A science, technology, engineering and mathematics (STEM) review of the research

Introduction
The purpose of this literature review is to bring together a range of research and resources on the implementation and development of Science, Technology, Engineering and Mathematics (STEM) education initiatives to inform the implementation of NSW statewide and school based programs.

The NSW Department of Education views STEM education as the learning of science, technology, engineering and mathematics in an interdisciplinary or integrated approach. Students gain and apply knowledge, deepen their understanding and develop creative and critical thinking skills within an authentic context. It may include inquiry and project-based...
learning. By developing curiosity and knowledge of STEM disciplines students make connections and see the relevance for future career pathways. STEM education is for all students and should be incorporated throughout all stages of learning from preschool through to Year 12.

STEM education has been identified globally as a core driver in economic development (Marginson, 2013; Tytler, 2008; Watt, 2009) and the lower educational attainment of females in the STEM subjects has been noted as an indicator of lower economic growth (OECD, 2015a). Innovation as a strong outcome of the STEM culture is core to this economic development (AI Group, 2015; FYA, 2015; PwC, 2015). International research indicates that 75 per cent of the fastest growing occupations now require STEM skills and knowledge (Office of the Chief Scientist, 2014, p.7). Nationally, the Australian Government has published a STEM strategy, to which all states agreed in 2015, to encourage education systems in supporting the development of skills in cross disciplinary, critical and creative thinking, problem solving and digital technologies, which are essential in all 21st century occupations.

Australian Government, 2015

An increasingly global society also requires the integration of STEM subjects to solve global and local problems which are multidisciplinary. These complex problems are the driving force behind national calls for changes in STEM education (Wang, Moore, Roehrig & Park, 2011).

Background to this review

The National STEM School Education Strategy 2016-2026 (Education Council Australian Government, 2015) defines STEM as both a collection of subjects with the stated disciplines as well as a cross disciplinary approach to the teaching of these in STEM related fields. In the literature, the definition changes depending on the perspective of the writer (Hogan & Down, 2015). However, core concepts in all definitions are critical thinking, analysis, collaboration, and real world contexts, within the disciplines of science, technology, engineering and mathematics.

The five key areas for action from the National STEM School Education Strategy (Education Council Australian Government, 2015 p.7):

1. Increase student STEM ability, engagement, participation and aspiration.
2. Increase teacher capacity and STEM teaching quality.
3. Support STEM education opportunities within school systems.
4. Facilitate effective partnerships with tertiary education providers, business and industry.
5. Build a strong evidence base (Figure 1).

These action statements are seen as the drivers to encourage innovation while, at the same time, they have strong links to the NSW Learning Across the Curriculum (BOSTES, 2012) statements which include the General Capabilities in the Australian Curriculum (ACARA, 2012). The following NSW syllabuses specifically link to STEM education skills and knowledge required for future learners:

![Figure 1 Goals/Five areas for national action, National STEM School Education Strategy (Education Council Australian Government, 2015 p.7)](image-url)
In the primary years, syllabus statements encapsulate the concepts of exploring ideas, questioning, designing solutions and applying critical thinking. In the secondary curriculum, syllabus statements focus on furthering the primary years’ concepts and design, planning, development of and evaluation of real world solutions (BOSTES, 2003 & 2012). Table 1 maps the links to STEM skills and knowledge statements in the NSW syllabuses.

Economic growth

Globally and nationally, the workforce has greater mobility and needs to compete on a global scale. The need for increased specialisation in the STEM field and a distribution of skills are issues for the future workforce (Tytler, 2008).

Price Waterhouse Coopers (PwC, 2015, p.9) have identified a 90+% risk of jobs being lost in the next 20 years owing to technological developments and automation. Jobs most likely to endure are those requiring high levels of social intelligence, technical ability and creative intelligence; STEM fosters these skills.

Decrease in STEM students

The STEM pathway shows that students’ participation and interest decreases to greater degrees in in the later primary and early secondary years (Tytler, 2008). Students lose interest by age 6; peer influence effects attitudes by age 12; they are bored in class by age 14; and their grades drop in STEM related subjects by age 15. Approximately only 13% of the initial intake remain in STEM by the time they enter the workforce.

