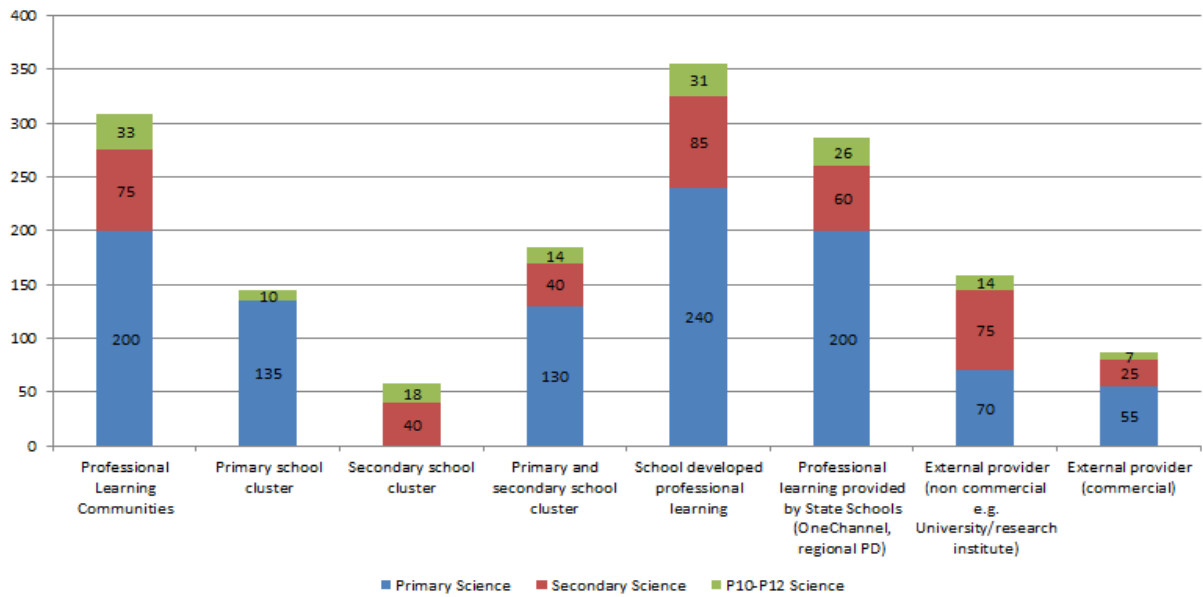
Figure 9 Processes used to improve teacher capability in mathematics by school type, Queensland (multiple responses by schools)
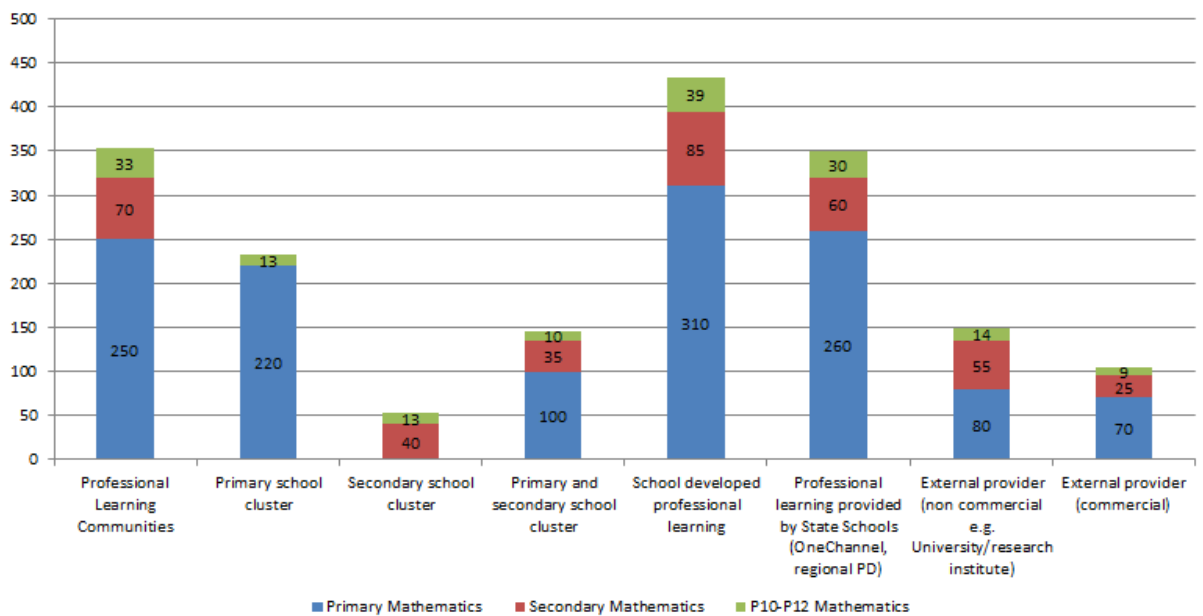
High-quality professional development that supports teachers developing their subject content knowledge and pedagogical practices for different STEM areas will support constructivist learning approaches.

