Consultant Report
Securing Australia's Future
STEM: Country Comparisons

This report can be found at www.acola.org.au

Snapshots of 23 Science, Technology, Engineering and Mathematics (STEM) constulants' reports: Characteristics, lessons, policies and programs

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WESTERN EUROPE – longstanding commitment to STEM

CHARACTERISTICS

- Varied student performance[1] with the highest standardised test results recorded in Finland, Switzerland and the Netherlands.
- Tracking into discipline-streams according to academic achievement at a young age, in many (but not all) Western European countries.
- Varied participation in STEM disciplines in upper secondary vocational education:
  - highest proportional participation overall (males) from Norway, Sweden and France;
  - highest proportional participation overall (females) from Finland, Norway, Sweden, Switzerland, Germany, Denmark and France.
- Varied participation in STEM disciplines at the tertiary level, with the highest participation in Finland, Sweden, Germany, Switzerland and France.
- Increasing human resources in science and technology in the labour force (most in Norway, Switzerland, Finland, the Netherlands, Sweden).
- Persistent gender disparities in most countries, although some have made progress. Women predominate tertiary enrolments overall but not in the STEM-disciplines. Men mostly predominate vocational enrolments overall. Disparities exist in the STEM labour market.
- There are both federal states (Germany, Switzerland), 'federation-like' states (Belgium given their language group divisions) and unitary states (Netherlands, Sweden, Norway and Finland). This has implications for the decentralized/centralized nature of policy and funding frameworks.

LESSONS FOR AUSTRALIA

- There has been a longstanding political commitment to STEM by the European Commission since the 1990s.
- National STEM strategies are reported in Austria, Germany, France, Ireland, the Netherlands, Norway, Spain and the United Kingdom.
- Country-specific strategies and a range of programs have been developed by members of the European Union and other European countries.
- The involvement of teachers is imperative to progress teaching-related initiatives (i.e. initiatives that are imposed on teachers must involve teachers).
- There is a focus on inquiry-based science education.
- There is a recognition of the need to change attitudes and perceptions:
  - challenge myths and stereotypes regarding STEM education and employment
  - introduce authentic engagement, and arrange direct contact with STEM professionals
  - introduce education/industry partnerships
  - provide STEM specific careers information
  - provide STEM role models for women.
- There is a focus on addressing women's under-representation in STEM education and employment.
- There is an emerging focus on financial literacy in the wake of the global financial crisis (GFC).
- There are structures for science and mathematics promotion and communication (e.g. Ingenius to promote and co-ordinate STEM).
- There is a strategic conception of STEM as a lifelong journey (e.g. Norway Science for the Future conceives STEM from kindergarten through to and including working life).
- The findings from cross-country STEM-related research are influential; ROSE (Relevance of Science Education; the more developed a country, the less interest students have in science), IRIS (Interest and Recruitment in Science: the immediate family is influential) and LILY studies.

[1] In this report, performance refers to mathematical and scientific literacy as assessed by PISA (15 year olds) and/or mathematics and science curriculum-specific knowledge as assessed by TIMSS (years 4 and 8).