In 2013, only 50% of ATAR eligible students did General Maths and 18% did 2 Unit. With an additional 15% of students studying no maths at all, this means that of the 2013 cohort eligible to apply for university entrance by HSC, some 65% did elementary level or no maths.

The decreasing enrolment in mathematics and sciences is noted as one of the major issues in developing a STEM education focus in schools. (Kennedy, 2014; Marginson, 2013, p.41).

National participation in intermediate and advanced mathematics is also declining. In 1995, the percentage of Year 12 students studying intermediate or advanced mathematics was 41.5%. By 2011, this had dropped to 29.4%. Decreasing enrolments in intermediate and higher mathematics negatively impact on further STEM related options (Tytler, 2008.). The move away from these levels of mathematics, noted in the NSW HSC data, is consistent with national trends.

Gender

It is not the purpose of this review to closely examine the role of gender in the STEM field, however, there is a higher proportion of male graduates in STEM related fields than female graduates (OECD, 2015). This is noted as a barrier to the development of a more robust STEM career path and ultimately STEM related industries. This is also reflected in female enrolment in senior subjects in high school. Of the ATAR eligible students, 27.5% of females studied 2 Unit mathematics in 2001 and, by 2013, this had decreased to 16.3% (Wilson & Mack, 2014).

Figure 2 Total participation in HSC maths and science by gender 2001–2013 (Wilson & Mack, 2014, p.40)
Table 1. An integrated approach to STEM education through mapping NSW syllabuses

<table>
<thead>
<tr>
<th>NSW syllabus</th>
<th>STEM education integration</th>
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<tbody>
<tr>
<td>Agricultural Technology Years 7–10 (BOSTES, 2003)</td>
<td>Mapped to STEM education through: practices and skills required in producing plant and animal products; skills in problem-solving including investigating, collecting, analysing, interpreting and communicating information in agricultural contexts (pp.10–11).</td>
</tr>
<tr>
<td>Design and Technology Years 7–10 (BOSTES, 2003)</td>
<td>Mapped to STEM education through: engaging students in technological innovation; developing knowledge and understanding of and skills in innovation, creativity and enterprise; skills in communicating design ideas and solutions; knowledge and understanding of and skills in managing resources and producing quality design solutions (pp.10–11).</td>
</tr>
<tr>
<td>Food Technology Years 7–10 (BOSTES, 2003)</td>
<td>Mapped to STEM education through: evaluate the relationships between food, technology, nutritional status and the quality of life; and designing, producing and evaluating solutions (pp.10–11)</td>
</tr>
<tr>
<td>Graphics Technology Years 7–10 (BOSTES, 2003)</td>
<td>Mapped to STEM education through: thinking creatively, devise solutions and communicate information; interpret, design, produce and evaluate (pp.10–11).</td>
</tr>
<tr>
<td>Industrial Technology Years 7–10 (BOSTES, 2003)</td>
<td>Mapped to STEM education through: planning, development and construction of quality practical projects; design and production of practical projects, relationship between the properties of materials, ability to critically evaluate manufactured products (pp.10–11)</td>
</tr>
<tr>
<td>Information and Software Technology Years 7–10 (BOSTES, 2003)</td>
<td>Mapped to STEM education through: analysing, designing, developing and evaluating information; problem-solving and critical thinking skills in order to design and develop creative information and software technology solutions (pp.10–11)</td>
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<tr>
<td>Mathematics K–10 (BOSTES, 2112)</td>
<td>Mapped to STEM education in the primary years through: questioning and use of known facts to explore mathematical problems and develop fluency with mathematical ideas; give valid reasons when comparing and selecting from possible solutions, making connections with existing knowledge and understanding. Mapped to STEM education in the secondary years through: demonstrate fluency in selecting, combining and applying relevant knowledge, skills and understanding in the solution of familiar and unfamiliar problems.</td>
</tr>
<tr>
<td>Science K–10 (incorporating Science and Technology K–6) (BOSTES, 2012)</td>
<td>Mapped to STEM education in the primary years through: observing, questioning and exploring ideas; design projects, and in collaboratively completing the tasks. Mapped to STEM education in the secondary years through applying scientific understanding and critical thinking skills to suggest possible solutions to identified problems.</td>
</tr>
<tr>
<td>Technology (Mandatory) Years 7–8 (BOSTES, 2003)</td>
<td>Mapped to STEM education through: design, produce and evaluate quality solutions; skills in design processes, researching, experimenting, generating and communicating creative design ideas and solutions, impact of innovation and emerging technologies, skills in managing quality solutions to successful completion (pp.10–11).</td>
</tr>
<tr>
<td>Textiles Technology Years 7–10 (BOSTES, 2003)</td>
<td>Mapped to STEM education through: design, production and evaluation of textile items; examining properties and performance (pp.10–11).</td>
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</table>
The disparity between the university intake, based on gender in the technology and engineering fields, is of concern. In 2010 (Marginson, 2013, p.45), the intake for females in the information technology field was 18% and only 16% in the engineering field. The gender gap in both girls’ participation in and selection of STEM subjects and STEM related careers has been identified as a concern for educational attainment and economic growth (Butler, 2014; Halpern et al, 2007; Knezek, Christensen & Tyler-Wood, 2011; Sadler, Sonnert & Hazari, 2012).