The three highest ranked processes were consistent for primary, P–10 and P–12, and secondary schools:

- school-developed professional learning
- professional learning provided by state schools (for example OneChannel and regional professional development)
- professional learning communities.

School clusters and external providers were also strongly identified processes. Proportionally, secondary schools indicated external providers more than primary schools, particularly science partnerships. Primary school responses identified more external partnerships in mathematics (80 responses) than in science (70 responses), which may be an area of research interest.

Figure 10 Processes used to improve teacher capability in technologies by school type, Queensland (multiple responses by schools)
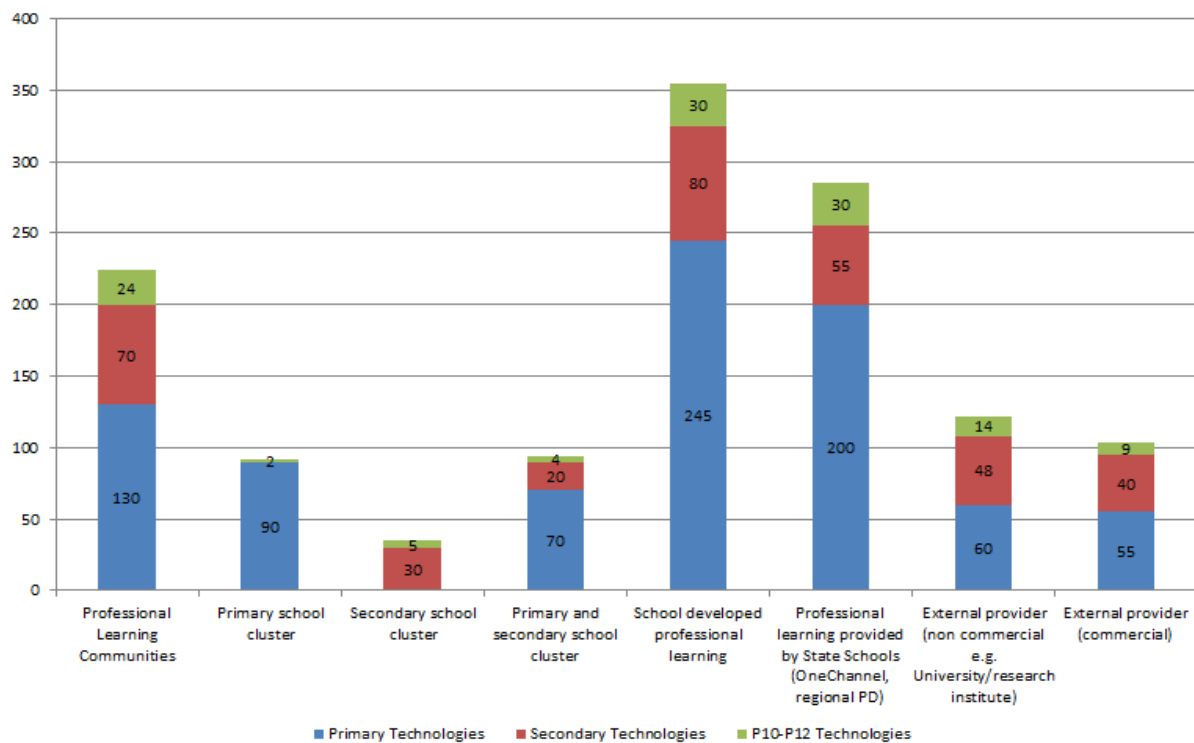
Primary teachers