POLICIES, STRATEGIES AND PROGRAMS

- National STEM policies and strategies have a range of objectives, including:
  - promote a positive image of science
  - improve the public knowledge of science
  - improve school-based science teaching and learning
  - raise interest in science, and participation in school science and tertiary STEM
  - address gender disparity in science, mathematics, technology education and STEM professions
  - provide employers with skills they need.
- Ingenius, funded by the European Union (consortium of ministries of education, businesses and university; STEM co-ordinating body; science communication; best practice repository; ‘educate, communicate, inspire’).
- European Schoolnet (EUN) is a network of 30 ministries of education (regular reports on: STEM teachers; innovative pedagogy/creative curriculum; engagement of industry; role models; information on the industry ‘demand’ side).
- National STEM centres (Norway – Centre for Mathematics Education, Norwegian Centre for Science Education; Finland – LUMA; Belgium – RVO-Society; France – Academie des Sciences; Netherlands – Freudenthal Institute for Science and Mathematics Education; Switzerland – MINT; Denmark – Centre for Science, Technology and Health).
- Scientix (portal managed by European Schoolnet on behalf of the European Commission; share EU science education projects, teaching materials, research reports, policy-making documents; online new service; calendar of professional development opportunities)
- SPICE – Science Pedagogy Innovation Centre for Europe (innovative pedagogy, particularly inquiry based learning).
- Xperimania (partnership with the Association of Petrochemical Producers in Europe; promote chemistry and physics).
- DESIRE – Disseminating Educational Science, Innovation and Research in Europe (with the European Network of Science Centres and Museums) (dissemination of science teaching tools and methods).
- STENCIL Network (Science Teaching European Network for Creativity and Innovation in Learning) (innovative science education).
- Women in STEM: European Union ‘Women in Research and Innovation’ campaign (Science: It’s a girl thing!; German Go MINT! part of the National Pact for Women in MINT [STEM]; Finland GISEL Project).
- Pollen project (inquiry-based science education, and gender inclusiveness in school science)
- SINUS Transfer program (improve learning and teaching of mathematics).
- Research recommendations for policies, strategies and programs:
  - common European policy
  - stimulate young peoples interest in school science, mathematics and technology (student engagement)
  - increase participation in science and mathematics (change image of and attitudes to science and technology professions and curriculum content; careers advice)
  - effective and attractive school science curriculum
  - compulsory school science
  - effective and attractive school science pedagogy (from deductive to inquiry-based science education; observe phenomenon in real world; discussion; sufficient time for content; continuity of activities)
  - teaching quality (teacher education; professional development; pedagogy re-training)
  - improve university teaching
  - address gender disparity
  - span lifelong learning
  - attract people to STEM labour market
  - popularize and communicate ‘science’
  - address the mismatch: unemployment of STEM professionals whilst shortage of STEM workers
  - involve families and communities
  - partnerships (school, university, vocational), industry, government, community.

FINLAND – excellent but different

CHARACTERISTICS

- Very high performance education system (indicated by student achievement on PISA, TIMSS; high rates of persistence to the end of schooling and into higher education).
- High participation in science and mathematics (school) and STEM disciplines (university and polytechnics), including the highest proportion of STEM doctoral enrolments in Europe.
- Persistent gender disparities in natural sciences and engineering at university, and science and engineering at polytechnics.
- High level qualifications are required for most professions, including STEM professions (3+2 Bologna Process, i.e. generally a Masters or equivalent is required in addition to a three year undergraduate program).
- STEM has been 'mainstreamed' (i.e. STEM is no longer prioritised in the Finland policy agenda).

LESSONS FOR AUSTRALIA

- Teachers are held in high esteem (i.e. teaching is a sought after profession; there is high competition for entry).
- Teaching qualifications are high for secondary schools (3+2 Bologna Process; mathematics and science discipline specific).
- Inquiry-based learning underlies all curriculum subjects including STEM.
- The use of technology is a cross-curricular theme in school education.
- The system caters for minorities (e.g. Finland is a bilingual country: Finnish/Swedish).
- There are good examples of the promotion of science, mathematics and technology through the National Science Education Centre (LUMA), and Resource Centre for Mathematics, Science and Engineering at School for the Swedish-speaking population.

POLICIES, STRATEGIES AND PROGRAMS

- National Science Education Centre (LUMA) (promote STEM; facilitate partnerships between schools, universities, industry, teachers and others; conduct LUMA workshops/courses, Science Fair, Millennium Youth Camp and webzines) supported by a network of science education centres with Finnish universities and the Finnish Science Centre, Heureka.
- Enrichment activities (interdisciplinary courses, mentoring programs, occupational coaching, elementary school co-operation, best practice material delivery and subject-related websites).
- GISEL project - Gender Issues, Science Education and Learning (between 2002-2005) (influence the attitudes of girls towards science and technology in making career choices).
- TiNA project (promote technology to girls; support women in their STEM careers) (discontinued).
- ASTeL project - Arithmetic, Science, Technology and e-Learning (develop a gender sensitive web-based science and technology learning environment for primary school and teacher education).
- Teaching quality projects (BioPop supports biology teaching; F2K supports physics and technology; Geopiste supports geography; Kemma supports chemistry; resource centres including the Summamutikka resource centre and the Resource Centre for Mathematics, Science and Engineering at School for the Swedish-speaking population; teachers/students visit industry).
- non-STEM-specific lifelong learning initiatives (activity clubs, summer camps, Ksenonit virtual club, Science Day, Luova webzine for young people).