National STEM education programs
The Australian Industry Group (AI Group) (2015) identified the following common characteristics of countries with successful STEM education programs:

- school teachers enjoy high esteem, are better paid and work within meritocratic career structures
- countries have unbreakable commitment to disciplinary contents – focused on STEM knowledge, teachers are expected to be fully qualified
- active reform programs in curriculum and pedagogy focused on making science and maths more engaging and practical
- innovative programs developed to lift STEM participation among formerly excluded groups
- strategic national STEM policy frameworks developed with centrally driven and funded programs, world class university programs, partnerships and engagement that link schools, vocational and higher education with industry.

For school systems to develop a strong STEM education program that leads into STEM related careers, there are three areas to consider. These will be the focus of the remainder of this review:

1. STEM education in K–12 schools
2. Pedagogical practices for STEM education
3. Teacher development.

Implementation of STEM education in K–12 schools
The Office of the Chief Scientist (2013) identified the following strategies in order to reverse the declining trends in STEM participation:

- focus content on the evolving character of STEM knowledge and provide a strong focus on the practice of STEM
- encourage curiosity and reflection
- emphasise inquiry based learning with a focus on critical thinking and the scientific method
- guide study decisions of students, at all levels of education, to highlight the diversity of the STEM workforce
- forge enduring and real partnerships between employers and education authorities/schools
- develop and implement approaches to raise the STEM participation of females, and disadvantaged and marginalised students.

Various research (CHSS, 2011; Duschl & Bybee, 2014; Tytler, 2008) articulates the need for STEM education to commence in the early years of schooling and develop into more sophisticated levels of performance.

Multidisciplinary vs interdisciplinary
There are a range of perspectives (Wang, 2011) as to what constitutes STEM education. Some see STEM education as a multidisciplinary program where each discipline (science, technology, engineering, mathematics) teaches the content and skills from the individual discipline to meet a common project goal. It can be broadened to include a project approach across a range of subjects.

A developing outcome of the need for innovation and curiosity in STEM is the inclusion of the arts to foster creativity. The STEAM (science, technology, engineering, arts and mathematics) movement argues that a multidisciplinary approach including the arts can contribute significantly to the development of creative, innovative and entrepreneurial thinking in STEM education. In the following video, Larry Rosenstock, the CEO of High-Tech High argues that the emphasis on science, technology, engineering and mathematics is detrimental to arts education. He continues by asserting that engineering and the arts are integral to the conceptual design process.

