Department of Education, Training and the Arts

Towards a 10-year plan for science, technology, engineering and mathematics (STEM) education and skills in Queensland

Discussion paper

Queensland **the Smart State**

Queensland Government
Department of **Education, Training and the Arts**

Foreword

Science, technology, engineering and mathematics (STEM) education and skills development plays an important role in the Smart State vision.

Fostering education and training in this area ensures that today's students can generate and test new ideas and contribute to the scientific developments and innovations of tomorrow.

Increasing our capacity in this area will also contribute to job creation and provide solutions to social concerns, such as medical, environmental and engineering breakthroughs.

We're already making progress with initiatives like the $20 million Queensland Academy for Science, Mathematics and Technology, and the $1 billion *Queensland Skills Plan*. We are laying the foundations now to prepare for the Queensland of tomorrow.

In considering a long-term plan for science, technology, engineering and mathematics education and skills development, our Government has developed this discussion paper – *Towards a 10-year plan for science, technology, engineering and mathematics (STEM) education and skills in Queensland*. The discussion paper examines the issues Queensland must address to increase engagement in science, technology, engineering and mathematics study and careers, from primary school to university and beyond.

The Queensland Government, together with key stakeholders and industry, is looking at all aspects of student participation and achievement, teacher recruitment and training, education courses, equipment and resources as well as career advice and community perceptions in these areas.

This discussion paper has been developed to guide discussion, invite feedback and inform future policy directions. We encourage you to respond to this paper as we lay the foundations to drive a skilled and Smart State into the future.

Anna Bligh MP

Premier

Rod Welford MP

Minister for Education and Training and Minister for the Arts

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Executive summary

The Smart State vision is underpinned by the development of a highly skilled workforce to support the growth of Queensland's expanding knowledge-intensive industries.

To deliver this, the Queensland Government is committed to improving general education standards by adopting international best practice in education delivery and ensuring all children receive strong educational foundations.

The role of science, technology, engineering and mathematics (STEM) cannot be underestimated in preparing Queenslanders for the challenges of the future. Innovation is key to economic growth and STEM is a key driver of innovation. In considering a long-term plan for STEM education and skills development we are laying the foundations now to prepare for the Queensland of tomorrow.

This discussion paper has been developed to gain the views of stakeholders – schools, training providers, universities, peak and professional organisations, researchers, industry bodies, government agencies and others – to contribute to the way forward for STEM education and skills in Queensland.

Queensland's skills requirements

For Queensland to be a productive and progressive economy in the future, a workforce of scientifically and technologically literate people is required. With identified shortages across the engineering, science and medical professions, there is also a growing need for a highly trained pool of experts who specialise in STEM disciplines.

To address skills needs, Queensland has introduced a range of initiatives through the *Queensland Skills Plan*. These initiatives are being implemented and will produce positive outcomes in meeting demands.

Queensland has also made substantial efforts to promote STEM education in schools. This work targets the 'supply chain' of skills. However, future policy will also need to consider demand-driven factors to make study, training and careers in STEM more attractive.

With rapid technological change in industry around the world, it is likely that specific skills demanded in the future will differ from those required in the past. Beyond meeting immediate or short-term skills demands, there is a need to change the way we think about skills acquisition and consider the importance of lifelong learning.

The generic skills required to adapt to jobs and technologies that don't yet exist will be increasingly important, in addition to the specific skills required in the job market.

Education and training programs

Schools

STEM education programs in schools, the vocational education and training (VET) sector and universities are vital for the development of the essential skills, knowledge, attitudes and values to ensure that all Queenslanders can access the opportunities a modern economy offers.

The current Years 1 to 10 Queensland syllabus documents cover eight key learning areas, three of which are mathematics, science and technology. The Queensland Studies Authority (QSA) is reviewing the senior syllabuses, with findings to be reported by the end of 2007. Current senior offerings include the 'enabling sciences' as well as a range of other subjects such as Industrial Technology and Computer Studies. In this paper the term 'enabling sciences' includes advanced senior mathematics (Mathematics B and Mathematics C), Chemistry, Physics and Biology.

Science education is attracting much international and national attention. The focus is on balancing its purpose and nature. There is debate about the stage at which science education should be compulsory for students. There is also tension between the need to provide a broad and balanced study of science for all students as well as the necessary foundations for students who wish to pursue more specialised studies.

In a rapidly changing social and technological environment there are challenges in keeping curriculum and assessment up to date. Pedagogy is also important, with the literature highlighting the importance of teacher content knowledge as well as teaching practice. An inquiry-based, practical and relevant approach to STEM teaching and learning produces the most positive outcomes.

In examining the transitions between the education and training sectors, there might be further opportunities for shared service arrangements. This potentially includes shared delivery of courses, teaching and training personnel and facilities necessary to provide STEM education programs.

Training

Currently in Queensland, almost one-third of all vocational education and training (VET) is delivered in STEM fields. These include mechanical and industrial engineering and technology; automotive engineering and technology; electrical and electronic engineering and technology; architecture and urban environment; and more.

As part of the *Queensland Skills Plan*, Queensland has begun to develop new training products, including vocational graduate certificates and vocational graduate diploma programs for various industry sectors.

Universities

Each of Queensland's universities provides teaching and research and offers undergraduate and postgraduate studies. A full range of STEM-related programs is available, including science, engineering, mathematics and information technology degrees as well as other professional and applied qualifications.

There is need to ensure that the nature and content of undergraduate courses is current and reflects the latest developments in STEM. Nationally, some universities are restructuring their STEM and other programs to make them more responsive to industry demands.

Student participation and achievement

Queensland participates in two key international studies, the Program for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS). These studies measure scientific and mathematical literacy.

In PISA, the latest results (2003) show that Queensland students perform well, with averages above the mean of Organisation for Economic Co-operation and Development (OECD) countries. Their average performance is generally either similar or slightly lower than the average performance of students in the majority of other Australian jurisdictions.

Similarly, in TIMSS the most recent data (2002) shows that Queensland students had averages above the international mean. Queensland students were not significantly different to any other Australian jurisdiction with the exception that Queensland students were below NSW students in Year 8 Mathematics. Queensland students had the lowest average age, equal to Western Australia, for all countries and jurisdictions reported.

On the international tests, Australia has been found to have a particularly large achievement gap between poorer and more affluent students, and between schools with large proportions of either poorer or more affluent students.

These findings may have particular implications for Queensland which, according to some research, has disproportionate levels of children who are at risk of social exclusion.

Queensland’s performance has also been analysed against other significant measures of student achievement. These include state-based examinations of students in Years 3, 5 and 7 against national numeracy benchmarks and the sample-based National Year 6 Science Assessment program.

Queensland’s performance in numeracy is generally comparable with the national average. However, the 2003 National Year 6 Science Assessment Report showed that only 54.9 per cent of Queensland students were at or above the proficient standard, compared to 58.2 per cent nationally. A closer examination of the national results found that the proficiency of non-Indigenous students was significantly higher than that of Indigenous students. Students whose home language was English showed significantly higher levels of proficiency than those whose home language was not English, and students classified as living in remote locations performed significantly worse than students from any other location.

In terms of student participation in STEM-related education and training, analysis of data shows the following trends:

- The proportion of students undertaking a STEM subject in Years 11 and 12 at school has declined over the past few years. This includes Computer Studies, Industrial Technology and mathematics and sciences subjects.
- In the Year 11 and 12 enabling sciences, student participation has declined or remained static. Significantly higher proportions of males than females undertake study in Mathematics B, Mathematics C, Chemistry and Physics. The reverse is true for Biology, where female participation is proportionately higher. However, the greatest declines in participation for both genders are evident in Biology compared to the other enabling science subjects.
- In contrast, student participation in VET has risen significantly, with growth in STEM fields strong. In 2006 almost one-third of all VET delivery in the state was STEM-related. However, the female share of enrolments was comparatively low – women represented just over one-tenth of total STEM-related VET enrolments in 2006.
- University enrolment trends over time indicate that there has been a drop overall in STEM commencing enrolments in Queensland (excluding health sciences). The most significant drop has been in information technology. Recent figures for engineering indicate an upward trend. However, industry argues that, with increasing demand, more must be done to address skills shortages at a local and national level.

Workforce

Recruiting, retaining and developing a workforce of enthusiastic and competent teachers and trainers who provide exciting and relevant experiences for students is a vital component of any STEM plan for Queensland.

Forecasts to 2015 show state school teacher supply and demand is broadly in balance, with some shortages of specialist teachers, particularly in non-metropolitan locations. It is significant that any imbalance is projected to be in subjects that include secondary science and mathematics, industrial technology and information technology. Similar trends have been reported by non-state school sectors.

The 2006 *Teacher Qualifications Survey* of all permanently employed state school teachers (approximately 32 500) found that over 90 per cent of teachers of science and Years 11 and 12 Industrial Technology, Mathematics B and Mathematics C indicated they are qualified or have significant experience teaching in their area.

However, the data also shows that approximately 30 per cent of Senior Mathematics A and Years 8 to 10 mathematics teachers indicated they lack subject-specific qualifications. Approximately 15 per cent of teachers of these subjects indicated they are neither qualified nor have significant experience.

Significant opportunities exist for teacher professional development through recent reforms to teacher professional standards as well as the establishment of the Department of Education, Training and the Arts' Professional Development and Leadership Institute.

Student demand for STEM programs in the VET sector has increased. Combined with an ageing workforce and the competing demands of industry, this means that significant recruitment initiatives for TAFE Queensland will be required. Ongoing professional development must ensure that the qualifications and experience of TAFE and other training instructors are maintained in accordance with the *Australian Quality Training Framework*.

In the higher education sector, there is a general shortage of academics because the current workforce is ageing and graduates are choosing other forms of employment. Shortages vary by discipline, but commentators believe universities face a considerable recruitment task over the next decade.

Community engagement and profile of STEM

The attractiveness of STEM as a pathway for study and careers is dependent on the attitudes and motivations of students as well as the views of the broader community. So, the level of public awareness and engagement in STEM education and training is important.

Career advisory processes are key because they potentially inspire more young people to pursue studies and careers in STEM. The role of classroom teachers cannot be underestimated in relation to their influence in student decision-making.

Opportunities exist for school–industry links in offering real-life experiences for young people. Similarly, it is important for teachers to maintain links with industry to maintain currency and relevance in their teaching practice.

Collaboration between government, industry, education and research institutions is particularly important as scientific and technological advancements require more resource-intensive methods of research and education.

Where to from here?

The Queensland Chief Scientist and the Smart State Council have advocated the development of a 10-year STEM education and skills plan for Queensland. This discussion paper aims to stimulate discussion on future policy directions and facilitate feedback from stakeholders on the development of such a plan.

The questions throughout this paper are consolidated in Appendix 1. We invite you to respond to these questions and to raise other relevant issues.

The consultation period in response to this discussion paper is open until 30 November 2007.

Feedback may be in the form of written responses to some or all of the questions raised in this paper. Alternatively, respondents may wish to provide detailed comments on one or more specific issues raised, or on other issues relevant to the development of a STEM plan, but which may not have been dealt with in this paper.

Priority should be given to matters that stakeholders see as important to achieving the best possible outcomes for planning for STEM education and skills development during the next 10 years.

Responses may be submitted electronically by following the directions at the website:
www.education.qld.gov.au/projects/STEMplan

or by mail:

STEM Plan Project
Department of Education, Training and the Arts
Floor 21 Education House
PO Box 15033
City East, Brisbane, QLD 4002

1. Introduction

1.1 Purpose of discussion paper

This discussion paper aims to gain the views of stakeholders – schools, training providers, universities, peak and professional organisations, researchers, industry bodies, government agencies and others – to contribute to the way forward for science, technology, engineering and mathematics (STEM) education and skills in Queensland.

The document offers an overview of the current situation and a broad analysis of trends in STEM education and training to encourage debate on the next steps forward.

Feedback will inform policy directions and help develop a strategy for a 10-year plan for STEM education and skills.

Most chapters are accompanied by questions to prompt further discussion. For ready reference, the questions are consolidated in Appendix 1.

This chapter provides key terms and definitions to establish a common basis for future STEM discussion. It considers what the aims of a proposed 10-year plan for STEM education and skills might be.

The Proposal

To develop a long-term plan now to ensure that Queensland has the human capital it needs to be competitive in science, technology, engineering and mathematics (STEM) in the future.

The Discussion Paper

This discussion paper does not represent government policy. It aims to stimulate discussion on future policy directions.

1.2 Terms and definitions

Science is a process of inquiry. It involves questioning, predicting, hypothesising, investigating, gathering evidence, organising data, testing, refining, explaining and communicating.[1] The practice of science has led to an evolving body of knowledge which continues to be built up over time and revised as new evidence comes to light.

Scientific literacy is defined by the Organisation for Economic Co-operation and Development (OECD) as the ability to use scientific knowledge and processes not only to understand the natural world but to participate in decisions that affect it.[2]

Science education is the process through which people learn about science. Formal science education refers to the educative process that takes place in established educational institutions such as schools, training providers and universities.[3] Science education relies on both content knowledge and pedagogy and seeks to balance the principle of scientific literacy against preparing students for more specialised science study or employment.

Technology is often used as a generic term for all the tools people develop and use that involve the purposeful application of knowledge, experience and resources to create products and processes that meet human needs.[4] Technology deals with our usage and knowledge of tools and crafts and how we use them to control and adapt to our environment. It is a consequence of science and engineering and refers to material objects – such as machines, hardware or utensils – but it also covers broader themes, including systems, methods of organisation and techniques. Technology also includes an aspect of enterprise and market analysis.

Technologically literate people can understand the designed world, its tools, systems and the infrastructure to maintain them. They have practical skills in using tools and fixing simple technical problems, they use products appropriate to their needs, and they contribute to decision-making about the development and use of technology in environmental and social contexts.[5] In particular, the use of information and communication technologies is vital in modern contexts.

Engineering refers to the application of scientific principles and the use of technological capabilities to convert natural resources into structures, machines, products, systems and processes for the benefit of society.[6] The application of engineering has increased significantly and affects most aspects of our lives.

Fields of engineering are diverse and include manufacturing, process and resources, chemical, mining, materials, automotive, mechanical, industrial, civil, construction, building services, geotechnical, ocean, electrical, electronic, computer, software, aerospace, maritime, environmental, biomedical and transport.

Mathematics is a way of viewing the world to investigate patterns, order, generality and uncertainty.[7]

Advanced mathematics is often described as an ‘enabling science’ given it is essential to many sciences, particularly for the role it plays in the expression of scientific models.

Enabling sciences are broadly considered to be the fundamental sciences essential to scientific discovery, technological advancement and innovation within emerging scientific fields.[8] The definition of enabling sciences varies somewhat throughout the literature. For the purpose of this discussion paper, enabling sciences are the senior schooling subjects Mathematics B, Mathematics C, Physics, Chemistry and Biology.