FRANCE – high performing, centralised system committed to increasing education and research sector STEM participation

CHARACTERISTICS

- Highly centralised education system (e.g. teaching content, teaching objectives, activities).
- Upper secondary education includes tracks: academically-oriented *Baccalaureat General*; professionally-oriented *Baccalaureat Professionnel* and vocationally-oriented trade diplomas known as the *Certificat d'Aptitude Professionalle* and the *Brevet d'Etudes Professionnelles*. Careers in STEM fields can lead from each of the three pathways.
- There has been significant decline in the proportion of students choosing upper secondary mathematics and science, tertiary STEM-disciplines and pursuing research pathways in the 1990s and 2000s, with some recent stability.
- High participation in STEM-disciplines at tertiary ISCED levels 5 and 6. However, there is concern that the proportion is not high enough.
- Recent introduction of national testing of science and mathematics for primary school grades 2 and 4.
- Science and engineering careers are generally desirable and prestigious occupations, but the length of study required deters students.
- Gender disparity is conceived as a significant and ongoing issue. Slow progress has been made.
- Engineering graduates experience fast access to, and stability in, employment.

LESSONS FOR AUSTRALIA

- A students' home background, their attitudes and self-confidence in learning have a significant impact on student curricular choices and performance levels exhibited at school.
- Classroom strategies have been adopted to stimulate interest in STEM (e.g. innovative mathematics education; problem solving; cross-curricular links particularly with technology and science; real-world science education).
- Student attitudes to study in science and mathematics, and STEM disciplines, and their understanding of both their own abilities in these fields and the nature of such careers shape their choices.
- An increase in the number of researchers is an economic priority for recovery, stability and growth.

POLICIES, STRATEGIES AND PROGRAMS

- Classroom strategies (policy and programmes which are innovative and evidence-based; the government stipulates the time devoted to teaching each discipline and sets curriculum content and national assessments).
- Revision of mathematics curriculum for primary and lower secondary (content 'thinned' to allow greater emphasis on student development of problem-solving and procedural skills).
- Revision of mathematics curriculum for upper secondary (content added plus greater focus on cross-curricular links such as the interaction of mathematics and technology, philosophy and science).
- Science curriculum (promotion of science and technology; build synergies across programs; improve interest in science by teaching science as an integrated subject; promote scientific studies and external activities and competitions; promote careers in fields with a focus on female students; connect scientific learning at school and students everyday life experiences).
- National testing (mathematics and science at primary school grades 2 and 4; identify low performers; encourage teacher innovation in assessment; inform future policy and better teaching practices).
- Remedial programs for low performers (small group support classes; teachers provided with professional development for personalized and remedial approach; individual learning plans).
- Sciences a l'ecole - 'Sciences at School' (lower and upper secondary schools; scientific projects carried out in workshops and clubs; extra-curricular activities; national framework of activities and programmes; overseen by a regional inspector in each regional education authority).

- European Union programmes - Ambition and Success Network (primary and lower-secondary schools); I like sciences project (confidence-based contract; personalized support for students encountering difficulties in science; self-confidence and motivation; teaching practices; evaluation measures).
- Contests, workshops and other activities (scientific contests, scientific and technical workshops, chess, Olympiades – Geo-science Olympiad, Mathematics Olympiad, Physics Olympiad, Chemistry Olympiad, Engineering Olympiad; top performing students; scientific and technical workshops).
- Recognition of teachers (award for teacher-researchers to recognize professional excellence in science; Prize of Scientific Excellence; develop traditional games, such as chess to stimulate skills to boost performance).
- National non-governmental organizations:
  - Cite de la Science and Palais de la Decouverte merged to Universciences (enhance students' interest in sciences; make scientific and technical culture accessible; education programmes; scientific products and activities)
  - La main a la Pate (co-operative scientific organization; international links; improve science and technology teaching for primary and secondary school levels; annual scientific festival).
- Programmes targeted at women in science including promotion of STEM fields to girls and women - Pour le sciences project (encourage girls to take up scientific careers); exhibition Les femmes en maths - Women in Mathematics (depict women who have chosen a successful professional scientific path); L'Oreal France Foundation contest for women in sciences – 'For Women and For Science' (grant funding for women).
- Research:
  - research and develop national initiatives to boost research into participation in STEM education
  - National Association for Research and Technology (ANRT) and INRIA (dedicated to the study of technology and digital sciences; research, innovation and development of European partnerships to improve research in the field
  - Institute for Engineering Sciences and Systems (INSIS) of the National Center for Scientific Research (CNRS) (engineering research)
  - French Institute for Education (ENS-INRP) and University of Burgundy's institutes and laboratories (examine policies and produce research pieces to collaborate with the government on STEM education; support events such as the National Mathematics Conference)
  - Evaluation Agency for Research and Higher Education (AERES) (evaluate tertiary institution's performance and managerial efficacy)
  - OECD (policy research; workshop – Education for Innovation: the Role of Arts and STEM Education; Global Science Forum.