Project-based learning at High-Tech High by Association for Learning Environments (A4LE)
An interdisciplinary approach is one that focuses on the concepts. It cuts across discipline boundaries and is based on a constructivist approach. An interdisciplinary approach is essentially project based learning where the project tasks and skills are the focus and the disciplines work together and across subject areas to achieve the project goals. Wang (2011) cites that the essential skills of an interdisciplinary approach are:

- critical thinking
- problem solving skills
- making connections with learning experiences that relate to personal meanings.

Additional skills, identified by Atkinson and Mayo (2010), are:

- inquiry
- design
- understanding and applying symbolic language.

This approach aligns with the Quality Teaching framework’s (NSW Department of Education and Training, 2003) emphasis on student focused learning and teaching. It also has synergy with the general capabilities, embedded in the learning across the curriculum component of NSW syllabus documents, relevant to the integrations endorsed by the STEM literature.

**Types of schools**
The Committee on Highly Successful Schools or Programs in K–12 STEM Education (CHSS, 2011) within the National Research Council (2013) identified four school types and their roles within STEM education.

1. Selective STEM schools where students are selected to attend.
2. Inclusive STEM schools where students select to attend and are based more on the disadvantaged sectors of the student population.
3. VET or Trade schools—at present separated institutional and curriculum pathways play a modest role in NSW. There are school based apprenticeships and VET in schools’ programs within academic schooling, many of which have some STEM components (Marginson, 2013 p.75).
4. Comprehensive schools, which are the majority of high schools in NSW.

The research is various as to the value of school type as an indicator of success in STEM education. Students attending specialised STEM schools, such as selective and inclusive STEM specialist schools, are more likely to actualise university goals in STEM when compared to peers from regular schools (Erdoğan, 2015; Lamberg, Trzynadlowski, 2015; Scott, 2012).

Other researchers argue the case for a comprehensive school system, as the belief is that the structure of schools can divide students into academic and non-academic which leads to a lack of engagement in learning, rigor and relevance for large numbers of students. If more students are going to engage with STEM, then more students need to access an interesting STEM curriculum (Hogan, 2015). This suggests that selectivity or streaming could be detrimental to the success of a STEM education implementation.

**Student perceptions of STEM**
Learning is not just about accumulating knowledge, it is a process of identity development as students decide who they are and want to be (Wenger, 2000). Subject selection and career paths will not be pursued by students who do not identify themselves as interested in STEM disciplines.

Inhibitors (Kennedy, 2014) towards student enrolments in advanced mathematics and physics are:

- self-perception of ability
- perceptions of difficulty and usefulness
- previous achievement
- liking for the subject.

For the majority of students, their life aspirations are formed before the age of 14 years (Knezek, Christensen, Tyler-Wood & Periahtiruvadi, 2013; Tytler, 2008), with the implication that engaging students in STEM pathways becomes increasingly difficult after the early secondary school years. Student engagement with STEM, therefore, needs to be in the early primary and early secondary years so that the students can be encouraged to be enthusiastic and open to the ideas and concepts presented in STEM fields.

Tytler (2008, p.126) and Naizer (2014) suggest that students need to be exposed to positive STEM role models, personalities, workers, professionals and projects or activities that encourage active learning engagement with STEM. An overview presented in Figure 3 provides a continuum of ideas and challenges throughout the K–12 years.
Internal school structures

Finegold (2012) identifies a range of school structures that are required in order to ensure a STEM education program is successful. Leadership at senior level and within the teacher cohort is needed to drive the change. This leadership should be actively committed to STEM education and drive the change within their school. The leadership also needs to communicate effectively (Johnson, 2012) and value the ideas and roles of staff within the implementation program. Rennie (2012) also noted that flexibility in timetabling and how classes are structured or accessed requires decisions by the leadership team when considering integrated STEM learning experiences.

Secondly, developing and implementing a program requires a clear action plan, stated roles, objectives, activities and timing. This needs to be managed in conjunction with considerations about how outcomes for students will be tracked and how the outcome of the STEM initiative will be evaluated.