Mathematical literacy, according to the OECD, is an individual’s capacity to identify and understand the role that mathematics plays in the world, to make well-founded judgments, and to use and engage with mathematics in ways that meet the needs of the individual’s life as a constructive, concerned and reflective citizen.[9]

Scientific literacy, technological literacy and mathematical literacy reinforce each other, while engineering involves the practical application and use of all sets of skills.

1.3 Classifying STEM

For its national audit of science, engineering and technology skills in 2006, the Australian Government considered the following fields: science – general; mathematical sciences; physical sciences; chemical sciences; earth sciences; biological sciences; information, computing and communication sciences; engineering and technology; and agricultural, veterinary and environmental sciences.[10] These correspond to Australian Bureau of Statistics (ABS) fields of research.

Notably, the audit did not include social sciences or health sciences. The question of whether or not to include the health sciences, in particular, is a key decision to be made in a 10-year STEM plan for Queensland. Occupations that may be classified as STEM, including health occupations, are set out in the following chapter.

1.4 Aims of a STEM education and skills plan

A productive and progressive economy like Queensland's needs a workforce of scientifically and technologically literate people to compete in a global marketplace. Innovation is key to economic growth and in order to promote innovation, we need a pool of highly skilled and qualified experts in STEM.

Calls for a long-term STEM education and skills plan for Queensland have emerged from a range of sources, including the Smart State Council in its 2006 report *Education and Skills for the Smart State* and the *2005 Report of the Queensland Chief Scientist*.

Targeted STEM initiatives such as *Spotlight on Science*, a key schooling sector investment program from 2003 to 2006, have identified STEM planning as a priority to advance Queensland's Smart State principles and promote continued economic prosperity.

It is proposed that a long-term STEM education and skills plan would aim to:

- encourage high levels of scientific, technological and mathematical literacy for all Queenslanders
- build a workforce with the high-level STEM skills required to remain competitive in a knowledge-based economy.

1.5 Questions for discussion

1.1 Are the definitions described in this chapter appropriate in terms of breadth and inclusiveness as a basis for a STEM education and skills plan? If not, what alternative or amended definitions should be used?

1.2 How do you view the role of science education as a key building block of a future STEM plan? Are there other key factors that should be considered when developing such a plan?

1.3 To what extent do you believe that a STEM education and skills plan should be dual-purposed, focusing on enhanced STEM literacies for the whole population as well as preparing young people for careers in specialist STEM fields? How compatible do you consider these goals?

1.4 What do you consider the priorities for a 10-year STEM plan should be?

1.5 What role can you or your organisation play to contribute to STEM education and training in Queensland?

2. Rationale

2.1 Background

The Queensland economy is booming. Strong demand for natural resources, particularly coal and minerals exports, and the fastest-growing population in Australia are priming the rapid growth of Queensland's economy.

At the same time, Queensland's economic performance has created a prosperous business climate leading to additional investment in new technologies, new products and new services.

However, Queensland's future prosperity cannot rely solely on the buoyancy of traditional industries and dynamic population growth. Global competition, market instabilities and changing trends in immigration are placing increasing pressure on the growth of the state's economy.

To meet these challenges, Queensland needs to continue to encourage the emergence of new high-value, high-growth industries of the future and apply strategies to value-add to traditional industries. International experience demonstrates that high-growth economies are those that build upon strong foundations to move towards a knowledge-based economy.

A knowledge-based economy is one that uses knowledge and learning to enhance the generation of wealth and prosperity in existing and new industries.

The drivers of a knowledge economy can be broken down into four key elements that build physical and human capital: investing in education; building up skills; facilitating research; and promoting innovation.

The first three drivers, education, skills and research, provide the building blocks which support innovation. STEM is fundamental in each of these areas.

This chapter is an overview of Queensland's current STEM skills needs. There is demand for highly skilled workers across many industry sectors and this is reflected in the reforms introduced under the *Queensland Skills Plan.* These initiatives are being implemented and are likely to continue to produce positive outcomes in meeting skills demands.

This chapter also considers the skills needs of the future and the importance of workforce participation strategies. The role of research and development (R&D) is considered as the heart of innovation.

2.2 Issues

2.2.1 Growing demand for STEM skills

In its *Science, Technology and Industry Outlook 2006*, the OECD reported that issues of human resources are taking on greater urgency. Demand for STEM skills is increasing and supply is declining relatively across the European Union (particularly Denmark, Italy, Germany, Hungary, Finland), the United States and Japan.[11]

Increasing global demand for STEM skills is a result of: growing use and impact of information and communications technologies; rapid application of recent scientific advances in new products and processes; high rate of innovation across OECD countries; and the shift to more knowledge-intensive industries and services.[12]

Supply is hampered by several factors, including fewer tertiary enrolments in science and engineering degrees as fewer school students choose to study science and mathematics beyond the compulsory school years.[13]

An increasingly global market for skilled labour has also resulted in labour mobility issues. Some developed countries are now major senders of personnel abroad and some developing countries are major receivers.[14] Underlying this are broader demographic shifts: over the next decade, many developed countries will face ageing populations while in developing countries around 700 million young people will join the labour market.[15]

The 2006 report on the Australian Government's audit of science, engineering and technology skills indicated that Australia has an extensive STEM sector that will play a key role in the nation's future economic development.[16] The report's findings included:

- There are sectoral STEM labour supply issues. These reflect tight labour market conditions and include recruitment difficulties with respect to engineering disciplines; sciences such as earth sciences, chemistry, spatial information sciences and entomology; and mathematics.
- Labour projections based on historical data may not accurately reflect future industry skills demands.
- Participation in STEM will be impacted by demographics, including workforce ageing.
- International demand for STEM skills will increase and may impact on global migration patterns and policies.

Queensland's labour market is even tighter than other states and territories; in May 2007 the Australian Bureau of Statistics (ABS) reported that Queensland's unemployment rate was as low as 3.5 per cent.[17]

Against this backdrop, the Queensland Chief Scientist's 2005 Annual Report estimated that local demand for staff in STEM professions has been growing far above the national rate.[18]

If this growth continues, Queensland will face a shortage of the scientists and engineers required to build and sustain a knowledge economy.

STEM professional occupations

- engineering managers
- information technology managers
- chemists
- geologists and geophysicists
- life scientists
- environmental and agricultural science professionals
- medical scientists
- other natural and physical science professionals
- architects and landscape architects
- quantity surveyors
- cartographers and surveyors
- civil engineers
- electrical and electronics engineers
- mechanical, production and plant engineers
- mining and materials engineers
- engineering technologists
- other building and engineering professionals
- computing professionals
- mathematicians, statisticians and actuaries

Source: Adapted from the Australian Bureau of Statistics Australian Standard Classification of Occupations (ASCO).

2.2.2 The skills needed today

The ABS recently changed its system for classifying occupations, moving from the Australian Standard Classification of Occupations (ASCO) to the Australian and New Zealand Standard Classification of Occupations (ANZSCO).[19]

ANZSCO takes the system from a focus on professional, associate professional and trades groupings to the concept of defined skills levels.

For the purposes of this paper, types of occupations will be broadly referenced with respect to categories including:

- *Professional occupations* – in this context meaning that a university qualification is required.
- *Technical and trades occupations* – while a large proportion of these occupations require Australian Qualifications Framework (AQF) certificate III or IV level qualifications, there is increasing demand for higher level qualifications such as vocational graduate diplomas or vocational graduate certificates for trade and technician workers at master tradespersons level.

Health professions

- generalist medical practitioners
- specialist medical practitioners
- nurse managers
- nurse educators and researchers
- registered nurses
- registered midwives
- registered mental health nurses
- registered developmental disability nurses
- dental practitioners
- pharmacists
- occupational therapists
- optometrists
- physiotherapists
- speech pathologists
- chiropractors and osteopaths
- podiatrists
- medical imaging professionals
- veterinarians
- dieticians
- natural therapy professionals
- other health professionals
- psychologists

Health technical occupations

- enrolled nurses
- welfare associate professionals
- ambulance officers and paramedics
- dental associate professionals
- Aboriginal and Torres Strait Islander health workers
- massage therapists

Source: Adapted from the Australian Bureau of Statistics Australian Standard Classification of Occupations (ASCO).

Professional occupations

In its 2007 report *An Assessment of Professional Skill Shortages – Queensland and Australia*, the Queensland Government's Department of Education, Training and the Arts (DETA) found that professional occupations have shown strong and fairly consistent growth over the past 25 years.[20] Research considered the demand for professional occupations and attempted to compare the potential supply of skilled labour through university graduate completions. Outcomes indicated that shortages are predominantly caused by an inadequate supply pool in relation to the engineering and building professions.

The Association of Consulting Engineers Australia in its 2006 report *Engineering Services in Queensland – Can they meet demand?* identified that, over the last five years, the demand for engineering consulting services has been growing by around 12 per cent a year both nationally and in Queensland, with the demand for engineers in Queensland expected to grow from 15 600 in 2005–06 to 17 300 in 2010–11.[21] The report found, however, that the supply of engineers is likely to be severely limited.

In the health field, the supply of medical practitioners has been found to be inadequate, particularly at the national level.[22] This is especially notable considering that, according to the Australian Government Productivity Committee, the demand for health workers will continue to grow significantly in years to come.[23]

Although the overall size of the predicted shortages in engineering and medical practitioners is clearly a cause of concern, it is important to also recognise the critical impact the lack of a key skill can have on an industry sector. Some occupations involve only a small number of people in highly specialised roles. Although demand may be numerically low, failure to meet the demand when required can have a large impact on an industry's productivity.

Poor working conditions can contribute to recruitment difficulties occurring in a particular profession. In particular, non-metropolitan regions may seem unattractive to professionals in comparison with urban areas, requiring greater incentive packages to attract and retain skilled workers.[24]

Trades and technical occupations

In 2006, the Queensland Government launched the *Queensland Skills Plan*, a major policy and investment framework developed to better match the supply of skilled labour to industry's needs and the economy's demands.[25] Its focus is on trades and technical occupations, including priority STEM industries such as manufacturing and engineering, health care, automotive and building and construction.

The *Queensland Skills Plan* was developed following statewide consultation and responded to the priorities identified in the *Skills for Jobs and Growth* discussion paper. It acknowledged that the intense employment growth in the Queensland economy has seen the emergence of skills shortages and that this is also reflected in other parts of Australia and OECD member countries. In particular, it identified two major skills challenges for the Queensland labour market:

- addressing the urgent demand for trades skills
- developing more high-level skills in the associate professional workforce.[26]

The *Queensland Skills Plan* responds directly to these challenges and, amongst other things, aims to:

- provide 14 000 extra high-level training places across the state in each year by 2010, including 400 additional high-level places in manufacturing and engineering
- increase the number of trade training places – 17 000 extra places available in each year by 2010, including 4500 additional places in manufacturing and engineering depending on demand.

Importantly, *Skills for Jobs and Growth* noted that skills shortages are also caused by a range of recruitment and retention issues at an industry or enterprise level, including:

- insufficient remuneration to retain skills in an industry or occupation
- adverse perceptions of industry attractiveness
- relative unattractiveness of work due to its remote location
- job design.[27]

2.2.3 The skills needed tomorrow

With rapid technological change in industry around the world, it is likely that specific skills demanded in the future will differ from those required in the past. Beyond meeting immediate or short-term skills demand, there is a need to change the way we think about skills and consider the attributes the future workforce will need.

Emphasis will be required on lifelong learning. The OECD reports that universal participation in lifelong learning is necessary for countries to meet the social and economic demands of the 21st century.[28] This means that we will need to look beyond traditional pathways to qualifications and encourage a continual and flexible approach to personal and professional learning and development opportunities.

It is particularly important to consider the generic skills required to adapt to jobs and technologies that don't yet exist as well as specific skills required in the job market. A STEM education, particularly in the enabling sciences, would help to provide the foundations for young people to acquire further skills as they make their lifetime transitions through the labour market.

An inclusive approach to STEM education and skills development has the potential to produce the most promising socioeconomic outcomes for all.[29] This includes the promotion of participation from groups who are under represented in the STEM workforce, including women and Indigenous Australians.

STEM occupations – trades and technical

- medical technical officers
- science technical officers
- civil engineering associate professionals
- electrical engineering associate professionals
- electronic engineering associate professionals
- mechanical engineering associate professionals
- other building and engineering associate professionals
- computing support technicians
- general mechanical engineering tradespersons
- metal fitters and machinists
- toolmakers
- aircraft maintenance engineers
- metal casting tradespersons
- metal finishing tradespersons
- motor mechanics
- automotive electricians
- panel beaters
- vehicle painters
- vehicle body makers
- vehicle trimmers
- electricians
- refrigeration and airconditioning mechanics
- electrical distribution tradespersons
- electronic instrument tradespersons
- electronic and office equipment tradespersons
- communications tradespersons
- carpentry and joinery tradespersons
- plumbers
- wood machinists and turners
- cabinetmakers
- marine construction tradespersons
- glass tradespersons
- drillers
- chemical, petroleum and gas plant operators
- power generation plant operators

Source: Adapted from the Australian Bureau of Statistics Australian Standard Classification of Occupations (ASCO).

2.2.4 The importance of research and development

The Queensland Government invests substantially in R&D. The rationale for this investment is simple – to build a knowledge-based economy that will lead to economic, social and environmental benefits for Queenslanders.[30]

However, the Chief Scientist argues that more can be done to optimise returns on Queensland's investment in R&D, with education and skills development a key area of opportunity.[31]

Figures prepared by the Chief Scientist in 2005 show that Queensland had 85 000 people with university-level STEM qualifications, including 14 000 researchers (mainly PhD qualified).[32] To reach parity with the leading OECD R&D economy, Finland, Queensland would need to more than double its stock of researchers and other R&D personnel, and increase the total number of STEM-qualified individuals by 60 per cent.[33]

2.3 Questions for discussion

2.1 To what extent is STEM a driver of innovation in a global knowledge economy and what is its role in future workforce preparedness?

2.2 To what extent are the types of STEM occupations listed in this chapter suitable as the focus of a future STEM education and skills plan? What modifications might need to be made?

2.3 How appropriate are the inclusion of health occupations and the exclusion of finance and some other mathematics-intensive occupations from a STEM education and skills plan?

2.4 To what extent can a future STEM education and skills plan adopt a demand-driven focus, given the rapidly changing skill requirements of industry?

2.5 What is the nature of the STEM skills needed by your industry/organisation/region?

2.6 How do the skills of the workers already employed in STEM-related roles by your organisation compare to the skills that might be required in the future?

2.7 For which occupations (if any) does your industry/organisation/region have difficulty in recruiting? What do you consider to be the main issues in relation to recruitment difficulties?