UNITED KINGDOM – long term government policy agenda for STEM

CHARACTERISTICS

- High performing education system, including school and higher education; however there is a long tail of underperformance. Their ranking in terms of PISA and TIMSS slipped significantly between 2000-2009 (i.e. relative to other countries).
- Performance in mathematics has improved markedly in the last 15 years.
- Participation in GCSE mathematics is increasing such that the Department has raised the target. Participation in A Level mathematics is increasing.
- Participation in GCSE science declined between 2001/02 – 2005/06, but showed signs of recovery from 2005/06 – 2009/10; participation in separate sciences increased (nearly 150%) between 2004/05 – 2009/10.
- There has been increased participation, generally, in higher education that has resulted in increased participation in STEM disciplines.
- University fees have recently been significantly increased (generally to £9,000), and this may influence participation in STEM disciplines and higher education more broadly.
- There has been an historic weakness in turning science into technological innovation.
- There is an increasing role of the European Union in the UK (and benefits for the UK) (e.g. investments in science and technology flowing from adoption of the Lisbon agenda).

LESSONS FOR AUSTRALIA

- Long term government policy agenda for STEM with respect to world-class research; partnerships with end users; investment in R&D; STEM teachers, school students, tertiary students, R&D careers; minority participation; universities/public laboratories; confidence and awareness.
- There has been a focus on science communication and public engagement (e.g. activities ‘outside the classroom’).
- Mathematics, science and ICT are compulsory in Years 10-11 (i.e. until the age of 16).
- Implementation of the National Curriculum (including changes) has had profound implications for teachers (e.g. in-service professional development focused on the National Curriculum; training science teachers for exploratory/practical science education; search for practical work linked to real life applications).
- Strength of the United Kingdom’s STEM research.

POLICIES, STRATEGIES AND PROGRAMS

- Science & Innovation Investment Framework 2004-2014 (long-term policy agenda for STEM):
  - World class research at the United Kingdom’s strongest centres of excellence (world class centres of research excellence; departments and broadly based leading universities)
  - Responsiveness of the publicly-funded research base to the needs of the economy and public services (Research Council programmes in partnership with end users of research; knowledge transfer and commercialisation)
  - Business investment in R&D and business engagement with United Kingdom science base for ideas and talent
  - Supply of scientists, engineers and technologists (science teachers and lecturers in every school, college and university; national targets for teacher training; student performance in science at GCSE; participation in SET subjects in post-16 education and higher education; better qualified students pursuing R&D careers; proportion of minority ethnic and women in higher education)
  - Sustainable and financially robust universities and public laboratories across the United Kingdom in scientific research and its innovative applications
  - Implementation: science research budget increased and maintained during the economic downturn; concentration of research funding in highly rated research centres; investment in infrastructure; increasing funding on research with demonstrable economic or social benefit; science communication and public engagement activities grown so wealth of science activities ‘outside the classroom’).