Lastly, the role of professional learning for staff is critical to the implementation. Designated meetings and times for learning from within the staff and outside experts is needed for both planning and ongoing implementation. Ultimately the climate of the school needs to be one where innovation is valued and the benefits to students and teachers is clearly articulated (Finegold, 2012).

Pedagogical practices

The predominant approach to increasing student engagement with STEM involves enriching students’ science, technology, engineering and mathematics learning experiences through local initiatives, and increasing teaching quality through coherent training and professional development. The solution is a focus on developing teachers’ capacities to enact new pedagogies (Marginson, 2013). STEM education should also foster inquisitiveness, cognitive skills of evidenced based reasoning, and an understanding of the process of scientific investigation (Wang, Moore, Roehrig & Park, 2011, p.3).

A number of frameworks or processes have been used in STEM pedagogical practices. The core practices are:

- project/problem based learning (PBL) (Asunda & Mativo, 2016; Boaler, 2014; Wang, Moore, Roehrig & Park, 2011)
- challenge based learning
- design thinking (Stanford University, n.d.)
- inquiry learning (School Libraries and Information Literacy unit, 2007; Wang, Moore, Roehrig & Park, 2011)

Project based learning

Project based learning (PBL), and all the derivatives of this, (Larmer, 2014) is a pedagogy that allows students to design or create a product or solution for a real world issue. In PBL the question is open ended and there is a range of solutions. PBL and challenge based learning, which focuses on collaboration, global issues and innovative use of technology, use the same essential elements (Buck Institute for Education,
In 2015. These pedagogies must include:

- initiation by a problem or question
- research or knowledge components that require depth in the inquiry phase
- real world issue or experience
- some student control over the learning process and product
- structures in place for students to self-reflect and evaluate
- high quality work
- solution or presentation accessible outside the immediate classroom environment.

Innovative teaching and learning: lessons from High Tech High’s founding principal by Edutopia

Slough & Milam (in Capraro, p.16) assert that there are four design principles within a PBL approach to STEM:

- Making content accessible – ensuring that the content is appropriate for students within their context
- Making thinking visible – using scientific processes to allow for visible exploration
- Helping students learn from others – grounded in constructivism and enables students to learn collaboratively
- Promote autonomy and lifelong learning – grounding the learning in inquiry and metacognitive practices leads to learner autonomy.

**Design thinking** is a series of activities formalised into a process to create a solution to a problem or issue. Design thinking as a process was implemented by Stanford University within their dschool (Stanford University) and has the following phases:

- empathise
- define
- ideate
- prototype
- test.

It is an iterative process that continually checks the purpose and need of the audience to create and re-create solutions until the design meets the need.

Programs for a specific purpose (project based learning combining inquiry learning) and duration that have intensive STEM knowledge have been implemented to bring in outside experts and, at the same time, encourage STEM graduates to consider teaching. One example of this is where graduate students from Berkeley mentor groups of 4-6 students once a week for six weeks. The mentors work with the students in an inquiry mode.

The mentors then guide the students in designing, carrying out, and analysing experiments to determine an answer (Axelson, 2016).

**Inquiry learning**

Inquiry learning is a process that enables students to research or develop skills through locating, gathering, analysing, critiquing and applying information in a wide range of contexts, some of which will be within a project based learning structure. Inquiry learning structures support learners to research effectively and is an approach to information acquisition that teaches the necessary information skills (School Libraries and Information Literacy Unit, 2015). Inquiry learning underpins the Australian Curriculum (ACARA, 2012) specifically in science, technology, mathematics and history, and is an important component of effective STEM education.

In early years’ classrooms, structured play has been found to use rigorous content and sustains learner engagement (Wohlwend & Peppler, 2015). Structured play is an early years approach to a guided inquiry process that allows the learner to develop curiosity and problem solving skills, important for STEM education.

The practice within curriculum integration planning is a backward design process (Wiggins & McTighe, 1998) that allows teachers to develop an integrated STEM unit and is also based in inquiry learning. Questions in this three stage process are:

- What is worthy and requiring of understanding?
- How will the teacher know that students understood the concepts of the lesson/unit?
- What activities does the teacher need to include...
that will lead to the desired outcomes?