2.8 What strategies are needed to better retain the skills and expertise of an ageing STEM workforce?

3. Snapshot of STEM initiatives

3.1 Background

Worldwide, countries are introducing policy measures to promote participation in STEM education and training and build the skills of their workforces.

This chapter provides a brief overview of international trends in STEM policy and also examines national policy developments. Relevant initiatives from other jurisdictions are highlighted, as is Queensland's strong commitment to date.

Several current Queensland Government initiatives are showcased, with emphasis on the need to look forward and build the education, training and industry sectors required for the future.

3.2 Context

In light of its social and economic importance, many OECD countries have introduced policy measures to strengthen investment in soft and hard infrastructure to promote STEM skills growth. These include initiatives in relation to education sectors, institutional structures, public/private partnerships, and research and development (R&D).[34]

Strategies are diverse, focusing on both increasing the supply of skills to the labour market and building the demand for specific skills sets through focused programs.

In terms of skills supply, reforming the school curricula to make science more accessible and attractive to students – in other words reforming science education – is a common initiative. The European Commission recently released *Science Education Now: A Renewed Pedagogy for the Future of Europe*. The report argues that:

> '*In recent years, many studies have highlighted an alarming decline in young people's interest for key science studies and mathematics. Despite the numerous projects and actions that are being implemented to reverse this trend, the signs of improvement are still modest. Unless more effective action is taken, Europe's longer term capacity to innovate, and the quality of its research will also decline. Furthermore, among the population in general, the acquisition of skills that are becoming essential in all walks of life, in a society increasingly dependent on the use of knowledge, is also under increasing threat.*'[35]

Across Australia, the importance of STEM has been highlighted through initiatives including: the *Backing Australia's Ability – Building our Future through Science and Innovation* strategy; the Prime Minister's Science, Engineering and Innovation Council (PMSEIC); and Questacon, the National Science and Technology Centre.

A number of developments have recently occurred through the Ministerial Council on Education, Employment, Training and Youth Affairs (MCEETYA). In April 2007 all states and territories committed to working together to develop nationally consistent curricula starting with English, mathematics and science.

The Australian Council for Educational Research (ACER) in 2007 published *Re-imagining Science Education: Engaging students in science for Australia's future.* The report suggests that science education in Australia is in crisis and requires immediate reform. It highlights the need to draw from successful, evidence-based practices to re-engage the school learner in science and argues for teacher-led change.[37]

Some policy measures used internationally to grow the STEM workforce

- Reforming school curriculums to make science more accessible and attractive
- Improving the quality of teaching in mathematics and science in schools
- Increased pathways in STEM studies and careers
- Enhancing public/private partnerships between industry, secondary schools and tertiary institutions to improve student performance, enhance the relevance of instruction and raise enrolments
- Shortening PhD programs while improving PhD supervision
- Increasing participation rates of women
- Incentives to businesses to hire more staff in targeted fields and occupations, particularly researchers
- More government assistance to PhD students

Source: Adapted from the OECD's *Science, Technology and Industry Outlook 2006* [36]

The Crisis in Science Education
The ACER report *Re-imagining Science Education: Engaging students in science for Australia's future* argues that there is a crisis in science education with four main elements:

1. evidence of students developing increasingly negative attitudes to science over the secondary school years
2. decreasing participation in post-compulsory science subjects, especially the enabling sciences of physics, chemistry and higher mathematics
3. a shortage of science-qualified people in the skilled workforce
4. a shortage of qualified science teachers

Source: Adapted from Tytler[38]

States and territories are increasingly concentrating on the role of STEM education and training to underpin economic growth, with schools a particular focus of policy interventions. In Victoria, the March 2006 *Inquiry into the Promotion of Mathematics and Science Education* led to the May 2007 roundtable on the teaching of mathematics and science chaired by the Victorian Governor. The Inquiry's outcomes will lead to the release of a new Victorian mathematics and science education strategy later this year.

In its 2007–08 Budget, the New South Wales Government committed $280 million over four years for the *Building Better Schools* initiative (which includes upgrading 800 science laboratories) and $38.8 million over four years for the *Connected Classrooms* initiative to significantly expand technology-based learning in government schools.

Strategic Directions for Science and Mathematics in South Australian Schools 2003–2006 aims to enhance the teaching and learning experience for teachers and students. The strategy aims to attract and retain high-quality teachers of science and mathematics and build partnerships with the wider community.

3.3 Queensland Government's initiatives

Queensland has demonstrated its leadership in STEM education and skills development through its *Smart State Strategy*. *Smart State Strategy* investment programs have launched a range of initiatives across the education and training sectors. In particular, *Science State – Smart State Spotlight on Science 2003–2006* committed $14 million under a Queensland Government push to increase the numbers of school students studying science and to attract and retain skilled science teachers.

Technology and innovation parks

A number of current initiatives directly promote STEM skills development across education and training sectors and provide key links to industry and R&D. One initiative is the establishment of technology parks to nurture technology-based companies. The Brisbane Technology Park aims to:

- develop as a community that makes visible and evident a range of business, economic and scientific skills
- provide resident companies involved in the commercialisation and exploitation of technology with a sense of identity
- provide an environment that develops a sense of community in which all residents contribute to the healthy exchange of scientific and other knowledge at both the business and the individual level.

The Brisbane Innovation Park is currently in preliminary development. It is envisaged that the park will be developed in collaboration with Griffith University and the private sector to encourage the clustering of research institutes and private enterprises to connect scientific research with industry development.

Queensland Skills Plan

The comprehensive *Queensland Skills Plan* has a broad range of initiatives to support the development of high-level and in-demand skills. This includes initiatives such as a new centre of excellence in manufacturing and engineering sectors; establishing a new statewide Trade and Technician Skills Institute; and developing skills formation strategies for industries such as aviation, biotechnology, building and construction, energy, food processing, health and enrolled nursing, IT and business services, manufacturing and mining.

Queensland Academies

The establishment of Queensland Academies marks a new era for senior schooling. The academies provide accelerated learning opportunities for high-achieving students, and are a pathway for future careers through direct links with industry and university partners.

The Queensland Academy for Science, Mathematics and Technology was opened in February 2007, along with the Queensland Academy for Creative Industries. A third Queensland Academy for Health Sciences will be launched in 2008.

Science Centres of Innovation and Professional Practice

Another key initiative has been the establishment of six Science Centres of Innovation and Professional Practice. The centres are based in a cluster of schools, both primary and secondary, and work with a partner university to deliver the professional development needs of teachers within each cluster. The centres also work with other clusters, sharing ideas, programs and expertise, bringing together teachers, students, universities, research bodies, government departments, science-based industries and employers.

Smart Women – Smart State Strategy

In 2005 the Smart Women – Smart State Taskforce was established to advise the Minister for Women on strategies to increase girls' and women's participation in emerging industries, particularly science, engineering and technology. The Taskforce developed the *Smart Women – Smart State Science, Engineering and Technology Action Plan (2006–2009)*, which sets out practical initiatives to achieve positive outcomes in these areas.

Priorities include to:

- raise awareness among women and girls and increase their exposure to educational and employment opportunities in science, engineering and technology fields
- foster collaborative partnerships between government, industry, educational and community organisations to deliver improved outcomes for women and girls considering or undertaking STEM careers
- promote better pathways for women and girls to make the transitions between schooling, further education, training and employment (including career breaks) in STEM industries
- monitor and measure the achievements of strategies for the enhancement of women's and girls' participation in STEM.

3.4 Questions for discussion

3.1 What are the characteristics of current and past government, education or industry initiatives that have been particularly successful in promoting participation in STEM-related courses and careers?

3.2 What lessons can be learned from any previous STEM education and training initiatives?

3.3 What implications will national trends (for example, moves towards nationally consistent curricula and a national science education framework) be likely to have for Queensland's future directions for STEM?

Science Education Strategy for Queensland State Schools 2006–2009

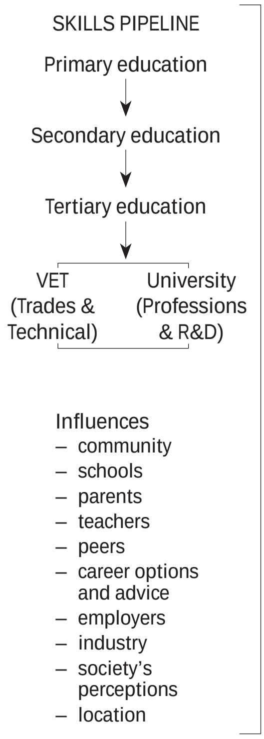
A major focus of the *Science Education Strategy 2006–2009* is the provision of targeted high-quality professional development for primary and secondary teachers of science.

Four Senior Science Officers work across the state to create opportunities for teacher professional development through building stronger partnerships with 'real world' scientific industry and research organisations.

The *Science Education Strategy* supports teachers in forming partnerships to improve their scientific knowledge and understanding of local industries and organisations. The benefits of such partnerships lead to improved student awareness and learning.

Smart Women – Smart State Awards

The annual *Smart Women – Smart State Awards* publicly acknowledge Queensland women and girls who are excelling in their education or careers to lead the way in science, engineering and information and communication technology. There are thirteen $2500 awards with seven categories applicable to secondary, undergraduate and postgraduate students.



4. Education and Training Programs

4.1 Background

STEM education programs in schools, as well as across the vocational education and training (VET) and university sectors, are vital platforms for the development of essential skills and knowledge.

At both state and national levels there is significant activity to review and reform school 'science education', with particular efforts around national collaboration on consistent curriculum and standards. Any broader proposals for STEM education and training will need to consider these movements.

Training initiatives that are gaining increasing significance in responding to skills shortages include bridging courses designed to support the entry of internationally recruited personnel into local industries, and the retraining or up-skilling of current employees looking to move into new or expanded roles.

This chapter provides a summary of Queensland's current STEM school curricula and highlights key issues that have been raised in recent literature. It describes the array of VET products offered locally and identifies relevant STEM fields of education. It briefly describes the STEM programs available through universities.

4.2 Issues

4.2.1 The nature and purpose of science education

As indicated in Chapter 3, there are moves to develop nationally consistent school curricula in certain areas, including mathematics and science. In April 2007, all jurisdictions committed to working together to achieve this. This work will map and assess current initiatives by the various education authorities with the aim to develop strategies to enhance the delivery of mathematics and science education across the country.

Over the past few years, the nature of school science education and school curriculum frameworks has been the subject of much scrutiny, particularly since the number of students studying science is declining.[39] Generally, there is agreement that the compulsory years of schooling should give all students a broad and balanced study of science.[40]

However, balancing the purpose and nature of science education in schools is challenging. On one hand there is the goal of developing scientifically and technologically literate members of society. On the other, there is the need to provide the foundations for students who wish to pursue more specialised studies in science, leading to further education, training and employment pathways.

This issue also has implications for the teaching workforce, in particular the tension between generalist teachers and specialist-trained teachers feeling confident in their respective teaching areas.

4.2.2 The relevance of curriculum to contemporary issues

The 2007 ACER report *Re-imagining Science Education* suggests that the failure of school science to respond to the changing needs of students and the changing nature of science itself has created a crisis in Australian science education.[41] The report calls for major curriculum reform and emphasises that the current curriculum frameworks and teaching of science across all states and territories turn students away from the discipline.[42] In describing the current situation it noted:

> *'... curriculum and classroom practice are failing to excite the interest of many, if not most, young people at a time when science is a driving force behind so many developments and issues in contemporary society'.*[43]

At the ACER Annual Research Conference in 2006, *Boosting Science Learning – what will it take?*, Professor Peter Fensham, Adjunct Professor at the Queensland University of Technology and Emeritus Professor of Science Education at Monash University, spoke about a crisis of interest in science.[44] Professor Fensham argued that many students do not enjoy studying science and have concluded that post-compulsory science studies should be avoided unless needed for some career purpose.[45] In addressing this issue, the conference heard that science curricula should emphasise 'the study of science as a story involving real-world people, situations and actions' and that 'this requires science education to be related to issues of personal and social significance, with personally engaging open problems for investigation'.[46]

At many levels, the issue of relevance to real-life and contemporary issues is one that should drive reforms to the overarching curriculum frameworks and professional development strategies. This presents substantial challenges for curriculum developers, and teachers of science, in keeping the curriculum and assessment accurate and relevant in a rapidly changing social and technological environment.

4.2.3 Curriculum products and provision

In Queensland, the Queensland Studies Authority (QSA) is the statutory body which provides schooling syllabuses. The QSA has developed Years 1 to 10 syllabus documents in eight key learning areas (KLAs): English; mathematics; science; studies of society and environment; technology; health and physical education; languages other than English; and the arts.

The syllabuses provide an estimate of the minimum time needed to provide students with opportunities to demonstrate the core learning outcomes. Table 1 summarises the number of hours expected to be spent on the mathematics, science and technology KLAs. The mathematics syllabus assumes a far greater allocation of time, particularly in the primary years.

Table 1: Indicative instruction times for mathematics, science and technology key learning areas (KLAs) in Years 1–10

	TOTAL HOURS INSTRUCTION (average per year)		
	Maths	Science	Technology
Years 1–3	200	60	60
Years 4–7	160	60	60
Years 8–10	80	60	60

Decisions regarding the allocation of curriculum time are school-based, if not predominately teacher-based. In terms of prescribing detail in the syllabuses, the selection of content and contexts that provide vehicles for demonstration of the outcomes are also school-based decisions. The core content section in some QSA syllabuses such as mathematics and science provides examples for schools to consider, but are not prescriptive.

Queensland Curriculum, Assessment and Reporting
The Queensland Curriculum, Assessment and Reporting Framework will be implemented across all Queensland schools from 2008 to support schools and teachers to implement a consistent, rigorous curriculum in each key learning area (KLA).

The framework will:
- explicitly define the essential knowledge, skills and processes in each KLA which all teachers must provide all students with multiple opportunities to learn by the end of Year 9
- provide a common frame of reference and a shared language for communicating student achievement across the state
- equip teachers with high-quality assessment tools for collecting evidence of student achievement
- promote teachers' professional learning, focused on good assessment practices and judging the quality of student achievement against statewide standards
- introduce comparable statewide assessment of student learning in Years 4, 6 and 9
- provide more meaningful reports of student achievement.