- Public understanding of the science movement (arguably started in 1985 with the Bodmer Report).
- Government commissioned public perceptions surveys (Public Attitudes to Science, Ipsos MORI report, 2011).
- National Curriculum (England, Wales, Northern Ireland) (compulsory in state schools; some differences between countries; independent schools, new academies and free schools not required to follow National Curriculum but most do; mathematics, science and ICT compulsory in Years 10-11; most students take national exams – General Certificate of Secondary Education; changes to GCSEs pending, with new target – Ebacc that requires three of the five GCSE subjects to be English, mathematics and science; new draft curriculu for English, mathematics and science just published).
- Upper secondary curriculum and certification (after GCSE, academic students stay on at school/college for a further 2 years to study for the General Certificate of Education [GCE] Advanced level ('A levels').
- Teacher professional development (state-funded schools timetable five non-teaching days per year for teacher professional development; In-service Education and Training or INSET; Continuing Professional Development or CPD).
- University funding (STEM courses attract additional funding).
- National Numeracy Strategy (introduced late 1990s).
- Mathematics specialists in primary schools (funded training program to place a mathematics specialist in each primary school).
- History of school science and mathematics developments (Nuffield Science – more experimental, investigative approaches; 'balanced science' – teaching of biology, chemistry and physics for all students; Triple Science; rise of 'process science' – opposed to focusing on 'the facts'; National Curriculum and associated assessment procedures; slimmed down National Curriculum – focus on scientific facts and emphasis on arithmetic).
- Science 5-16 (DES, 1985) (broad and balanced science education – curriculum containing biology, chemistry and physics throughout the school system, occupying 20% of the time).
- Graduate Certificate of Secondary Education (GCSE) (variety of science courses including all three main sciences intended for all students).
- Revision of science curriculum (greater focus on the role of science in society, and how it works; 21st Century Science course).
- Schools with a specialism in science, technology, engineering or mathematics and computing (1,300 schools in England).
- National Network of Science Learning Centres (response to lack of established, well-defined structure of further training, accreditation and recognition / path of progression for teachers to systematically acquire further professional development drawing on local networks; subject-related continuous professional development to be treated differently to other professional development requirements concerning whole school issues, matters of administration and national initiatives; National Science Learning Centre established, and regional centres, based in centres of science education; grants to teachers for fees, travel and accommodation and teaching cover costs).
- Cognitive Acceleration through Science Education (two-year program of professional development; pedagogy based on Piagetian view of child development).
- Enrichment activities (or 'informal' or 'life-long' science education) (science centres, museums, science festivals, science talks and activities outside school or university classes, zoos, planetaria, aquaria and botanical gardens).
- Science Centres (following the model of the Exploratorium in San Francisco) (typically charge visitors for entry; 'millenium science centres' – regional focal points for formal and informal science education activities; need to establish evaluation indicators).
- Science, Technology, Engineering and Mathematics Network (STEMNET) (educational charity established in 1996; national and regional hubs; 3 program: STEM Ambassadors, STEM Clubs Network and Schools STEM Advisory Network) (note: positive evaluation results in terms of student engagement).
- Millennium Mathematics project (based at University of Cambridge; range of programs and events aimed at school children and at general public; NRICH – free mathematics enrichment resources, discussion forums, face-to-face outreach activity and professional development for teachers; Roadshows that visit schools).

UNITED STATES – commitment to STEM reflected in legislative and policy framework

CHARACTERISTICS

- Extensive legislative and policy framework for STEM overlaying a decentralized, fragmented education system spanning school, community and tertiary sectors.
- The President has embraced the STEM agenda and actively promotes science, mathematics and technology.
- There is large diversity in the student population.
- National policy focus on quality, with this measured through student achievement in science and mathematics through national and international tests at the school level.
- There is large variation of quality between schools, districts, and suburban, urban and rural settings.
- Lack of interest in STEM disciplines.
- Concern that students do not learn prerequisites for learning sciences (which need to be studied from middle school).
- Many STEM teachers did not minor, major or earn a certificate in the discipline they teach in.

LESSONS FOR AUSTRALIA

- There has been a concerted national effort and co-operation beyond party differences to provide the focus and continuous funding and continuity for long-term plans regarding STEM.
- Most labour market demand for STEM is predicted to be for holders of STEM certificates and associate degrees (and their systems will seek to provide a focus on these educational levels).
- Grow existing networks of science education scholars and develop a capacity in physics / chemistry / biology / mathematics / engineering education.
- Take advantage of qualified immigrant STEM workforce (i.e. legal pathways to gaining residence; balance between STEM workforce trained in Australia and immigrants).
- Disciplinary committees in STEM education (e.g. Australian Research Council).

POLICIES, STRATEGIES AND PROGRAMS

- America COMPETES Act (innovation in STEM and STEM education; grants to high-risk/high-reward areas; increase STEM qualified teachers serving in high-needs areas and delivering advanced courses in STEM; co-ordination of efforts across scientific agencies – NASA, NOAA, NSF; stimulate R&D; promote and improve STEM education; national day of STEM for schools) (reauthorized by President Obama in 2010):
    - Director of the Office of Science and Technology Policy (OSTP) to establish a committee responsible for co-ordinating federal efforts in STEM education, and develop a 5 year STEM education strategic plan (annual and long-term objectives; common metrics to assess progress; evaluation strategy; describe role of each agency in supporting programs/activities)
    - Teachers for Competitive Tomorrow (TCT) (increase qualified teachers in areas of critical need, including science and mathematics; teacher education BA's/Masters with STEM content knowledge and teacher certification)
    - Promote participation of under-represented minorities in STEM
    - Programs that use cyber-learning tools to train and retrain the STEM workforce
    - Prize-based competitions to spark innovation
    - National Centre for Science and Engineering Statistics (data on STEM research, development and education)
- Federal funding for K-12 (Department of Education, agencies with STEM-related missions including National Science Foundation, National Aeronautics and Space Administration) (2010 PCAST report suggests efforts should be increased and better co-ordinated)
- Student visas (PhD graduates can stay for additional 12 months beyond graduation on nonimmigrant visa)
- Employment-based visas (visas issues to foreign nationals sponsored by US companies, and visas issues to foreign nationals with graduate degrees from US universities)
- STEM Jobs Act - initiatives with an impact on immigration policies (both initiatives blocked/not enacted) (STEM Jobs Act reallocation of immigrant visas from the Diversity/Visa