Active pedagogical practices are suggested as more enjoyable and engaging for students (McDonald, 2015, p. 5); however, many school survey respondents ranked traditional teacher-led approaches as the most frequently used for STEM subject classroom practices in primary schools (Figure 1 and Figure 2).

Out-of-field secondary teachers

At a junior secondary school level, out-of-field teaching of STEM subjects highlights the need for teachers to first build subject content knowledge and then pedagogical practices specific to the STEM area.

In the state schools STEM survey, schools indicated their current level of out-of-field teaching of STEM subjects in junior secondary (Years 7–10). The most common response for out-of-field teaching in science, technologies and mathematics in P–10 and P–12 and secondary

schools was zero, or no teachers teaching out-of-field. Survey responses ranged from 23 to 64 per cent of no teachers teaching out-of-field.

Cumulative responses indicating high levels of out-of-field teaching as limited to below 30 per cent in most schools. The higher occurrences of out-of-field teaching of STEM subjects were recorded for junior secondary science, technology and mathematics in Years 7–10, in P–10 and P–12 schools.

STEM specific content knowledge and pedagogical practices

McDonald (2015, p.12) identified a general lack of science content knowledge, low confidence in teaching science, limited science teaching pedagogy, a lack of science-specific qualifications and time limitations as constraints on primary science teachers.

Across primary and junior secondary schools, confidence, content and pedagogical knowledge constraints can result in teachers using transmissive pedagogies rather than context-based and active learning experiences that will encourage students to participate in senior science subjects.

Technologies

Technology use in classrooms can be used as a simple tool in other activities or as an enabler of more complex learning and thinking such as modelling scenarios and simulations. The scope and level of technology integrated into pedagogical practices varies across classrooms with mixed results for its impact on student achievement (McDonald, 2015, p. 7).

STEM teachers can use scenario modelling and simulations to demonstrate real-world processes and phenomena that engage students and help them to understand abstract concepts and access immediate feedback when testing their own theories (McDonald, 2015, p. 6). Computer programming is shown to benefit student thinking, attitudes and motivation, particularly in younger students (McDonald, 2015, p. 8).

Computer programming and robotics are proposed as learning technologies that enable the development of student problem-solving and higher-level thinking skills. In the majority of the responding primary schools coding is not offered or is undertaken as an extra-curricular activity in Years 3–6. From Years 7–10, coding or programming may be embedded in the curriculum or as an extra-curricular activity (Figure 11).

Figure 11 Teaching of coding or computer programming in junior secondary school, Queensland (single response by secondary schools)
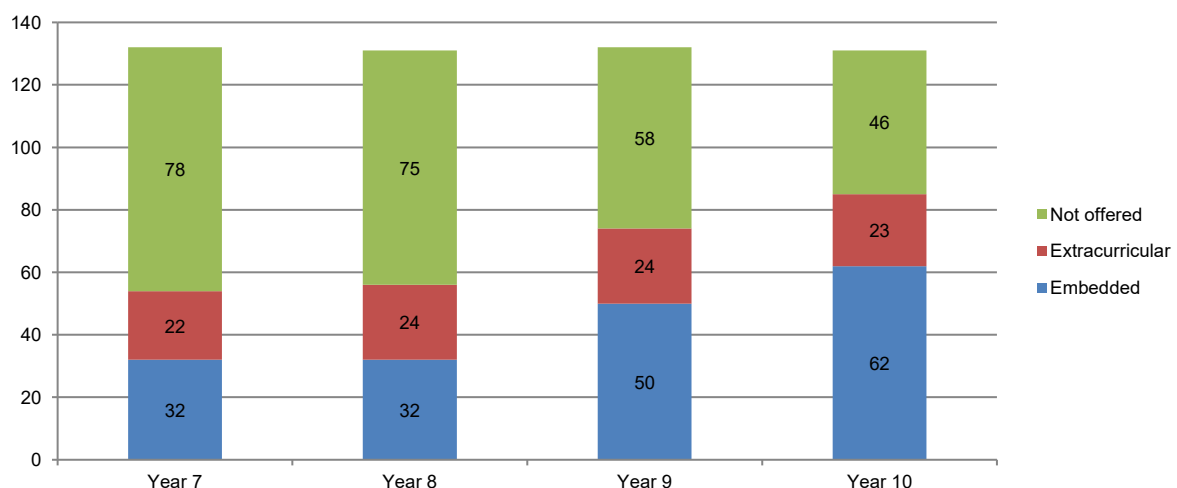
Potential direction and responses