STEM Key Learning Areas (KLA)
Years 1 to 10

Science
The science KLA is organised into five conceptual strands:
- Science and Society
- Earth and Beyond
- Energy and Change
- Life and Living
- Natural and Processed Materials

Technology
The learning outcomes of the technology KLA are organised into four strands:
- Technology Practice
- Information
- Materials
- Systems

Mathematics
The Years 1 to 10 Mathematics Syllabus is organised into five strands:
- Number
- Patterns and Algebra
- Measurement
- Chance and Data
- Space

Source: Queensland Studies Authority (QSA) Years 1 to 10 Syllabus [48]

There have been calls for the inclusion of science across all years of schooling to support the growing demand in STEM and other employment streams for these necessary skills. In Queensland, it is intended that the implementation of the QSA Years 1 to 10 syllabuses achieves this for the compulsory years. However, while there is no quantitative data available regarding participation rates in science in the compulsory phase, the review of the *Spotlight on Science* strategy highlighted a concern about inconsistency in the delivery of science education to all students in Year 10.[47]

In Queensland, Years 11 and 12 students make choices from a large range of subject offerings, with all subjects considered electives. Generally, the senior subjects can be categorised into two main streams: those that are Authority subjects and eligible for consideration as part of the tertiary entrance procedures; and those that are vocationally oriented and can incorporate recognised VET certifications. Many schools also offer stand-alone VET courses.

The list of Authority subjects includes a wide range of STEM studies. These include the enabling sciences (Mathematics B, Mathematics C, Physics, Chemistry and Biology) and subjects like Engineering Technology that combine science and mathematics study with societal development and change, while also developing knowledge and understanding of the engineering profession.

The issue of whether the study of science should be mandatory across all years of schooling needs to be addressed in the ongoing QSA Senior Syllabus Review. It should be noted that the proposed development of a 10-year STEM education and skills plan coincides with this review, which is considering:

- the curriculum frameworks in the senior phase (and the role of Year 10 in this phase)
- participation by students in certain subject areas
- the continuity and coherence in the senior school curriculum with the Years 1 to 10 Queensland Curriculum, Assessment and Reporting Essentials and Standards as well as further education and training courses.

4.2.4 VET Sector

A vast array of VET products is available through registered training organisations in Queensland, including the public provider (TAFE Queensland) and private providers. VET training products are competency-based and approved through either national training packages or by state or territory course-accrediting bodies.

Training products

There are two main types of training products:

- *Courses/qualifications from nationally endorsed training packages*: These are packages developed by industry to meet the training needs of an industry or group of industries. Currently, there are close to 80 endorsed training packages with almost 4000 qualifications ranging from Certificate I to Advanced Diploma level in accordance with the Australian Qualifications Framework.
- *Accredited courses/qualifications*: Accredited courses address skill requirements for industry, enterprises and the community where these are not covered in nationally endorsed training packages. At 31 December 2006, there were 2700 accredited courses/qualifications, with 545 offered in Queensland.

As part of the *Queensland Skills Plan*, Queensland has begun to develop new training products, including vocational graduate certificates and vocational graduate diploma programs for various industry sectors. The development of the higher-level trade or master tradesperson qualifications will be coordinated through the Trade and Technicians Skills Institute.

Training providers

At 31 December 2006, there were 4342 registered training organisations nationally. Of these 1961 were registered to operate in Queensland, but only a small number offer STEM fields. Significantly, these include the 13 TAFE institutes.

STEM-related VET fields of education
- aerospace engineering and technology
- architecture and urban environment
- automotive engineering and technology
- biological sciences
- building
- chemical sciences
- civil engineering
- computer science
- electrical and electronic engineering and technology
- information systems
- information technology
- manufacturing engineering and technology
- maritime engineering and technology
- mechanical and industrial engineering and technology
- other natural and physical sciences
- process and resources engineering

4.2.5 Universities

Queensland has nine of Australia's 39 universities and each university has the freedom to specify its own mission and purpose, modes of teaching and research, constitution of the student body and the range and content of educational programs.[49] All provide teaching and research and offer undergraduate and postgraduate studies. A full range of STEM-related programs is available, including science, engineering, mathematics and information technology degrees as well as other professional and applied qualifications.

The nature and content of undergraduate courses should be accurate and relevant and should reflect the latest developments in STEM. In a presentation at the 2007 *Science and Engineering: Skills for Australia's Future*, Professor Kathleen Parson from the University of Queensland suggested that while scientific research is rapidly changing, science education has changed relatively little. She highlighted the following issues as contributing to 'the flight from science':

- a rapidly changing knowledge base
- the ageing of the science instructor cohort
- a lack of professional development
- minimal communication between universities and the schooling sector
- limited communication between science and education university faculties
- negative community perceptions.[50]

Nationally, some universities are restructuring their STEM and other programs to make them more responsive to industry demands. A 2007 article in the *Australian Financial Review* argued that the resources boom is fuelling a major revamp of engineering curricula and university entrance criteria as the higher education sector responds to mining sector needs for highly skilled graduates.[51] The article identified the University of South Australia, the University of Adelaide and University of Western Australia as institutions implementing major change.[52]

4.2.6 Resources and equipment

While scientific excellence requires people with the right skills to undertake research, develop ideas and apply new technology, it also requires physical infrastructure such as laboratories, resources and equipment to be relevant in a technologically advanced society.

Smart Classrooms
The Queensland Government's Smart Classrooms strategy brings together the future perspective and the momentum established by the *2002–2005 ICTs for Learning Strategy*, to build the classroom of the future: the smart classroom.

Through Smart Classrooms, schools will cement new technologies into the core of education.

In its 2007–08 Budget, the Queensland Government committed $70 million over four years to provide a laptop computer for every teacher in a state school or TAFE institute. This will reinforce the vital role that technology, ICTs in particular, plays in teaching and learning contexts.

Practical work in science

The ACER report, *Re-imagining Science Education*, notes that practical work in science fulfils a variety of functions: to illustrate, verify or affirm science concepts or principles; to engage students positively with the science enterprise; and to develop understandings of investigative methods in science, involving the gathering and use of evidence.[53] Practical work in both science and technology is most effective when facilities offer appropriate equipment and resources.

The 2006 *Parliamentary Inquiry into the Promotion of Mathematics and Science Education in Victoria* noted that inquiry-based learning through hands-on experimentation should be central to the science curriculum for both primary and secondary students.[54] The Committee heard that the quality of laboratory facilities and scientific equipment has a direct, significant influence on the quantity and variety of practical work in secondary schools.[55] In terms of primary schools, the Committee also heard evidence suggesting that a greater number and range of interesting and challenging science experiences could be offered if the availability and quality of equipment were improved.[56]

In addressing the challenges of declining student interest and participation in science, Professor Leonie Rennie from Science and Technology Education at Curtin University in Western Australia suggests that the school science curriculum must move beyond the textbook, using community resources to explore science-related community issues.[57]

In a keynote address to the ACER research conference in August 2006, Professor Rennie provided several examples of successful school–community partnerships. She argued that community resources have a critical role to play in promoting relevance and interest in science, and that using such resources to complement those in schools increases the variety of stimuli and sources of information for students.[58] Such strategies might also be useful as a means to ensure school science education maintains currency and relevance.

It has been argued that Occupational Health and Safety requirements can impede practical learning in STEM. The Association of Consulting Engineers Australia (ACEA) suggests that schools need to proactively respond to necessary requirements, particularly in primary school.[59] A recent article in the *Courier-Mail* went even further, claiming that 'safety sanitises science' and eliminates 'the fun'.[60] The article suggested that parents should be able to enter the classroom to oversee science experiments and 'this could make a great difference to the way science teachers teach'.

4.2.7 Transitions from school to further education and training

VET in schools

Queensland is a national leader in the provision of VET in schools. Preliminary figures for 2006 indicate there were over 43 000 Queensland school students undertaking VET within secondary schools, including 7542 School-Based Apprenticeships and Traineeships (SATs).

More than 70 per cent of SAT commencements have been in the state school system. Occupations where school-based apprenticeship commencements have increased in recent years include mechanical and fabrication engineering trades, construction trades, food trades and automotive trades.

In 2006, the Queensland Government announced a target of 12 400 SATs by 2009 and the Department of Education, Training and the Arts is working to:

- improve the image of SATs to students and their parents as a valuable choice in the senior phase of learning
- maximise employers' uptake of SATs, by removing any barriers and providing appropriate support
- support schools to expand the number of students that can access SATs.

Recent data shows that Year 12 graduates who undertake a SAT are more likely to be in full-time work or study after completing school than other Year 12 graduates. Ninety-five per cent of Year 12 graduates participating in SATs go on to full-time study or employment after Year 12 with almost one in seven going on to university. Notably, data for the first quarter for 2007 showed that the number of young Indigenous people taking up a SAT has increased by 80 per cent compared to the first quarter of 2006.

School to university pathways

The transition from school to university has been highlighted as an issue for young people. Anecdotally, universities indicate that there is much inconsistency in the knowledge level of students entering first year courses. Some indicate there has been an extensive decline in standards over the years. In its submission to the Australian Government audit of STEM skills in 2006, the Australian Science Teachers Association argued:

> *'University entry (is) a significant factor in influencing student choice at secondary school. It is no coincidence that enrolments in enabling science courses at school began to decline when the universities moved enabling sciences from prerequisite status to assumed knowledge status. Students can be accepted into science-based courses at university without having studied science at school, provided that their tertiary entrance score is sufficiently high. This change had been made to encourage more students to study science at university but has served to increase drop-out rates, presumably a larger proportion of the candidature commence with insufficient background.'* [61]

An examination of prerequisite requirements for engineering degrees at Queensland universities from 1995–2007 shows that students used to be required to have undertaken studies in Mathematics B and at least one or more other subjects in mathematics and science at school. The requirements now are for students to have achieved a sound result or above in English and Mathematics B only, with Physics and Chemistry being recommended in most cases, rather than required.

In *The End of the Pipeline: Profiling Commencing Students To Ease Their Transition into an Engineering School* (2005), Dowling and Burton reported that some initial findings of a longitudinal study undertaken at the University of Southern Queensland indicated that students who are more likely to be successful in their first year engineering studies studied, in addition to Mathematics B, two or more of the subjects Physics, Chemistry, Mathematics C, and Information Processing and Technology while at school.[62]

4.3 Questions for discussion

4.1 What approaches can be employed to enrich primary school STEM learning experiences?

4.2 What strategies could be implemented in junior secondary schooling to promote the uptake of STEM subjects in post-compulsory years?

4.3 Should the study of science be compulsory in schools? What in your opinion are the arguments for and against making the study of science compulsory:
a) in Years 1 to 10?
b) in Years 11 and 12?

4.4 What opportunities for addressing STEM-related issues might be presented by the implementation from 2008 of the Queensland Curriculum, Assessment and Reporting Framework and the QSA review of senior syllabuses?

4.5 What examples are there of STEM subjects and fields of study that are most responsive to student interests and industry needs in a knowledge economy?

4.6 What do you identify as the essential skills/understandings/knowledge to be associated with:
a) general STEM literacy?
b) preparedness for STEM occupations?

4.7 To what extent do current school and training facilities enable and foster innovative approaches to the teaching and learning of science and technology?

4.8 What might be done to ensure that new or refurbished facilities improve the quality of students' science experiences?

4.9 What might be done to improve the effectiveness of vocational training programs in preparing students for STEM-related trades and associate professional occupations?

4.10 What evidence is there of strategies that have been effective in increasing student enrolment and success in vocational training and university courses?

4.11 What strategies are there to ensure that the nature, content and pedagogies used in university undergraduate courses are accurate and relevant and reflect the latest developments in STEM?

4.12 What could be done to increase the uptake of School-Based Apprenticeships and Traineeships in STEM-related areas?

5. Student participation and achievement

5.1 Background

Student participation and achievement can be measured in many ways. This chapter provides a snapshot of the most relevant data sources and key identified trends.

Two relevant international studies, the Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS), measure scientific and mathematical literacy.[63, 64]

Other significant measures are carried out through state-based testing of students in Years 3, 5 and 7 against national literacy and numeracy benchmarks, as well as through the National Year 6 Science Assessment Report.

Queensland Studies Authority (QSA) data shows relevant local trends, focusing on senior school participation. Similarly, vocational education and training (VET) sector participation and achievement data is analysed to highlight important trends. A brief summary of university participation is provided.

5.2 Issues

5.2.1 Trends in student achievement

Programme for International Student Assessment

In general, 2003 PISA outcomes indicate that Australia performs well in comparison with students from the other 40 countries involved. Queensland's students achieve averages above the OECD mean in all areas assessed.

However, their average performance is generally either similar or somewhat lower than the average performance of students in the majority of other Australian jurisdictions. Outcomes from 2006 tests will be available in 2008.

Trends in International Mathematics and Science Study

In TIMSS outcomes in 2002, Australian students performed well in science with an average score above the international average at both Year 4 and Year 8. In mathematics, Australian students performed reasonably well with an average score similar to the international average at Year 4 and above the international average at Year 8. However, Australia's performance in science and mathematics in both Years 4 and 8 is only either equal to or below the performance of other developed nations such as the United States of America, England, Singapore and Japan.

Queensland's students had averages above the international mean for Year 4 and Year 8 in science and Year 8 in mathematics. In both science and mathematics, Queensland students were not significantly different to any other Australian jurisdiction with the exception that Queensland students were significantly below New South Wales students in Year 8 mathematics.

Queensland students had the lowest average age, equal to Western Australia, for all countries and jurisdictions reported.

Although the results in international tests such as PISA and TIMSS indicate that Australia's school students perform well in literacy and numeracy in terms of a global comparison, Australia has been found to have a particularly large achievement gap between poorer and more affluent students, and between schools with large proportions of either poorer or more affluent students.

Programme for International Student Assessment (PISA)

The Programme for International Student Assessment (PISA) is an initiative of the OECD which began in 1998.

Data collection for PISA has been established on a three-yearly cycle. The first assessment cycle occurred in 2000, and the most recent testing occurred in 2006.

The project aims to assess the knowledge and skills that 15-year-old students possess which will enable them to participate fully in adult life.

Trends in International Mathematics and Science Study (TIMSS)

The Trends in International Mathematics and Science Study is an initiative of the International Association for the Evaluation of Educational Achievement (IEA), which began in 1995.

Data collection for TIMSS has been established on a four-yearly cycle, offered in 1994, 1998, 2002 and 2006.

The project assessments are aimed at students in Year 4 and Year 8.

2003 National Year 6 Science Assessment Report

In 2003, a nationally comparable science assessment was carried out under the auspices of MCEETYA for the first time, with the intention that further assessments will occur every three years.

Students were assessed on their scientific literacy, as defined against proficiency standards. The proficient standard (proficiency level 3.2 or above) is a challenging level of performance that requires students to demonstrate more than minimal or elementary skills.