Lottery program to highly qualified foreign graduates of American universities with advanced degrees in STEM fields; STAR Act – permanent residency to STEM graduates working in institutions receiving at least $5million/year federal research grants)

- Rising Above the Gathering Storm (2005), Committee on Prospering in the Global Economy of the 21st Century: An Agenda for American Science and Technology report:
    - o multiplicative effect of well-prepared science and mathematics teachers on their students (recruit mathematics and science teachers, undergraduate teaching scholarships, summer institute teacher training, Masters programs, world-class K-12 curricular materials, specialty high schools to provide intensive immersive learning for best students, inquiry-based learning)
    - o attract the brightest people into STEM (students, scientists, engineers) from the national talent pool (competitive undergraduate scholarships, graduate fellowships, tax credits for companies encouraging employees' continuous education) and the international talent pool including students and scholars (access to education, employment, visa-granting, skill-based immigration, access to technical information and equipment)
    - o science, engineering and research (emphasis on basic research; research grants; research facilities; high-risk/high-payoff research)
    - o incentivise innovation (impact manufacturing and marketing, modernize the patent system, adjust the taxation system, affordable internet access)
- National Action Plan for Addressing the Critical Needs for the US Science, Technology, Engineering and Mathematics Education System 2007 (strong, coherent, national STEM education system):
    - o (recommended only) national co-ordination: new co-ordinating structures including the National Council for STEM Education (independent), one with the President's Office of Science and Technology Policy, one with the Department of Education
    - o roadmap to improve STEM education from pre-kindergarten to college (National Science Foundation)
    - o horizontal co-ordination: STEM content guidelines; metrics used in student performance aligned with proposed guidelines, assessments mandated under No Child Left Behind Act; promote STEM learning; share information / best practice on STEM teaching and learning
    - o vertical alignment: linkages between high school, higher education and the workforce (STEM education councils in each state, alignment of STEM content throughout the P-12 education system)
    - o STEM teachers (market rate compensation, resources, national STEM teacher certification standard, preparation to teach STEM content effectively)
- National Science Board STEM education recommendations to President-Elect Obama administration (2009)
    - o motivated public, students and parents (public awareness campaigns, appeal to parents, coalitions among interested stakeholders)
    - o clear educational goals and assessments (address variability amongst states and school districts, articulate core concepts/skills, assessments that promote STEM learning, critical thinking, communication, problem solving, talents of all children)
    - o teachers (resources for STEM teachers pay, STEM undergraduate majors and professionals becoming K-12 teachers in the neediest schools)
    - o resources and assistance for teachers (advanced technology in education; Science Corps of active/retired STEM professionals to assist teachers; web-accessible resources of validated STEM instructional materials and best practices; web resource of research from cognitive sciences and STEM education fields relevant to educational practice; funding for research on learning and STEM teaching)
    - o early start in science (STEM core concepts in early education programs; extent and quality of elementary school STEM education; motivate parents and community members to support goals)
    - o communication, co-ordination and collaboration (coalitions between K-12 school systems, colleges and universities, informal science education organisations, business and industry to address STEM issues, streamline co-ordination of STEM education research; disseminate successful STEM education activities)
- Building a Science, Technology, Engineering and Math Education Agenda (2011)
    - o expand the number of students ready to enter post-secondary education and pursue STEM careers