Due to the new and evolving fields of STEM, primary, out-of-field, and other teachers require specialised professional development to support them to develop their STEM-specific content knowledge and pedagogical practices. Potential programs to support teachers in specific STEM areas include:

- utilising the *#codingcounts* initiative to support teachers (particularly primary teachers) to develop coding and robotics pedagogies that engage students

- STEM-specific content (science, technology, engineering and mathematics) professional development for new and out-of-field teachers

- research into the influence of STEM teacher content knowledge on student achievement and classroom practice

- school developed professional learning

- professional learning provided by state schools (for example OneChannel and regional professional development)

- utilising STEM champions to support research and partnerships, as included in the *Advancing Education* and *#codingcounts* initiatives.

Building teacher capability

Ensure STEM studies are relevant to the real-world context to help engage students, including by connecting their existing knowledge with new STEM knowledge.

Current state and research findings

International research and reforms across all STEM areas advocate constructivist learning and teaching approaches that employ authentic, inquiry-based pedagogical practices that connect students' existing knowledge and current scientific knowledge (McDonald, 2015, p. 5).

In science, inquiry-based science curricula and pedagogical practices have been found to improve student achievement, engagement and development of skills in scientific reasoning and data analysis (McDonald, 2015, p. 6). Collaborative group activities encourage students to "act like scientists", making their school science meaningful and encouraging their scientific literacy.

Traditional teacher-centred instruction and procedural learning are still frequently used in secondary school science and mathematics (Figure 12 and Figure 13). However, student-centred collaborative, independent and investigatory practices are also used.

Figure 12 How often various practices are used in the teaching of science in Year 10 (multiple responses by secondary schools)

Legend: Mostly ■ Regularly ■ Sometimes ■ Rarely ■ Do not use
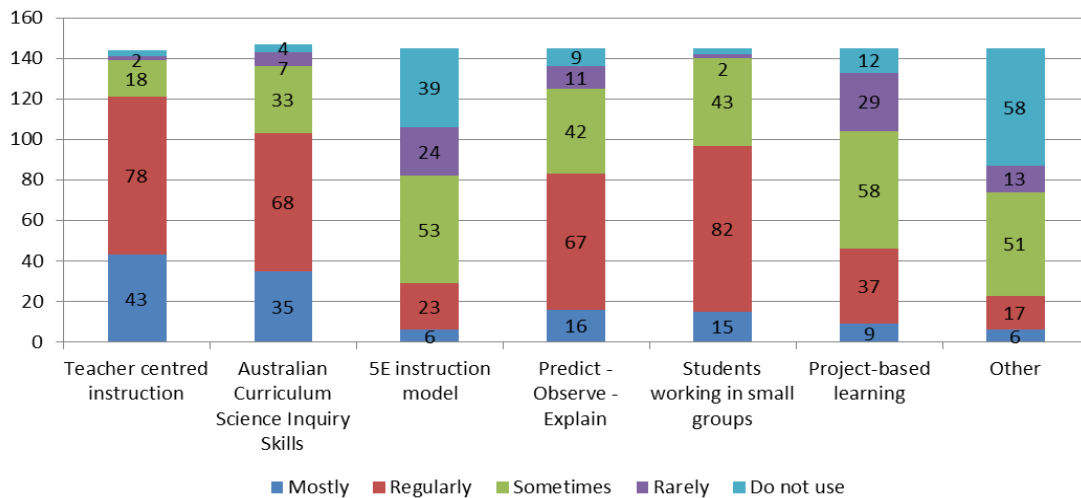
Figure 13 How often various strategies are used in the teaching of mathematics in Year 10 (multiple responses by secondary schools)