This has particular implications for Queensland, which has disproportionate levels of children who are at risk of social exclusion. Based on 2001 census data, while only 20 per cent of all Australian children from birth to 15 years of age live in Queensland, almost 49 per cent of all children most at risk of social exclusion live in Queensland.[65]

National Numeracy Benchmarks

National Numeracy Benchmarks are used for reporting achievement in three aspects of numeracy – 'number sense', 'spatial sense' and 'measurement and data sense' – at each of Years 3, 5 and 7. The benchmarks are performance indicators that articulate nationally agreed *minimum* acceptable standards for numeracy at these years. The benchmarks describe *minimum* standards, below which students will have difficulty in schooling. Results of national benchmarking are published in the annual *National Report on Schooling in Australia.*

Queensland's performance in numeracy is generally comparable to the national average. However, as the most recent (2005) comparative data shows, although Queensland's performance was on par with the Australian average performance in all year levels, Queensland's performance was below Victoria in all year levels; below the Australian Capital Territory at Year 5 and Year 7; and below New South Wales in Year 3 and Year 5.

Notably, an investigation of the performance trends for Queensland state school students on the Years 3, 5 and 7 tests indicates that Queensland currently has a long tail of students in the lower performing end of the student score distributions. There is a significant positive correlation between student performance and socioeconomic status. This is a pattern seen nationally and internationally; nevertheless a large proportion of the variance in student performance remains unexplained.

2003 National Year 6 Science Assessment Report

The 2003 National Year 6 Science Assessment Report provides a snapshot of student performance across the national science literacy scale and an analysis of various trends across states, territories and student sub-groups. Approximately six per cent of the total Australian Year 6 student population, drawn from schools in all sectors, were sampled randomly and assessed.

The report shows that 54.9 per cent of Queensland students were at or above the proficient standard, compared to 58.2 per cent nationally. In addition, Queensland performed behind all other states and territories in higher proficiency levels.

At the national level, the results across the scientific proficiency levels showed the following trends:

- for males and females, there were no significant differences in proficiency
- the proficiency of non-Indigenous students was significantly higher than that of Indigenous students
- students whose home language was English showed significantly higher levels of proficiency than those whose home language was not English
- students from zones classified as 'remote' by MCEETYA performed significantly worse than students from any other location.[66]

5.2.2 Student participation in STEM subjects in Years 11 and 12

Overview

The Australian Government audit of science, engineering and technology in 2006 found that the proportion of domestic students in STEM study across all education and training sectors has remained static or declined in Australia over the past decade, particularly in the enabling sciences.[67] Data from the QSA indicates that this trend is reflected in senior schooling participation in Queensland.

A number of reforms to the education and training sectors has resulted in considerable increases in student retention levels in senior schooling. The latest initiatives include 'learning or earning' strategies and the introduction of the Queensland Certificate of Education (QCE). The QCE will replace the Senior Certificate from 2008 and give young people more options and flexibility for completing Years 11 and 12, or their equivalent.

Student participation fluctuates from year to year. For this reason, data pertaining to student participation has been examined from a range of perspectives. This includes comparing participation by OP-eligible students (these students receive a Tertiary Entrance Statement to gain entrance to university if they choose) against all students receiving a Senior Certificate. Data is examined from recent years (2000 to 2006) as well as across the longer term (1992 to 2006).

Overall, despite increased student retention and more students than ever receiving Senior Certificates, the number of students who are OP-eligible has declined. Likewise, the number of students undertaking Authority subjects has also declined. For example, while the number of students receiving a Senior Certificate increased by 1368 from 2000 to 2006, OP-eligible students declined by 1608 in the same period.

Decreases have occurred in the uptake of Authority subjects in general, not just in STEM-related subjects. For example, the decline in enrolment in the Authority subject English since 2001 is greater than the decline in enrolment in any of the enabling sciences.

Notably, there has been a rise in participation in school-based VET courses and other non-Authority subjects.

Analysis: 2000 to 2006 data

With respect to the Authority subjects in the computer studies, industrial technology, mathematics and sciences fields, 78 per cent of students awarded Senior Certificates in 2006 undertook at least one STEM subject. This is a drop of 4.5 per cent from 2000. Similarly, the proportion of students awarded Senior Certificates who undertook at least one science or mathematics subject declined by about five per cent. Table 2 sets out a range of relevant participation data over 2000 to 2006.

An analysis of OP-eligible students reveals that participation levels in at least one science or mathematics subject have remained fairly static around 93 per cent since 2000. However, given the decline in the population of OP-eligible students this represents a drop of approximately 1500 in the actual numbers of students.

Table 2: STEM participation in senior schooling data snapshot

From 2000 to 2006 the percentage of students receiving a Senior Certificate and:

- taking either Physics or Chemistry fell by 2 per cent to 22.5 per cent
- taking both Physics and Chemistry fell by 2 per cent to 7.9 per cent
- taking an Authority Science subject fell by 8 per cent to 48.7 per cent
- taking an Authority Mathematics subject fell by 4 per cent to 68.7 per cent
- taking an Authority Mathematics or Science subject fell by 5 per cent to 76.3 per cent
- taking at least one STEM-related Authority subject fell by 4.5 per cent to 78.3 per cent

From 2000 to 2006 the percentage of OP-eligible students:

- taking either Physics or Chemistry remained static around 33.5 per cent
- taking both Physics and Chemistry fell by 1.8 per cent to 11.9 per cent
- taking an Authority Science subject fell by 5.5 per cent to 64.6 per cent
- taking an Authority Mathematics subject remained static around 85 per cent
- taking an Authority Mathematics or Science subject remained static around 93.0 per cent
- taking at least one STEM-related Authority subject remained static around 94.0 per cent

Enabling Sciences

In the context of this discussion paper, the enabling sciences incorporate Mathematics B, Mathematics C, Chemistry, Physics and Biology. Table A at Appendix 2 shows changes in the proportions of students studying the enabling sciences in Years 11 and 12 over 2000 to 2006. In summary:

- participation levels in Mathematics B are declining among students undertaking a Senior Certificate, while participation levels remain reasonably static for OP-eligible students
- participation levels in Mathematics C have remained relatively static. Notably, less than 10 per cent of OP-eligible students undertake Mathematics C
- participation in Biology shows the greatest decline overall, by about five per cent
- a decline in participation is evident in Chemistry overall, although participation is static in OP-eligible cohorts. The decline is primarily attributable to male participation
- participation in Physics is generally static.

Significantly higher proportions of males than females undertake study in Mathematics B, Mathematics C, Chemistry and Physics. The reverse is true for Biology, where female participation is proportionately higher. However, the greatest declines in participation for both genders are evident in Biology compared to the other enabling science subjects.

Long-term trends

A number of contextual factors need to be considered when examining student participation and retention over the long term. Data is available from 1992 to 2006, but it must be balanced against the impact of a range of educational reforms. For example, changes to mathematics subject structures mean that data is not comparable prior to 1996 and the range of study options available to students has increased dramatically due to the integration of more VET opportunities in schools.

An analysis of the data over 1992 to 2006 reinforces that more students are completing a Senior Certificate, but the numbers of OP-eligible students are significantly declining. In 1992, 35 085 students completed Senior Certificates and 28 202 were OP-eligible. In 2006, 39 579 students completed Senior Certificates (an increase of 4494) and 26 231 students were OP-eligible (a decrease of 1971).

Analysis of long-term participation data in relation to actual student numbers for the enabling sciences indicates participation in all subjects has declined, except for Chemistry in which participation has increased slightly (by around 60 students).

The attrition from the enabling sciences has largely related to students in the lower achievement levels. For example, while the percentage of OP-eligible students who completed four semesters of Biology dropped by 11 per cent from 1990 to 2006, the percentage of students achieving a sound level of achievement or higher dropped by only 4 per cent. While the percentage of OP-eligible students who completed four semesters of Chemistry remained static at 26 per cent over the same period, the percentage of students achieving a sound level of achievement or higher actually increased by two per cent.

The data indicates that to some extent, the decline in participation in the enabling sciences is linked to the decline in the number of students eligible to receive a Tertiary Entrance Statement. It appears that students who once might have unsuccessfully studied the enabling sciences are deciding instead to take advantage of the increasingly wide range of Study Area Specification subjects and stand-alone VET subjects on offer in schools and are undertaking a course of study not geared towards university entrance.

5.2.3 Student participation in VET in Queensland

For the purposes of this discussion paper, 17 VET fields of education were identified as associated or aligned with STEM occupations (listed on page 15 in Chapter 4). This selection was based broadly on definitions used in the Australian Government audit of science, engineering and technology in 2006.

The data reveals that, in 2006, almost one-third of all VET delivery in the state was STEM-related. The most popular STEM fields of education in Queensland were building, mechanical and industrial engineering and technology; automotive engineering and technology; and electrical and electronics engineering and technology.

Enrolment trends

Overall, the total number of enrolments in Queensland in STEM-related fields of education increased significantly – from 77 476 in 2002 to 90 927 in 2006, an increase of 17 per cent.

This increase was driven primarily by growth in male enrolments. The female share of enrolments was just 12.4 per cent in 2006.

Fields of education that experienced the greatest absolute increases in enrolment included mechanical and industrial engineering and technology; automotive engineering and technology; electrical and electronic engineering and technology; and architecture and urban environment.

Indigenous student participation has remained static, while participation by students from a non-English-speaking background has slightly risen. Enrolments between 2002 and 2006 in STEM fields of education by Indigenous students remained relatively stable at 3600, accounting for around 4.5 per cent of total enrolment in these fields. People from a non-English-speaking background increased slightly their share of enrolments from 2850 in 2002 to 3300 (or 4 per cent) in 2006.

Award completions trends

An analysis of award completion trends is distorted because of the changing nature of the qualification level that students are completing. While a 13 per cent decline was reported in STEM-related completions – from 15 813 in 2002 to 13 729 in 2006 – this is seen to be a consequence of students pursuing higher-level qualifications. Instead of exiting and being reported as a 'completion' after finishing Certificate I or II, students are going on to study Certificate III or IV. More students are enrolling but completion trends are skewed because they are studying for longer. For example, in 2006, 50 per cent of the awards were at Australian Qualifications Framework III or higher level in contrast to just 33 per cent in 2002.

5.2.4 STEM enrolments/completions in universities

In *Sustaining Science: University Science in the Twenty-First Century*, a 2007 study commissioned by the Australian Council of Deans of Science, Ian Dobson examined Australia-wide data for the period 2002 to 2005. He found that science enrolments grew by 8.9 per cent, and the teaching of subjects in the science disciplines to students in science courses increased by 7.1 per cent.[68]

Dobson notes, however, that although enrolments in natural and physical sciences courses over this short period might seem to pose no cause for concern, the major concern ought to be with the longer term and with the patterns discernible over the past 15 to 20 years.[69] He points out that the 'steady as she goes' pattern of 2002–2005 hides the fact that the 1990s saw sharp declines in enabling sciences participation by students enrolled in courses in the natural and physical sciences.[70] Although the number of university enrolments has roughly doubled since 1989, the number of equivalent full-time science students taking chemistry, physics and mathematics has declined by approximately 5 per cent, 19 per cent and 33 per cent respectively.[71]

From 2002 to 2005 in Queensland, there was an overall drop in STEM commencing enrolments (domestic) in Queensland universities (excluding health). The most significant drop was in information technology, which declined from 2497 commencing students to 1363. There was also a downturn in agriculture, environment and related studies enrolments. Commencements in natural and physical sciences fell by a small margin (some 130 students).

In 2005, nearly 60 per cent of Queensland's domestic undergraduate university students were female. However, females represented less than 50 per cent of students in STEM-related fields, and a significant number of these were in health-related fields. Notably, only about 10 per cent of engineering and 20 per cent of information technology enrolments were women.

Although firm enrolment figures since 2005 are not yet available, a picture of trends can be gained from Queensland Tertiary Admissions Centre first preferences. First preferences for information technology declined by 11 per cent from 2005 to 2006, suggesting enrolment numbers are continuing to trend downwards. Agriculture and environment and related studies show a downward trend of about one per cent. Natural and physical sciences have also declined in popularity, down seven per cent.

The downward trend in demand for science courses has coincided with an increase in places available. The net result has been a drop in median Overall Position (OP) scores.

However, the picture is different for engineering and architecture and building, which have shown growth in demand and enrolments in recent years. Engineering places have increased by around 220 in 2006 and 2007, with a further 40 or more likely to be available from 2008.

In 2005 there were around 5000 STEM graduates in Queensland: 2300 graduates in science, 1500 in Information Technology and 1300 in Engineering.

Although both the Australian and state governments have prioritised STEM university places, institutions have not been bidding for many of the additional places available in 2007 and 2008. A general softening of student demand overall has seen institutions reluctant to bid for places they may not be able to fill. Many say marginal funding levels limit their capacity to offer more places in some priority areas. Engineering, for instance, requires significant capital infrastructure for delivery of programs, which is not covered by Commonwealth funding under the Commonwealth Grant Scheme.

Attrition nationwide for new students in university undergraduate courses is around 17 per cent, although the current definition includes students who merely move to another university.

After graduation, many students go on to further study, with a particularly high rate of science students doing so – over 40 per cent, compared with the other STEM fields of less than 20 per cent.

Postgraduate-commencing STEM student numbers have fallen in Queensland from 5497 students in 2002 to 5419 students in 2005, consistent with the national trend. The trend is largely due to the fall in information technology postgraduates, with most other fields being relatively stable.

5.3 Questions for discussion

5.1 In your opinion, what strategies currently work well to improve student participation and achievement in science, mathematics and other STEM-related subjects? What evidence is there to demonstrate their effectiveness?

5.2 Female participation compared to male participation in the enabling sciences in Years 11 and 12 is generally lower. What reasons might there be for this? What strategies could be implemented to encourage higher levels of female participation in these subjects?

5.3 Given the overall significant increase in enrolments in STEM-related VET over the last five years, what strategies could be considered for enhancing the articulation from VET into university STEM courses?

5.4 What explanations are there for the comparatively low levels of female enrolments in STEM-related VET and how might this be addressed?

5.5 What reasons might there be for lower female participation in engineering and information technology courses at university? What strategies could be implemented to encourage more females to participate in these programs?

5.6 Which types of targeted interventions might assist to increase student participation and achievement in STEM-related subjects, particularly noting the generally lower levels of participation and achievement by students from the following backgrounds: Indigenous, low socioeconomic, non-English-speaking and remote locations?

5.7 What opportunities are there for enhancing retention in STEM subjects across the schooling, training and higher education sectors?

5.8 What evidence is there regarding the impact of relaxing subject prerequisites on the participation, retention and achievement of students in STEM-related university courses?

6. Workforce

6.1 Background

Recruiting, retaining and developing a workforce of enthusiastic and competent teachers and trainers who provide exciting and relevant experiences for students is a vital component of any STEM plan for Queensland.

This chapter examines the Queensland state school teaching workforce, particularly demand and supply of staff, recruitment, qualifications, skills and professional development. The chapter provides an overview of the training workforce and highlights key workforce issues being experienced by universities.

6.2 Issues

Teaching

6.2.1 Workforce demand

Student population growth

There has been a slight increase in student numbers since 2003. For the secondary student population, an increase of 10 per cent is expected by 2014. Data indicates that the actual and anticipated growth in teacher numbers in the state school sector as a result of this student population growth is less than one per cent a year (refer Table B in Appendix 3).