  - improve the basic STEM knowledge of all students as a means for them to access problems, use STEM concepts and apply creative solutions to everyday lives
  - rigorous mathematics and science standards and improved assessments (Common Core State Standards Initiative for mathematics and English language; A Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas; common and consistent measures of student performance across states)
  - recruit and retain more qualified and effective teachers (financial incentives as recruitment and performance bonuses to attract teachers into hard-to-serve areas or hard-to-place positions; institutional conditions to promote retention; discipline, leadership, teacher input into school-wide decisions, classroom autonomy, professional development)
  - rigorous preparation for STEM students (STEM-specialised schools provide students with college-ready curriculum; early college: high school courses / college curriculum; online STEM learning, combined with on-site study)
  - informal learning to expand mathematics and science beyond the classroom (hands-on mathematics and science activities, organised educational opportunities outside classroom)
  - STEM teachers (enhanced preparation programs; alternative pathways which allow science and mathematics professionals to enter the teaching profession)
  - Goals for post-secondary institutions to meet STEM job needs (metrics)
- Competitiveness and Innovative Capacity of the United States (2012) (learning of STEM skills at all levels within the educational system)
- Prepare and Inspire (2010) (standards; recruit and train 100,000 STEM teachers; STEM Master Teachers Corps; educational technology; create 1,000 STEM-focused schools; strong and strategic national leadership)
- Engage to Excel (2012) (increase the number of STEM graduates by 1 million; STEM teaching strategies that emphasize student engagement; tools for students – pre-requisites to STEM study unevenly acquired due to SES/gender/race-ethnicity/income; diversified pathways to STEM degrees)
- Co-ordinating Federal Science, Technology, Engineering and Mathematics (STEM) Education Investments: Progress Report (2012):
  - evidence-based teaching practices; STEM Institutional Transformation Awards grants program at NSF; metrics to evaluate STEM education
  - replace standard laboratory courses with discovery-based research courses
  - national experiment in postsecondary mathematics education to address mathematics-preparation gap; partnerships – STEM programs for school students; pathways from 2- to 4- year institutions; public-private partnerships to support successful STEM programs; improve data)
  - Presidential Council on STEM undergraduate education (academic and business communities)
- Transformation and Opportunity: The Future of the US Research Enterprise (2012):
  - empirically validated teaching methods
  - research opportunities for STEM undergraduates
  - attract the world's best students and researchers (adjust visa system)
  - early career researchers
- Skills for America's Future (national network of partnerships among employers, community colleges, industry associations to bridge skills gap)
- ARPA-ED (use technological breakthroughs to transform teaching and learning through education R&D)
- Master Teachers Corps (recognise and reward the best STEM teachers)
- STEM Talent Expansion Program (STEP) and Graduate 10K+ Focus program (increase the annual number of engineering and computer science degree graduates by 10,000)
- Education to Innovate (public-private partnerships to foster interest and engagement in STEM through out of school activities)
- Common Core State Standards (CCSS) (common standards for K-12 English Language Arts, Mathematics and Science)

CANADA – high performance system with decentralized authority for education

CHARACTERISTICS

- Provinces, rather than the national government, have legislative authority for all levels of education under the Constitution. As such, there is no national ministry, national higher education policy or national legislation.
- There is a decentralized university 'system', with provincially supported public or private institutions holding significant autonomy.
- High performance education system in terms of school mathematics and science (PISA and TIMSS) (note: males outperformed females; variability between the provinces).
- Very high participation generally in tertiary education (i.e. very high ISCED level 5 / tertiary type-B attainment; high ISCED level 5 / tertiary type-A attainment).
- Graduation rates in some science-related fields have increased significantly over the past five years (e.g. life and physical sciences), but there has been a near-collapse in computing, and only limited increases in mathematics and engineering.
- There is under-representation of Indigenous peoples in school and tertiary education generally, and in STEM-fields specifically.
- There is under-representation of girls and women in STEM-fields.

LESSONS FOR AUSTRALIA

- Funding for federal research priorities and programs produced a shift in the narratives of STEM-related research funding at provincial/territorial levels.

POLICIES, STRATEGIES AND PROGRAMS

- Mobilising Science and Technology to Canada's Advantage report (2007) (strategy for science and technology research and researchers; increased engagement with the S&T sector to develop national advantages: Entrepreneurial Advantage; Knowledge Advantage; People Advantage; private-sector investment in S&T; focus on priority areas; sustain public standing of S&T; alternative management arrangements for non-regulatory federal R&D labs; consolidation of advisory council into a single Science, Technology and Innovation Council; funding opportunities for S&T researchers and students)
- Networks of Centres of Excellence (ties between post-secondary institutions and industry, incentives for commercialisation of academic research)
- Tax rates for investment in R&D (reduction in a variety of tax rates for private sector investment in R&D and new businesses, including Scientific Research and Experimental credit)
- Federal research granting programs in priority areas (mapped onto agendas of federal funding agencies, particularly the Natural Science and Engineering Research Council)
- Science, Technology and Innovation Council (centralizing S&T advice in a more tightly controlled agency; removal of the National Science Advisor as a direct advisor to the Prime Minister)
- New industrial internship program (S&T related scholarship programs)
- Let's Talk Science Spotlight on Science Learning (national, charitable organisation delivers science learning programs and services across Canada; national surveys of parents and students)
- Council of Ministers of Education, Canada (CMEC) Common Framework for Science Learning Outcomes: Pan-Canadian Protocol for Collaborations on School Curriculum (general direction for national curriculum compatibility for primary and secondary science curriculum) (note: now out of date)
- Provincial science curriculum (e.g. Ontario)
- Tri-Council Granting Agencies (federal government support for research and scholarship at Canadian academic institutions distributed by Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council, and Social Sciences and Humanities Research Council) (programs: Vanier Canada Graduate Scholarships, Banting Post-Doctoral Fellowships program)
- Natural Sciences and Engineering Research Council (NSERC) (students, post-doctoral fellows, professors and university-industry research partnerships)