Legend: In > 90% lessons ■ In >75% lessons ■ In >50% lessons ■ In > 25% lessons ■ In <25% lessons
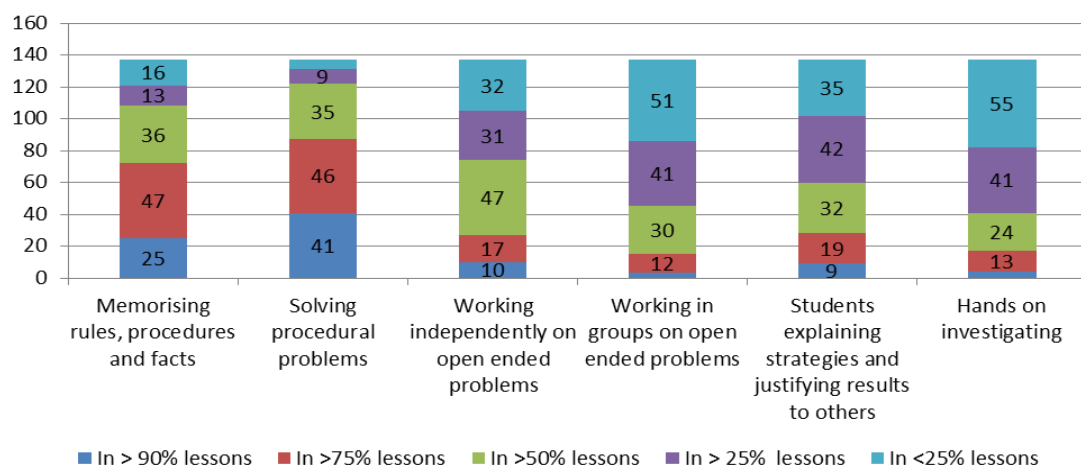
Potential direction and responses

Approaches that can support teachers to develop authentic, inquiry-based classroom practices for students include:

- encouraging partnerships with STEM professionals to enable students to link school science to STEM careers and inquiry-based learning experiences

- use of real-world experimental investigations for classroom activities to link existing knowledge and current scientific knowledge

- encouraging argumentation in science classes and assessment to develop authentic learning experiences that mirror practices of professional scientists and relevance to society

- utilising technologies for computer simulations and modelling to study real-world examples.

Increasing student participation

Review strategies to target students underrepresented in STEM (for example females) at a senior schooling level and in professional fields (for example engineering and ICT professions). Revise existing programs or develop new initiatives based on review results.

Current state and research findings

The review of literature and the proposed *State Schools STEM Strategy* identify girls as an underrepresented group in senior STEM subjects and professional fields. The recent Queensland Women 2015 report highlights the low percentages of Queensland female Year 12 students in subjects such as Engineering and Technology (9.8% of enrolments), Technology Studies (9.9%) and Information Processing and Technology (14.5%).

It is suggested that while students may recognise the importance of STEM to society they do not connect this importance to their own lives (McDonald, 2015, p. 2). Students may not be aware of the impact of not studying senior STEM subjects that may be prerequisites for tertiary courses, impacting on their future career opportunities. The Queensland Women 2015 report highlights STEM trade occupations and higher education fields of study with low enrolments of females (Queensland Government, 2015).

Key strategies are also required to engage other underrepresented groups in STEM including Aboriginal and Torres Strait Islander (ATSI) students and those from a low socio-economic background throughout all levels of schooling, but particularly to increase participation from early primary school (The Office of the Queensland Chief Scientist, 2014).