STEM teachers age profile

The current profile of the teaching workforce in STEM-related specialist areas illustrates that a greater proportion of the teachers in these areas lie within all the age bands over 45 years. So, the average ages of teachers in the various STEM specialist areas are consistently higher than the average age of Queensland teachers in general (refer Table C in Appendix 3).

However, the age profile of mathematics teachers in Queensland state schools still compares favourably to the national profile with only 27.9 per cent of mathematics teachers in Queensland aged above 50. The Australian Council of Deans of Science report *The Preparation of Mathematics Teachers in Australia* indicated that 37.8 per cent of mathematics teachers are aged above 50 in the national context.[72]

Compared to the national average, a comparatively smaller proportion of Queensland's teaching workforce will reach 55 over the next five years. Also, recent data indicates that the average retirement age of the government teaching workforce rose from 56 to 58 over the past decade, and is likely to increase over the next five to 10 years.

Attrition rate

Expected attrition rates for the state school sector over recent times are summarised in Table D in Appendix 3. The attrition rate for mathematics and science teachers over the past few years averages approximately six per cent per annum which is slightly higher than the average attrition rate for Queensland teachers in general (4.0 per cent). This difference may be related to the slightly older age demographic for mathematics and science teachers.

However, further analysis of teachers in their early career phases is required. Fifty per cent of all mathematics and science teacher attrition in the state school sector is because teachers leave within their first 10 years of service. Since 2000, the greatest proportion of mathematics and science teachers exiting state schools was in the first five years of service (29.5 per cent) followed by the six to 10-year service bracket (22.0 per cent).

This reflects national trends reported by the *Committee for the Review of Teaching and Teacher Education* in 2003. The Committee noted that these teachers can gain employment in other sectors, where salaries are more competitive at the mid-career stage.[73]

6.2.2 Workforce supply

An analysis of the teaching workforce supply must consider the number of expected teaching graduates in STEM-related disciplines. Queensland universities data in August 2006 showed a significant increase in the number of graduates expected in mathematics and science with a large proportion qualified in senior secondary subjects (Table E in Appendix 3). This is partly due to the introduction of a one-year postgraduate course as well as an increase in the number of students electing to teach in this area.

6.2.3 Demand and supply analysis

Forecasts to 2015 show schoolteacher supply and demand is broadly in balance. However, some shortages of specialist teachers, particularly in non-metropolitan locations, are expected. There is an expected surplus of primary teachers until 2009.

In terms of STEM, any imbalance is projected to be most likely to be in specialist teaching disciplines that include secondary science and mathematics, industrial technology and information technology.

The workforce trends in the state school sector are generally reflected in the non-state sector. For example, Brisbane Catholic Education advises that senior Mathematics B, Mathematics C, Physics and Chemistry teaching positions are more difficult to fill, while schools outside the metropolitan area are also experiencing problems in recruiting teachers of Industrial Design and Design Technology, as well as teachers for positions in vocational education areas.

6.2.4 Recruitment and selection

Forecasts indicate that, overall, demand for specialist STEM should be met over coming years. However, strategies will need to be put in place for regions experiencing difficulty filling specialist positions with suitably qualified candidates. There needs to be a particular focus on non-metropolitan schools.

Specialist teacher education programs are being introduced to encourage current state school primary teachers and recent graduates to convert to specialist teaching roles in some secondary areas. The program will specifically target teachers wishing to continue or commence teaching in rural and remote locations.

It should be noted that student contribution charges (HECS) are a disincentive to qualify as a mathematics or science teacher. University students are paying for each specific discipline unit or subject in their teacher education course rather than paying for a teacher education course per se. They also pay more for science subjects than the national priority-capped rate for education subjects.

The student contribution for science/mathematics teacher study has been raised as an anomaly in policy to make teacher education, with nursing, a national priority area, and to ensure an adequate supply of quality graduates in these areas. The *Committee for the Review of Teaching and Teacher Education* noted:

> *'… those qualifying to teach through completion of a Bachelor of Science degree followed by a graduate teacher education award accrue a higher HECS debt than other teachers, but receive the same pay once employed as teachers. The great majority of newly qualifying science and mathematics teachers are in this category. A number of submissions to the Review commented that the higher HECS liability faced by teachers of science, technology and mathematics, combined with teacher pay rates that do not distinguish between specialist areas such as science and mathematics, acts as a disincentive for graduates in those fields to take up teaching.'*[74]

In *Sustaining Science: University Science in the Twenty-First Century*, Ian Dobson suggests that, as a direct result of the differential HECS that was introduced from 1997, a three-year Bachelor of Science plus Diploma of Education graduate is likely to enter the workforce with a HECS debt around $5000 higher than an equivalent Bachelor of Arts plus Diploma of Education graduate.[75]

6.2.5 Teacher preparation and pedagogy

All Queensland schoolteachers must hold teacher registration with the Queensland College of Teachers. To be eligible for registration, teachers must have appropriate qualifications and meet the suitability to teach criteria.

There are several ways to complete a pre-service teacher education program. For example, a student wishing to become a high school science teacher may complete a:

- four-year Bachelor of Education
- double degree, Bachelor of Science/Bachelor of Education
- three-year Bachelor of Science plus a one-year Graduate Diploma of Education or two-year Graduate Bachelor of Education.

Some contentious issues have been raised about pre-service teaching courses and the teaching of mathematics and science. At the primary and junior secondary level, it has been argued that general pre-service programs like a Bachelor of Education do not contain a sufficient amount of mathematics or science education to enable teachers to be confident in teaching the subjects across these years.[76] At the Primary School level, it is suggested that many teachers are uncomfortable in teaching science and conducting in-class experiments. The European Commission in its 2007 *Science Education Now* report noted that this may be because some primary teachers lack sufficient self-confidence and content knowledge.[77] It recommended that teaching should concentrate more on scientific concepts and methods and that stronger support should be given to teacher training in science.[78] Locally, an evaluation of *Spotlight on Science* recommended that primary school teachers should be a particular focus of future policy initiatives.[79]

For the high school years it is argued that general pre-service programs do not require teachers to undertake science and mathematics training at a sufficiently high level in the respective specialist discipline. A 2003 Australian Government report, *Clever teachers, clever sciences. Preparing teachers for the challenge of teaching science, mathematics and technology in 21st century Australia*, suggested that a higher-level knowledge of science helps to make better science teachers.[80] It argued that teachers' content knowledge influences not only what they teach, but how they go about teaching it.[81] Further, more interactive approaches to teaching are employed by teachers with good content knowledge and who also formulate high-quality questions, explanations and activities for students.[82]

The need for teachers to be educated at a high level in the specialist discipline they wish to teach has been emphasised in a range of literature. The 2006 review of mathematical sciences research in Australia highlighted the issue of mathematics (and science) teacher education programs as a key factor in providing greater numbers of adequately trained teachers. The review pointed to the lack of mathematical content in courses for primary teachers as cause for concern.[83] Drawing on a submission made by the Australian Mathematical Science Institute, the report outlined evidence that courses for teaching the middle years (upper primary and lower secondary) lack discipline-specific studies and stressed that courses must have relevance to the discipline concerned, be it science, mathematics or technology.[84]

On a similar note, in 2006 the Australian Council of Deans of Science reported that many teachers of senior mathematics and science do not undertake any discipline-specific third-year study at university.[85] The study also found that more than 20 per cent of all mathematics teachers in Australian schools did not undertake any university study of mathematics beyond the first year, if at all.[86] A 2005 study by the Council indicated that most Heads of Departments in schools had a preference for teachers of science who undertook their university study through science faculties (rather than education).[87] Likewise, the Academy of Science recommends that teachers of high-level mathematics and science be prepared predominantly by the mathematical and science faculties in conjunction with education faculties and that course content be contextualised to the year level which they will be teaching.[88]

6.2.6 Qualifications and skills

The *Teacher Qualifications Survey* in 2006 of all permanently employed Queensland state school teachers (approximately 32 500) collected information regarding qualifications, current teaching areas and teaching areas where they have significant experience.

Findings showed that well over 90 per cent of teachers of science, and Years 11 and 12 Industrial Technology, Mathematics B and Mathematics C indicated that they were either qualified or had significant experience teaching in their area (refer Table F in Appendix 3). However, the data also showed that approximately 30 per cent of Mathematics A and Years 8–10 mathematics teachers indicated that they lacked appropriate qualifications in mathematics and approximately 15 per cent of teachers of these subjects indicated that they were neither qualified nor had significant experience. This data reflects national trends, such as those identified in the recent Australian Council of Deans of Science reports *The Preparation of Mathematics Teachers in Australia* and *Who's teaching science?*

There is a number of reasons why teachers may teach subjects outside of the primary fields in which they are qualified. The 2007 Victorian Government *Inquiry into the Promotion of Mathematics & Science Education* noted that the reality of the school system means that it is sometimes necessary, or even preferable, for a teacher to be allocated to a subject that was not one of the main subjects in which they qualified as a teacher.[89] *Australia's Teachers: Australia's Future* outlines a number of reasons for this: teachers need to fit into the requirements of the school in which they find themselves; changing curriculum patterns over the years; changing patterns of student subject choice; and changing teacher interests and expertise.[90]

Professional development for state school teachers

In 2006–07, the Queensland Government invested approximately $40 million in professional development for its school-based workforce.

The Professional Development and Leadership Institute, launched in June 2007, ensures consistent and coordinated approaches for professional development initiatives delivered or managed by the Queensland Government. The Institute promotes effective approaches to professional development and ensures alignment of professional development initiatives with professional standards/capabilities frameworks for teachers and school leaders.

Therefore, the significance of 'teaching out of field' varies. There are sometimes different priority needs between a Year 12 class where the teacher's depth of subject knowledge is vital, and a Year 8 class where encouraging student interest may be the prime objective.[91] It is a way for many teachers to extend their professional expertise and re-energise their teaching by taking on a new challenge.[92] However, teachers regularly teaching in areas in which they lack adequate background must therefore be offered opportunities, support and incentives to acquire appropriate expertise.[93]

Notably, the *Teacher Qualifications Survey* also identified that approximately 270 mathematics, science and technology teachers were undertaking further tertiary studies, with over 30 per cent of these studies at the masters or doctorate level.

6.2.7 Professional development

Professional development for teachers can extend from pre-service teacher education through to retirement, and include a range of learning experiences such as workshops, courses, industry and research experience, conferences, study for additional qualifications, sabbaticals and collaborative projects.

An analysis of the literature indicates that the following factors are vital in fostering a professional and up-to-date workforce of educators able to adequately develop STEM skills of students:

- ongoing and up-to-date professional development for math and science teachers in targeted subject areas
- opportunities for teachers to get real-world experience in STEM areas
- appropriate training, particularly in the early years of teaching, to master new methods of delivery
- integrative and cohesive opportunities for development, rather than a piecemeal approach.[94, 95, 96, 97]

Recent government developments in Queensland mean that several opportunities exist to strengthen professional development opportunities for teachers in STEM-related fields. Major reforms to teacher registration and professional standards began last year through the establishment of the Queensland College of Teachers. The College has established professional standards for teachers which outline the capabilities they need to provide high-quality instruction and to support improved student learning. It monitors pre-service courses in Queensland with respect to these standards. The College will also develop a continuing professional development framework by the end of 2007.

In addition, a new Professional Development and Leadership Institute offers an integrated approach to professional development programs and incentives for state school leaders and teachers. The Institute enables teachers and school leaders to make informed choices when planning and accessing professional development related to key departmental priorities, team and personal requirements, and career aspirations. It collaborates with principals' associations and other professional associations to ensure that both departmental and personal professional development needs of teachers and school leaders are identified, planned for and met.

Training

6.2.8 Workforce demand

Student demand

VET delivery in STEM-related areas grew by over a quarter between 2002 and 2006. This was a result of significant increases in areas including automotive engineering and technology and mechanical and industrial engineering and technology. Although this was offset by declines in other STEM areas such as information systems, there is an increase in demand for STEM trainers.

Age profile

Approximately 50 per cent of training staff in TAFE are over 50 years of age. While it is difficult to pinpoint an age profile specifically for STEM trainers, it is likely that the general trends from workforce data across the system apply also to STEM.

This suggests that an increased level of recruitment activity will be needed to meet not only the expected growth of the system, but also the impacts of an ageing workforce.

6.2.9 Workforce supply

The VET system competes directly with industry for supply of its training resources. So at a time of high industry demands for particular skills, the VET sector will experience workforce shortages as competitive market forces attract candidates into the industry arena.

An emerging issue is the increasing uptake of VET subjects in schools. This creates further competition for qualified teachers and trainers. These issues need to be examined more closely in the context of enhancing partnerships between training providers and schools. This could also consider any perceived duplication of services.

For the most part, VET trainer shortages are related more to the dynamics of employment and workforce demands in the relevant industry than to inadequacies of systemic training capabilities. In some instances it is possible to predict the growth and replacement requirements but market forces will continue to mean unpredictability for the VET workforce.

6.2.10 Demand and supply analysis

Key issues arising from demand and supply analysis include:

- Current shortages in the training workforce are in the industry areas of highest demand. There are trainer shortages in boiler making, diesel fitting, electrical, carpentry, plumbing, metal fabricating, automotive and fitting and machining. Many of these align to STEM categories.
- Regional and location-specific shortages are experienced as a result of industry and individual circumstances at those locations. Finding a candidate with a very specific set of skills, teaching experience and a desire to relocate to a specific location can be difficult.
- Workforce planning for the VET sector is particularly complex because it is demand driven. The ability to match workforce resources with future industry needs is a difficult process which sometimes results in planning being ‘out of step’ with future industry requirements.

Professional development for VET trainers and assessors

The professional development strategy for VET teachers, trainers and assessors has seven key dimensions:
- teaching, learning and assessment
- industry and technical currency
- working with clients
- working in Queensland's vocational education and training system, including meeting compliance requirements
- business planning and development
- developing leadership
- supporting major vocational education and training policy initiatives.

6.2.11 Recruitment and selection

Within TAFE Queensland, a number of attraction, recruitment and employment arrangements and retention initiatives have been initiated to entice a continued workforce supply. This includes a 'Teach Your Trade' pilot initiative involving a national targeted advertising campaign. Retention initiatives focus on two key areas of need: retention of older workers through initiatives supporting the Experience Pays Program; and initiatives providing support for those trainers commencing their careers within the public provider system.

6.2.12 Qualifications and skills

Trainers must hold a qualification and experience relevant to their area of trade or professional expertise. The ability to teach is supported by a minimum standard of a Certificate IV Training and Assessment. While a significant number of VET trainers may hold diplomas or degrees, these are not mandatory for participation as a trainer.