A pedagogical knowledge practice framework (Hudson, 2015, p.136) has been used to implement a STEM education program in Queensland. This framework explicitly moves the teacher as curriculum developer and deliverer through the following steps as part of an inquiry model or a project based learning methodology in a primary school:

• planning
• timetabling
• preparation
• teaching strategies
• content knowledge
• problem solving
• classroom management
• questioning skills
• implementation
• assessment
• viewpoints.

The explicit nature of these steps shows promise with supporting teachers designing and delivering in the STEM area. It provides scope for problem solving, questioning, real world experiences and inquiry research that is core to engaging students with STEM and related fields.

Additionally, the 5D instructional framework (Duschl & Bybee, 2014) has component elements of:

• deciding
• determining.

These are noted as the type of problematic processes within an inquiry or PBL methodology that the students of K-12 might consider or encounter when engaging in STEM activities. The intent is to enable rich opportunities for discussions and engagements to take place.

Another framework or model that has been identified for use in the STEM education area is that of the Engaged to Learn model (Tytler, 2008). This model focuses on engagement and reducing apathy, anxiety and boredom which have been previously identified as barriers to student learning and engagement. Tytler (2008) states that transmissive teaching methods, traditionally encountered in mathematics and science, together with a perceived lack of relevance, have a direct correlation to the attitudes of students in these disciplines.

Co-curricular models such as MESA (Mathematics, Science and Engineering achievement) (Denson, 2015), which is an informal learning environment, can support students learning through the following strategies:

• informal mentoring
• make learning fun
• time management
• application of mathematics and science
• feelings of accomplishment
• confidence building
• camaraderie
• exposure to new opportunities.

Future learning skills (Future Workskills, 2020; Sahin & Top, 2015, Wall & Bonanno, 2014) can be developed and encouraged through using an instructional style that allows students to explore their world. STEM education in a project based and inquiry based learning framework can embed these future skills.

Teacher development

There is confusion among teachers as to the definition of STEM education (Lamberg & Trzynadlowski, 2015). Definitions and perceptions of STEM education are varied, as are teacher perceptions of integration. Most teachers also believe that the use of technology, such as a laptop, meet the requirements of integrating the T in STEM education. This lack of a clear understanding also exacerbates the difficulty of implementing a rigorous STEM program in primary schools.

Lyons and Quinn (2010 & 2012) have identified that teachers have an impact on student interests in STEM. Teachers have more influence than they realise on student perceptions, subject selection, and career choices.

STEM graduates do not consider teaching as a career (Tytler, 2008; Watt, 2009) and the encroaching retirement age of many in the STEM disciplines will increase shortages. Owing to the lack of qualified staff, the accepted practice of using teachers outside their field of expertise to teach in the STEM disciplines, influences student take up of subjects and teachers’ abilities to deliver a rigorous program.

Out-of-field teachers need resources, support and mentoring. Developing teachers’ skills and orientation to take this area seriously will need to go hand-in-hand (Fiengold, 2012; Morony, 2015). Primary school
teachers as generalists have difficulty in improving effective engagement with science as they have a lack of confidence, competence and a proven ability to support students in their scientific investigations (Tytler, 2008). Bell’s (2015) research recognised that the effectiveness of delivery of STEM education in the classroom was dependant on the knowledge and skills of teachers. If teacher knowledge is deficient then the impact on student learning is limited.

A range of professional learning approaches have been found to be of value depending on the school context and culture. These approaches include:

- **external partnerships**
  Teachers developing an interdisciplinary curriculum with support from university partners led to an ongoing relationship between the Australian School for Maths and Science and Flinders University (Bissaker, 2014, p.56)

- **internal school structures**
  There is a need to use time effectively at school and in meetings to encourage professional dialogue between teachers (Finegold, 2012).

- **specialist support**
  Given the aptitudes of the general education profession as outlined by Wai (2016), teachers have lower maths and spatial aptitudes in comparison to those who move into a STEM related field. Hence the need for content knowledge at primary and secondary levels (if specialist teachers are not available).