Making STEM studies relevant to the real-world context would help engage underrepresented students from different backgrounds into STEM studies. Research indicates positive science (or STEM) education experiences, and competency and engagement in STEM need to be developed from early schooling years to encourage post-compulsory enrolment and maintain student interest in STEM during the transition from primary to secondary school (McDonald, 2015, p. 3).

Initiatives are underway to encourage participation in STEM for different target groups such as the 2016 STEM Girl Power Camp.

Potential direction and responses

Further investigation is required to identify groups underrepresented in STEM and to develop or revise strategies to encourage their participation. Suggested approaches include:

- identify students underrepresented in STEM and investigate targeted approaches suited to students including ATSI students, females, regional and remote students, and students with English as a second language

- identify and evaluate current initiatives and programs for underrepresented students in STEM, including in what STEM area and years of schooling

- promote programs that encourage participation in STEM from underrepresented groups (for example through OneChannel presentations, industry organisations or research studies).

Lifting student achievement

Inquiry-based and constructivist learning approaches support student achievement and make school STEM subjects relevant to students' real-world experiences. Promoting the use of technologies, engineering thinking and design-based learning will support student improvement.

Current state and research findings

International research and reforms across all STEM areas advocate constructivist learning and teaching approaches that employ authentic, inquiry-based pedagogical practices that connect students' existing knowledge and current scientific knowledge (McDonald, 2015, p. 5).

Inquiry-based science curricula and pedagogical practices have been found to improve student achievement, engagement and development of skills in scientific reasoning and data analysis (McDonald, 2015, p. 6). Collaborative group activities and STEM partnerships encourage students to "act like scientists" or other STEM professionals, making their STEM subjects meaningful in the context of society.

Positive experiences in STEM from early years can develop deep thinking and sustained engagement with STEM during the transition from primary school to junior secondary school, and when students begin making decisions about enrolment in senior STEM subjects. To support positive experiences, primary school STEM teachers in particular require support and professional development of their capabilities to deliver inquiry-based learning in STEM, as survey results indicate traditional teaching strategies rank highly as classroom practices.

The STEM survey of state schools indicates that science is the predominant focus of external partnerships across all school types. Mathematics is the second highest area of focus for external partnerships, with less emphasis on technologies or engineering. However, using engineering and design-based learning and technologies to investigate real-world problems engages students; therefore, these types of partnerships should be further explored.

Technologies

Technology can be used as an enabler of more complex learning and thinking strategies such as modelling scenarios and simulations. Computer programming is shown to benefit student thinking, attitudes and motivation, particularly in younger students (McDonald, 2015, p. 8).

Partnerships that provide opportunities for students to develop their digital literacy and interact with STEM professionals using technologies support a student-centred learning approach. Such partnerships also provide teachers with the opportunity to build their content knowledge and pedagogical capability in new fields.

As a new field of teaching, teachers need to be confident and competent in the use of technologies and in their STEM pedagogy to enable student learning. However, in P–10 and P–12 schools, junior secondary technology has a higher portion of out-of-field teachers who may require professional development.

Engineering

Engineering thinking and design-based learning can support students' critical thinking and literacy in other STEM areas (scientific literacy, digital literacy and mathematical literacy) in a similar way to how technologies, such as computer programming, game-based learning and robotics, can be used to support higher-order thinking in students.