6.2.13 Professional development

Within the VET system, contemporary training relies on trainers and assessors familiar with the latest technology and trade developments and the most current teaching and learning techniques.

A comprehensive professional development strategy for the state's VET sector is supported by both TAFE Queensland and the private providers through a partnership established with the Australian Council for Private Education and Training to support and maintain a highly capable, responsive and flexible workforce.

Universities

6.2.14 University workforce

The university academic workforce is critical to the long-term development of STEM in the state. Institutional capacity to accept more students to meet STEM demands depends in no small part on the availability of academics to teach the programs.

The higher education sector in general is facing a shortage of academics as the current workforce ages and as graduates choose other employment. The 2006 report *Mathematics and Statistics: Critical Skills For Australia's Future* argued that staff losses across universities between 1995 and 2005 have been severe.[98] In particular, this has compromised mathematical science experts' ability to maintain standards in statistics and mathematics teaching and practice on campus.[99] Further, the talent pool within universities available for consulting work or collaboration with industrial partners is shrinking.[100] This issue may be exacerbated in regional universities as the relevant departments are typically small and any loss of staffing has immediate effects on research and teaching diversity.[101]

While the 2002–2005 figures show no significant drop in the number of commencing postgraduate students, the high demand from industry for STEM graduates in recent years may well lead to a downturn in students choosing higher degree study. Further, there is anecdotal evidence that universities are losing experienced academics to industry.

6.3 Questions for discussion

6.1 To what extent is a high level of content knowledge a significant factor for the teaching of science in secondary schools?

6.2 What, if any, formal and specific academic qualifications should be required for the teaching of senior STEM subjects? What evidence supports the need for formal qualifications?

6.3 To what extent do current teacher pre-service programs (such as a Bachelor of Education) prepare teachers to enable graduates to be confident in teaching the mathematics, science and technology syllabuses across Years 1 to 10?

6.4 What are the particular professional development needs of specialist science, technology and mathematics teachers/trainers and how might these best be met?

6.5 How can industry and professional associations work with teachers/trainers to make the connections between STEM subjects and practical applications in industry?

6.6 What recruitment strategies could assist to attract STEM graduates and practising professionals into teaching careers?

6.7 What strategies could assist to attract specialist STEM teachers/trainers to regional or rural and remote locations?

6.8 What do you see as possible reasons for greater levels of attrition for beginning teachers in STEM?

6.9 What strategies could assist in retaining specialist STEM teachers/trainers in the workforce?

6.10 To what extent are university student contribution charges (HECS) acting as a disincentive for mathematics and science graduates to enter into a career in teaching? What other disincentives, if any, are there to attracting and retaining STEM graduates in teaching careers?

6.11 Given the VET sector's competition with industry for workforce resources, can you suggest any ways in which VET and industry might work together to ensure an adequate supply of VET trainers/teachers, particularly in relation to STEM programs?

Peter Doherty Awards for Excellence in Science and Science Education

The Peter Doherty Awards for Excellence in Science and Science Education are open to students, scientific laboratory assistants and teachers in state and non-state schools and all Queensland-based tertiary institutions, industries, businesses and research organisations.

The Awards recognise and reward students, teachers, schools and organisations demonstrating outstanding and innovative contributions to science and science education in Queensland.

7. Community engagement and profile of STEM

7.1 Background

The attractiveness of STEM as a pathway for study and careers is dependent on the attitudes and motivations of students as well as the views of the broader community. So, the level of public awareness and engagement in STEM education and training is important.

This chapter explores key influences on student interest, subject choices and perceptions of STEM more broadly while highlighting the importance of career advisory processes to inspire more young people to pursue STEM studies and careers. The role of school–industry linkages to offer real life experiences for young people is considered, as is collaboration between government, industry, education and research institutions.

7.2 Issues

7.2.1 Student attitudes and perceptions of STEM

A recent OECD report, *Evolution of Student Interest in Science and Technology Studies*, identified the poor image of science and technology professions as a core issue underpinning decreasing student interest in science and technology fields.[102] It reported that although science and technology professions continue to generate great interest among youth in developing countries, this is no longer the case for industrialised countries, with an even stronger distaste expressed by girls (except for health-related professions).[103]

Many young people have a negative perception of these careers and lifestyles – incomes are perceived as low relative to the amount of work involved and the difficulty of the required studies; few pupils have a full or accurate understanding of science-related professions; and many are largely unaware of the range of career opportunities opened up by science and technology studies.[104]

As part of the 2006 report on the Australian Government's audit of science, engineering and technology skills a youth attitudes survey found that the strongest influences on student interest in science, mathematics and technology relate to their experiences in the classroom, primarily their personal enjoyment of the subject. [105] Other factors also contributed to this, including the use of real-life examples in the subject and participation in project work (especially for science and technology) and the influence of their teachers. Parental encouragement was less influential (although more so for mathematics) with other external factors such as the media considerably less. For students that were uninterested in these subjects, lack of interest was generally related to perceptions that the subject was 'boring' or had a lack of real-life examples.

Internationally, the TIMSS 2002–03 survey provides a sense of students' attitudes towards mathematics and science. Notably, in Australia there is a drop in students' attitudes towards school science between Years 4 and 8. Almost two-thirds of students in Year 4 express a liking for science but less than a third of students enjoy it in Year 8; and around twice the proportion of students dislike science in Year 8 compared to Year 4.[106]

The outcomes of a 2005 survey by the Office of Economic and Statistical Research (OESR) in Queensland Treasury revealed that there are some inconsistencies in the way that Queenslanders view science and technology, particularly when compared with attitudes in the USA, Europe, New Zealand and the United Kingdom:

- 51 per cent of Queenslanders agree that because of science and technology there will be more job opportunities for the next generation (compared to 85 per cent USA, 72 per cent Europe, 77 per cent UK)
- 65 per cent of Queenslanders agree a career as a scientist has great prestige compared to 51 per cent in the USA
- 86 per cent of Queenslanders agree that Queensland needs to develop science and technology to enhance international competitiveness compared to 77 per cent NZ and 79 per cent UK.[107]

Some specific issues that have been identified in relation to the attractiveness of careers structures in some science and engineering professions include:

- Science and engineering graduates and postgraduates can be put off entering R&D due to unattractive career structures – with short-term contracts, low levels of responsibility, few chances for progression within R&D and poor job design (for example, jobs that do not use their skills to the full).[108]
- Many students who pursue a career in science are striving for a specialist field, for example, medicine, engineering or physiotherapy, rather than pure science courses. The popularity of the specialist science fields is likely to be related to the fact that the career paths are more obvious and clear-cut.[109]

There is a need to improve information about STEM and STEM-related careers to encourage growth in the number of school students studying in these fields.[110] Comprehensive approaches are required to counteract poor images, targeting specific audiences including teachers, students, parents, employers and society as a whole.[111]

7.2.2 Career advisory processes

Several national reviews in recent years have highlighted the importance of career advice to students.[112, 113] This includes that students should have access to:

a) well-presented information, guidance and follow-up services that integrate educational, labour market and social counselling

b) high-quality career services that are offered by personnel with appropriate skills and qualifications.

The same holds true for career advice about STEM disciplines, with the literature supporting that:

- there is a need for specialist career advice across education sectors, including universities
- the advice offered needs to be of a high quality and up to date
- industry and university sectors need to work closely with education and training sectors to provide advice.[114, 115, 116]

A range of personnel in Queensland schools share the responsibility of providing career advice to students. These personnel include heads of departments, youth support coordinators and guidance officers. Guidance officers in particular play a key role in the provision of a career guidance service. However, accelerating societal change has meant guidance officers must manage competing demands for time within a context of growth in the complexity of personal, social and mental health problems experienced by students.

STEM careers websites

Websites providing general career information, including STEM careers:

www.cis.qsa.qld.edu.au.

www.myfuture.edu.au

www.careeradviceaustralia.gov.au

Websites that focus specifically on providing STEM career information:

www.smartfuture.qld.gov.au

www.careersinscience.gov.au

Industry–School Engagement Strategy

The Industry School Engagement Strategy promotes local interactions between schools and community employers as well as major system-level initiatives between Education Queensland and leading industry players, including:

- Aerospace Project, based in Brisbane
- ICT Industry Partnership, based on the Sunshine Coast
- Queensland Minerals and Energy Academy (QMEA), with hubs in Mount Isa, Gladstone and Moranbah.

Queensland students can access a number of web-based career advisory services for STEM careers information, including *myfuture,* a national career information service developed as a joint initiative of the Australian, State and Territory governments; and the Queensland Studies Authority's Career Information System (CIS), an individualised, online service.

The role of teachers cannot be underestimated in relation to their influence in student decision-making. The 2005 *Macquarie University Science, Engineering and Technology Study* identified that high school science teachers hold a strong influence over the attitudes of their students, with general enthusiasm the most important factor in maintaining student interest.[117] The inherent challenge is how we can make the most of our teaching resources in encouraging more students to consider STEM careers.

The Australian Science Teachers Association in its response to the Australian Government's audit of science, engineering and technology in 2006 gave further insights to the nature of this challenge.[118] The association asserted that 'teachers do not have the access to stay in touch with current scientific research and career information and hence are not always good public relations machines for science careers'.[119] They added that 'the ageing structure of the science teaching workforce with limited knowledge on the emerging fields within science, such as biotechnology and nanotechnology, are going to have difficulty in providing the type of information and enthusiasm about these fields that would entice students to pursue rewarding careers in science'.[120]

At the tertiary level, an increasing number of structured links are being developed between universities and schools designed to promote student interest in STEM courses and careers. Recently, the Australian Technology Network of Universities announced they would be trialling an Engineering Selection Test as a means of seeking out potential students with the aptitude to be engineers, even though they may not have the traditional Year 12 mathematics and science background.

7.2.3 School–industry links

A central element of a STEM education and skills plan is in considering new approaches for bringing together educators and industry. There are many ways in which industry can be instrumental in developing more attractive career opportunities and perspectives of work in STEM, including industry involvement in:

- promotional activities to highlight attractive career opportunities
- determining what longer-term skills might be required
- offering programs of work experience to provide hands-on experience in STEM-related occupations.[121]

A number of government departments and major companies in Queensland provide focused work experience programs for students in STEM-related areas. These include Aviation Australia and Boeing Australia Ltd, Riviera Marine, the Queensland Institute of Medical Research, CSIRO and Queensland Health's *Health Careers in the Bush* initiative. Through participation in authentic, real-world science experiences, students develop the essential knowledge, attitudes and skills that help them become active and informed citizens, capable of making personal decisions about the world around them and in relation to career opportunities.

The Queensland Department of Main Roads in particular is involved in supporting

Skilling Solutions Queensland

Skilling Solutions Queensland is a new training and employment information service developed by the Queensland Government.

Sixteen sites across Queensland provide a face-to-face career and training information service.

The service will give Queenslanders training and skilling options through access to current, accurate and customised training and employment information, helping them to gain skills for and knowledge of sustainable career options.

and promoting careers in engineering, including school-focused activities such as the Science and Engineering Challenge (Years 9 and 10), the Maths Tournament and the Engineering Link Group (Years 11 and 12), the provision of scholarships and cadetships, internships and vacation work and mentoring programs.

The Department of Education, Training and the Arts offers Teacher Industry Placements to a limited number of state school teachers who are placed into ICT businesses and research facilities for up to four weeks. These placements provide the teachers with the opportunity to advance their technical knowledge and gain first-hand experience in specialist areas of the ICT industry. The main objective of the program is to help make ICT integral to learning by developing strong links between teachers, schools and the ICT industry to enhance the transfer of ICT and teaching knowledge.

Manufacturing Starter Initiative

The Queensland Government's Manufacturing Starter Initiative has enabled individual schools across Queensland to work with local manufacturing industries on projects that are designed to provide students with the opportunity to apply their maths, English, graphic and engineering skills to real projects.

The initiative also broadens students' awareness of the variety of job pathways available in the manufacturing sector.

The initiative has been highly successful in linking school curriculum and engineering projects undertaken in industry.

7.2.4 Collaboration across government, industry, education and research institutions

Collaboration across the broader community, government, industry, education and research sectors contributes to the formation of an inquiring and innovative culture in STEM. Collaboration can occur directly or indirectly. This might include working with students to demonstrate STEM applications; excursions, targeted events or work experience; working with teachers for professional development; or working with bodies like the QSA and university academic councils to influence education and training program content and structures.

It might also extend to research institutions, recognising the important synergies between teaching and learning and scientific discovery.

Working across community, sectoral and institutional frameworks to raise the profile of educational and research endeavours can reduce the disparity between the public reliance on STEM and the profile of these fields. A focus on the enabling sciences is particularly important because the knowledge contained within these sciences represents the foundations upon which all scientific discoveries are built and technology developed.[122]

The education system alone cannot reverse declining participation in these important fields; a collaborative approach is required across education, training and research institutions, industry sectors and government agencies.

In relation to the future of STEM in Queensland, the Chief Scientist suggests:

> *'We need to honour our champion scientists as we honour our champion sportspeople. We need elite courses in the enabling sciences that offer students fast tracks and industrial experiences.*
>
> *We need to create scholarships for high achievers. We need to promote links between postgraduate and undergraduate science students.*
>
> *We need to involve eminent scientists from industry and learned sciences in our tertiary teaching. We need to involve scientists from industry on university councils.'* [123]

Science and Engineering Challenge

The Science and Engineering Challenge is an outreach program conducted by the University of Newcastle.

The main aim of the Challenge is to encourage junior students to study science and mathematics at the senior level.

It involves up to 260 students per day engaging in a number of interesting and exciting activities related to science, technology and engineering.

In Queensland, the Challenge is sponsored by Engineers Australia, six universities with engineering faculties, local Rotary Clubs, Queensland Government authorities such as Main Roads and Queensland Rail and local engineering companies.

Building Skills for a Better Queensland

Through the *Building Skills for a Better Queensland* policy the Queensland Government is establishing five School Industry Trade Centres in far north Queensland, north Queensland, Mackay/Whitsunday, Gold Coast and the Sunshine Coast.

The School Industry Trades Centres will:

- through partnerships with industry, provide a learning environment that duplicates the expectations and discipline of the workplace – the focus being real learning for real jobs
- provide students with access to material and equipment of industry standard, as well as industry expertise
- establish a link between key schools and key industries
- offer 'real' training in real industry settings
- create pathways to enable students to access a broad range of career opportunities – starting from Year 10 through to Years 11 and 12.

7.3 Questions for discussion

7.1 What strategies can be developed, or more widely applied, to promote better student and teacher understanding of STEM-related careers?

7.2 What more can be done to improve career advisory processes and information?

7.3 How can the potential of classroom teachers of science, technology and mathematics be maximised in promoting careers in STEM?

7.4 What are the characteristics of any current career-advisory initiatives that have been particularly successful in promoting the uptake of careers in STEM?