The effective implementation of STEM education in NSW schools requires the following actions:

- **professional learning to inform a clear understanding by all teachers in NSW schools as to the definition and purpose of STEM education**
- **professional learning for teachers at all levels in the STEM fields**
- **consideration of teachers in the STEM subject fields and their impact on the perceptions of students about STEM related disciplines.**

STEM education in K–12 schools

Implementing STEM education in NSW schools requires a focus on how and who. How will the school implement STEM education? NSW schools will need to consider how an interdisciplinary approach to implementation can meet the need for curiosity and reflection. Leadership in schools will need to consider how staff skills and school structures can support the implementation of STEM education. It is also important for primary schools to implement STEM education as early as possible.

All four areas of STEM are equally important and play different roles, they may not have the same weighting in time allocation for subjects but are all necessary for STEM e.g. mathematics is applied in the science or engineering areas and technology is the tool, the vehicle through which the areas connect.

Findings and implications

This review has outlined the need for STEM education in K–12 schools and explored the specific factors to consider for its effective implementation in NSW schools:

- STEM education in K–12 schools
- Pedagogical practices
- Teacher development

Pedagogical practices

An active learning methodology such as project based learning (PBL) underpinned by inquiry learning has been recognised as the most effective strategy for STEM education. PBL provides a process for teachers to incorporate student centred learning in real world contexts that encourage curiosity, critical thinking and reflection. The NSW Quality Teaching Framework (NSW Department of Education and Training, 2003) provides a basis to build STEM education upon as it promotes deep learning and authentic real world experiences.

Teacher development

Teachers need access to professional learning in the STEM education disciplines, in particular in the primary school. Where possible, schools should...
ensure that teachers involved with STEM education have the necessary qualifications or expertise to share with students.

Implications of STEM research for designing STEM education programs and initiatives for NSW schools:

System implications

• Professional learning as part of the everyday learning of teachers needs to become a part of their week or meetings
• Leadership and a commitment to STEM education at the school level is critical
• Time in schools for meetings and planning are critical
• Aligning STEM subjects with teacher expertise and passion is critical to student perceptions of the STEM field. Role models are an important factor in students selecting STEM careers.

Implications for primary schools

• STEM education is for all students, not only for selected students who may already show an interest or talent in that field
• An interdisciplinary approach is a more effective construct for delivery of STEM education, however in secondary schools this will take coordination and collaboration due to existing practices and timetables
• Core knowledge and understandings need to be better communicated across faculties particularly in secondary settings
• STEM education should focus on teaching skills not facts.

Implications for secondary schools

• STEM education is for all students, not only for selected students who may already show an interest or talent in that field
• An interdisciplinary approach is a more effective construct for delivery of STEM education, however in secondary schools this will take coordination and collaboration due to existing practices and timetables
• Core knowledge and understandings need to be better communicated across faculties particularly in secondary settings
• STEM education should focus on teaching skills not facts.

The STEM Academy Transdisciplinary Approach Year Three

by Foxbrite LLC

Conclusion

STEM education is about creating opportunities for authentic learning experiences to occur to develop critical thinking skills and problem solving through an iterative design / building or developing process that produces an end product which showcases student learning.

STEM education should be seen as an integrated component of curriculum in NSW. Both in NSW (BOS NSW, 2003; BOSTES, 2012) and nationally (ACARA, 2012), the curriculum highlights the need for inquiry learning and authentic learning using active learning methodologies such as project based learning and design thinking. Active learning includes critical thinking, problem solving and reflection, all core elements of an effective STEM education program.

The research literature in the STEM field is developing and changing, so it is important for schools and teachers to engage with STEM research literature to inform the development of an effective STEM education program.

NSW schools have a range of curriculum to link to and from in order to design and develop an effective STEM education program. Primary schools can utilise a core concept of curriculum integration and secondary schools have the expertise of teachers in the STEM fields to design a curriculum program that best meets their needs.
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