Figure 14 Subject learning areas offered in a combined STEM course in P–10 and P–12 schools (single responses only from P–10 and P–12 schools with a STEM course)
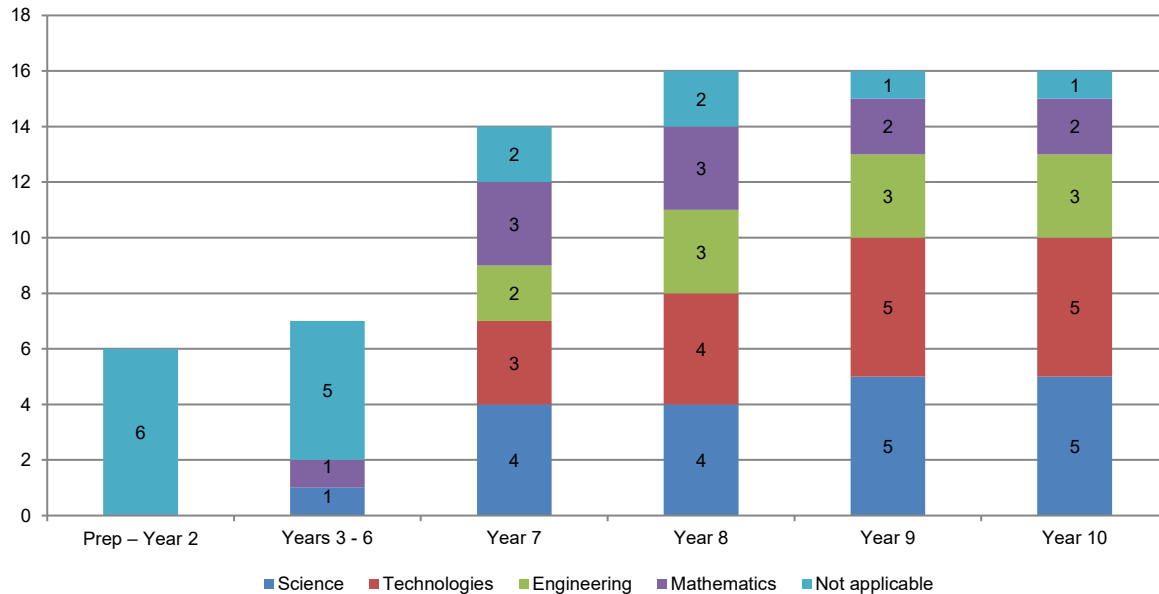
The purpose of engineering and design-based learning is to encourage students to develop engineering thinking in other STEM areas by engaging students to solve real-world design problems through the engineering process of identifying a problem, understanding its constraints, then designing, testing and refining solutions to optimise the final result (McDonald, 2015). By providing authentic inquiry-based learning, students are more likely to be engaged in their learning, with research indicating students can translate this learning to achievement in science and mathematics and interest in STEM careers (McDonald, 2015, p. 4).

While engineering features in some external partnerships, it is not yet commonly incorporated into P–10 and P–12 STEM courses in schools based on survey responses (see Figure 14). This relatively new field of school education highlights its key challenge for teachers.

The open-ended nature of engineering education requires teachers to take a student-centred rather than traditional approach; however, there is limited research into pedagogical practices to guide primary and secondary teachers in how to effectively scaffold student learning in the classroom (McDonald, 2015, pp. 9, 13). As with other STEM areas, researchers highlight the need for discipline-specific content knowledge and pedagogical knowledge to support teacher competence (McDonald, 2015, p. 13).

Potential direction and responses

Approaches that can support authentic, inquiry-based classroom practices for students include:

- encouraging partnerships with STEM professionals to enable students to link school learning to STEM careers and inquiry-based learning experiences

- the use of real-world experimental investigations for classroom activities to link existing knowledge and current scientific knowledge

- utilising technologies for computer simulations and modelling to study real-world examples

- research into international engineering education pedagogical practices

- promoting incorporation of engineering into combined STEM courses in Queensland schools

- professional development for teachers about modelling, robotics and engineering thinking and teaching strategies
- utilising the *#codingcounts* initiative to support the proposed *State Schools STEM Strategy* goals for technology, particularly with its emphasis on primary students.

Next steps

Potential directions of the 2016 review of STEM teaching in Queensland will focus on the issues highlighted for STEM in general.

Investigations will be considered into key issues such as:

- improving participation of underrepresented groups in STEM, including girls and Aboriginal and Torres Strait Islander students
- options for providing high-quality professional development in specific STEM areas identified
- analysis and evaluation of existing STEM partnerships between schools, industry, tertiary institutions and educational organisations, and future approaches and target areas
- approaches to integrate engineering and technology to enhance student participation and achievement in STEM areas
- implementing key initiatives and activities that support the three goals of the proposed *State Schools STEM Strategy*.

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