7.5 What strategies are needed to raise community awareness of the importance of STEM and in particular the perception that science is not a financially worthwhile and appealing career?

7.6 How can your industry/organisation assist in promoting a greater understanding of, and interest in, STEM-related careers?

8. Where to from here?

8.1 Summary

This paper has canvassed a range of issues relevant to STEM education and training. It considered:

- Queensland's current and emerging skills needs, noting the importance of the generic skills required to adapt to rapid technological change, as well as job-specific skills
- the types and nature of education and training programs offered by schools, training providers and universities
- student participation and achievement, examining Queensland's performance in scientific and mathematical literacy studies, as well as participation in senior schooling, VET and university programs
- recruiting, retaining and developing a workforce of enthusiastic and competent STEM teachers and trainers
- the importance of community engagement and partnering across government, industry, education, training and research institutions to promote STEM studies and careers.

8.2 Consultation

The questions throughout this paper are consolidated in Appendix 1. They have been raised to stimulate and guide discussion.

We invite you to respond to these questions and to raise other relevant issues. Your responses will guide the development of a 10-year plan for STEM education and skills in Queensland.

The consultation period in response to this discussion paper is open until 30 November 2007.

8.3 Process for feedback

Feedback may be in the form of written responses to some or all of the questions raised in this paper. Alternatively, respondents may wish to provide detailed comments on one or more specific issues raised, or on other issues relevant to the development of a STEM plan, but which may not have been addressed specifically in this paper.

Priority should be given to matters that stakeholders see as important to achieving the best possible outcomes for planning for STEM education and skills development during the next 10 years.

Feedback is required by 30 November 2007.

Responses may be submitted electronically by following the directions at the website (details below) or by mail.

Email	stemproject@deta.qld.gov.au
Fax	(07) 3237 1175
Mail	STEM Plan Project Department of Education, Training and the Arts Floor 21 Education House PO Box 15033 City East, Brisbane, QLD 4002
Website	www.education.qld.gov.au/projects/STEMplan
Telephone	(07) 3237 1700

9. Appendices

Appendix 1: Questions for Discussion

Chapter 1 – Definitions and aims

1.1 Are the definitions described in this chapter appropriate in terms of breadth and inclusiveness as a basis for a STEM education and skills plan? If not, what alternative or amended definitions should be used?

1.2 How do you view the role of science education as a key building block of a future STEM plan? Are there other key factors that should be considered when developing such a plan?

1.3 To what extent do you believe that a STEM education and skills plan should be dual-purposed, focusing on enhanced STEM literacies for the whole population as well as preparing young people for careers in specialist STEM fields? How compatible do you consider these goals?

1.4 What do you consider the priorities for a 10-year STEM plan should be?

1.5 What role can you or your organisation play to contribute to STEM education and training in Queensland?

Chapter 2 – Queensland's skills requirements

2.1 To what extent is STEM a driver of innovation in a global knowledge economy and what is its role in future workforce preparedness?

2.2 To what extent are the types of STEM occupations listed in this chapter suitable as the focus of a future STEM education and skills plan? What modifications might need to be made?

2.3 How appropriate are the inclusion of health occupations and the exclusion of finance and some other mathematics-intensive occupations from a STEM education and skills plan?

2.4 To what extent can a future STEM education and skills plan adopt a demand-driven focus, given the rapidly changing skill requirements of industry?

2.5 What is the nature of the STEM skills needed by your industry/organisation/region?

2.6 How do the skills of the workers already employed in STEM-related roles by your organisation compare to the skills that might be required in the future?

2.7 For which occupations (if any) does your industry/organisation/region have difficulty in recruiting? What do you consider to be the main issues in relation to recruitment difficulties?

2.8 What strategies are needed to better retain the skills and expertise of an ageing STEM workforce?

Chapter 3 – Past and future initiatives

3.1 What are the characteristics of current and past government, education or industry initiatives that have been particularly successful in promoting participation in STEM-related courses and careers?

3.2 What lessons can be learned from any previous STEM education and training initiatives?

3.3 What implications will national trends (for example, moves towards nationally consistent curricula and a national science education framework) be likely to have for Queensland's future directions for STEM?

Chapter 4 – Education and training programs

4.1 What approaches can be employed to enrich primary school STEM learning experiences?

4.2 What strategies could be implemented in junior secondary schooling to promote the uptake of STEM subjects in post-compulsory years?

4.3 Should the study of science be compulsory in schools? What in your opinion are the arguments for and against making the study of science compulsory:
a) in Years 1 to 10?
b) in Years 11 and 12?

4.4 What opportunities for addressing STEM-related issues might be presented by the implementation from 2008 of the Queensland Curriculum, Assessment and Reporting Framework and the Queensland Studies Authority review of senior syllabuses?

4.5 What examples are there of STEM subjects and fields of study that are most responsive to student interests and industry needs in a knowledge economy?

4.6 What do you identify as the essential skills/understandings/knowledge to be associated with:
a) general STEM literacy?
b) preparedness for STEM occupations?

4.7 To what extent do current school and training facilities enable and foster innovative approaches to the teaching and learning of science and technology?

4.8 What might be done to ensure that new or refurbished facilities improve the quality of students' science experiences?

4.9 What might be done to improve the effectiveness of vocational training programs in preparing students for STEM-related trades and associate professional occupations?

4.10 What evidence is there of strategies that have been effective in increasing student enrolment and success in vocational training and university courses?

4.11 What strategies are there to ensure that the nature, content and pedagogies used in university undergraduate courses are accurate and relevant and reflect the latest developments in STEM?

4.12 What could be done to increase the uptake of School-Based Apprenticeships and Traineeships in STEM-related areas?

Chapter 5 – Student participation and achievement

5.1 In your opinion, what strategies currently work well to improve student participation and achievement in science, mathematics and other STEM-related subjects? What evidence is there to demonstrate their effectiveness?

5.2 Female participation compared to male participation in the enabling sciences in Years 11 and 12 is generally lower. What reasons might there be for this? What strategies could be implemented to encourage higher levels of female participation in these subjects?

5.3 Given the overall significant increase in enrolments in STEM-related VET over the last five years, what strategies could be considered for enhancing the articulation from VET into university STEM courses?

5.4 What explanations are there for the comparatively low levels of female enrolments in STEM-related VET and how might this be addressed?

5.5 What reasons might there be for lower female participation in engineering and information technology courses at university? What strategies could be implemented to encourage more females to participate in these programs?

5.6 Which types of targeted interventions might assist to increase student participation and achievement in STEM-related subjects, particularly noting the generally lower levels of participation and achievement by students from the following backgrounds: Indigenous, low socioeconomic, non-English-speaking and remote locations?

5.7 What opportunities are there for enhancing retention in STEM subjects across the schooling, training and higher education sectors?

5.8 What evidence is there regarding the impact of relaxing subject prerequisites on the participation, retention and achievement of students in STEM-related university courses?

Chapter 6 – Workforce

6.1 To what extent is a high level of content knowledge a significant factor for the teaching of science in secondary schools?

6.2 What, if any, formal and specific academic qualifications should be required for the teaching of senior STEM subjects? What evidence supports the need for formal qualifications?

6.3 To what extent do current teacher pre-service programs (such as a Bachelor of Education) prepare teachers to enable graduates to be confident in teaching the mathematics, science and technology syllabuses across Years 1 to 10?

6.4 What are the particular professional development needs of specialist science, technology and mathematics teachers/trainers and how might these best be met?

6.5 How can industry and professional associations work with teachers/trainers to make the connections between STEM subjects and practical applications in industry?

6.6 What recruitment strategies could assist to attract STEM graduates and practising professionals into teaching careers?

6.7 What strategies could assist to attract specialist STEM teachers/trainers to regional or rural and remote locations?

6.8 What do you see as possible reasons for greater levels of attrition for beginning teachers in STEM?

6.9 What strategies could assist in retaining specialist STEM teachers/trainers in the workforce?

6.10 To what extent are university student contribution charges (HECS) acting as a disincentive for mathematics and science graduates to enter into a career in teaching? What other disincentives, if any, are there to attracting and retaining STEM graduates in teaching careers?

6.11 Given the VET sector's competition with industry for workforce resources, can you suggest any ways in which VET and industry might work together to ensure an adequate supply of VET trainers/teachers, particularly in relation to STEM programs?

Chapter 7 – Community engagement and profile of STEM

7.1 What strategies can be developed, or more widely applied, to promote better student and teacher understanding of STEM-related careers?

7.2 What more can be done to improve career advisory processes and information?

7.3 How can the potential of classroom teachers of science, technology and mathematics be maximised in promoting careers in STEM?

7.4 What are the characteristics of any current career-advisory initiatives that have been particularly successful in promoting the uptake of careers in STEM?

7.5 What strategies are needed to raise community awareness of the importance of STEM and in particular the perception that science is not a financially worthwhile and appealing career?

7.6 How can your industry/organisation assist in promoting a greater understanding of, and interest in, STEM-related careers?

Appendix 2: The enabling sciences

Table A: Proportion of students studying four semesters in the enabling sciences 2000–2006

Breakdown	2000	2006	DIFFERENCE
MATHEMATICS B			
Senior Certificates	33.5 %	29.5 %	–4.0 %
OP-eligible	45.4 %	43.8 %	–1.6 %
Female Senior Certificates	30.5 %	26.5 %	–4.0 %
Female OP-eligible	38.7 %	36.7 %	–2.0 %
Male Senior Certificates	36.7 %	32.8 %	–3.9 %
Male OP-eligible	53.8 %	53.0 %	–0.8 %
MATHEMATICS C			
Senior Certificates	7.0 %	6.1 %	–0.9 %
OP-eligible	9.6 %	9.2 %	–0.4 %
Female Senior Certificates	4.3 %	3.8 %	–0.5 %
Female OP-eligible	5.4 %	5.3 %	–0.1 %
Male Senior Certificates	10.0 %	8.7 %	–1.3 %
Male OP-eligible	14.8 %	14.4 %	–0.4 %
BIOLOGY			
Senior Certificates	28.5 %	23.3 %	–5.2 %
OP-eligible	37.7 %	33.5 %	–4.2 %
Female Senior Certificates	35.0 %	29.2 %	–5.8 %
Female OP-eligible	43.4 %	39.1 %	–4.3 %
Male Senior Certificates	21.5 %	16.8 %	–4.7 %
Male OP-eligible	30.4 %	26.1 %	–4.3 %
CHEMISTRY			
Senior Certificates	19.6 %	17.2 %	–2.4 %
OP-eligible	26.8 %	25.6 %	–1.2 %
Female Senior Certificates	18.2 %	16.5 %	–1.7 %
Female OP-eligible	23.2 %	22.9 %	–0.3 %
Male Senior Certificates	21.2 %	17.9 %	–3.3 %
Male OP-eligible	31.4 %	29.2 %	–2.2 %
PHYSICS			
Senior Certificates	15.0 %	13.3 %	–1.7 %
OP-eligible	20.4 %	19.7 %	–0.7 %
Female Senior Certificates	8.4 %	7.4 %	–1.0 %
Female OP-eligible	10.7 %	10.3 %	–0.4 %
Male Senior Certificates	22.2 %	19.8 %	–2.4 %
Male OP-eligible	32.6 %	32.0 %	–0.6 %

Appendix 3: Teaching workforce

Table B: Expected growth in need for STEM teachers

Subject	2007	From 2007 to 2011	From 2007 to 2016
Mathematics B	6	30	60
Mathematics C	2	15	30
Physics	2	10	25
Chemistry	3	15	30
Manual Arts	5	25	50

(Based on permanently employed state school teachers as at May 2006)

Table C: Average age state school STEM teachers

Subject area	Average age of teachers
Mathematics B	44.2
Mathematics C	45.7
Physics	42.8
Chemistry	43.8
Industrial Technology	43.2
Queensland teachers in general	41.8

Table D: Teacher Attrition – STEM – 2000–2006 (state schools)

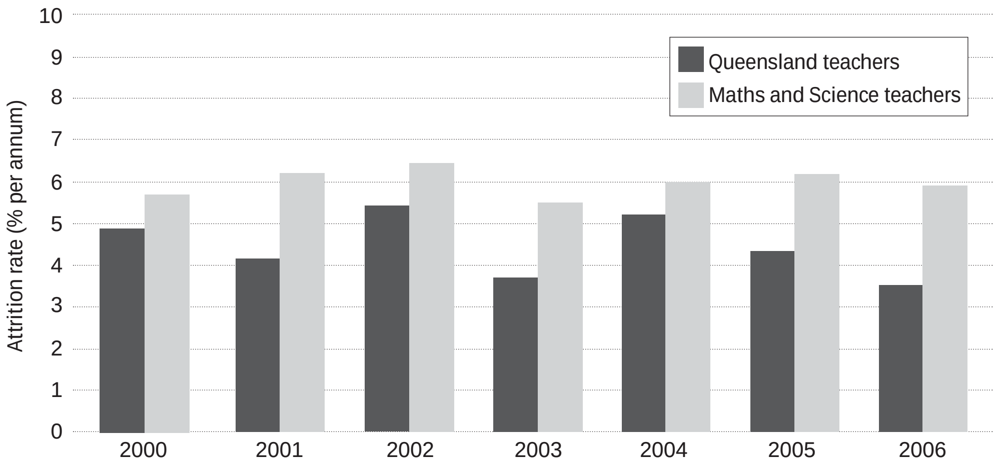


Table E: Number of specialist STEM teachers expected to graduate in Queensland in 2006

Year	Subject area	2006
Undergraduate	Mathematics B	44
	Mathematics C	28
	Physics	12
	Chemistry	12
	Manual Arts	16
Postgraduate*	Mathematics B	148
	Mathematics C	88
	Physics	83
	Chemistry	93
	Manual Arts	74

Source: *Strategic Human Resources – University Pre-Service Teacher Collection August 2006*
* Please note – Postgraduate figures may capture graduates of both one year and two year graduate courses.

Table F: Teacher qualifications and experience (state schools)

Specialist teaching area	Qualified	Not qualified > 5 years experience	Not qualified < 5 years experience	Qualified and/or have significant experience
Mathematics Years 8–10	68.0%	16.0%	16.0%	84.0%
Mathematics A	73.0%	14.8%	12.2%	87.8%
Mathematics B	88.0%	8.0%	4.0%	96.0%
Mathematics C	92.2%	5.6%	2.2%	97.8%
Science Years 8–10	85.1%	8.6%	6.3%	93.7%
Physics	86.0%	7.4%	6.7%	93.3%
Chemistry	89.8%	5.5%	4.7%	95.3%
Biology	92.1%	4.5%	3.4%	96.6%
Industrial Technology	93.1%	1.1%	5.8%	94.2%

Teacher Qualification Survey, May 2006

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