- Mitacs-Globalink Internship Program (public-private partnership supporting short-term summer internships for international undergraduate students at Canadian universities with research industries; funds travel, visa and accommodation costs, stipend, local transit fees, institutional fees; second generation program that supports previous recipients accepted for graduate study)
- Networks of Centers of Excellence: Industrial R&D Internship Program (tripartite arrangements between universities, industry and government to support world-class research and researchers; technology-transfer between universities and industry; commercialisation; partnerships; four sub-programs: Networks of Centres of Excellence, Centres of Excellence for Commercialisation and Research, Business-Led NCEs and Industrial Research and Development Internships program; internships for graduate students and post-doctoral fellows)
- Canadian Research Chairs (attracting and retaining top Canadian and international researchers)
- Genome Canada (GC) (under Industry Canada; projects in genomics and proteomics through Genome Centres)

NEW ZEALAND – recognition of Maori rights; but persistent disparities and challenges for education and STEM

CHARACTERISTICS

- Maori, as the indigenous people, have specific statutory rights under the Treaty of Waitangi, the nation's founding document.
- Kuru kaupapa Maori (KKM) are full immersion Maori schools. They tend to be small. Students emerge proficient in te reo Maori (Maori language) and with extensive Maori knowledge; however such schools frequently have limited curriculum offerings due to their size, particularly STEM subjects, and few STEM-qualified teachers in comparison to mainstream schools. Such schools have positive influences in terms of attitudes/expectations, teacher quality and parental engagement.
- Maori and Pacific Island peoples (Pasifika) tend to do less well than their European and Asian counterparts, noting that there are also issues of poverty and health with New Zealand minority peoples.
- Early childhood and school curricula are published in both English and Maori.

LESSONS FOR AUSTRALIA

- Reflection of Maori needs at system level.
- ICT based initiatives to underpin education.
- Resources to support mathematics and science education.
- Various Learning Experiences Outside the Classroom (LEOTC).

POLICIES, STRATEGIES AND PROGRAMS

- ICT in teaching and learning programs (enabling tools including the Laptops for Teachers scheme; School Network Upgrade Project; rollout of Ultra-fast Broadband; teacher professional development e.g. Virtual Learning and Professional Development initiative; supporting innovation – digital opportunities program, e-learning teacher fellowships; Virtual Learning Network)
- Mathematics and Science Taskforce (established by Ministry of Education; published Connected – a resource to excite primary school students interest in science, technology and mathematics; Building Science Concepts booklets; Numeracy Development Project)
- Professional development for technology teachers (online resource to showcase contemporary teaching and learning in technology; Technology Beacon Practice Project; Technology Leader Support Programme; Curriculum Support Package for technology curriculum; National Technology Professional Development Manager; learning community of teacher educators; in-service and pre-service teacher education learning communities)
- Professional development for ICT-PD clusters and Te Kotahitanga (program for culturally responsive instruction)
- Learning Experiences Outside The Classroom (LEOTC) (programs run by community-based organisations – zoos, museums, historic parks, art galleries, performing arts and science centres; authentic, hands-on, interactive learning)
- Biotechnology and Science Learning hubs (web-based resources)
- Assessment Resource Banks (ARBs) (collections of science, mathematics and English assessments resources for formative and summative purposes)
- Teacher fellowships (primary, intermediate and secondary teachers)
- Maori and Pasifica policies and strategies:
    - education system that creates an environment that allows Maori students to succeed as Maori; and allows Maori students to succeed on the same terms as their Pakeha peers, to have access to global knowledge and achieve in the environment of the knowledge economy
    - Maori strategy: Ka Hikitia – Managing for Success: The Maori Education Strategy 2008-2012 (being redeveloped as Ka Hikitia – Accelerating Successes 2013-2017)
    - Pasifika strategy: Pasifika Education Plan 2009-2012
    - curriculum: Maori language; Maori history and values; language development necessary to implement science, mathematics and technology curriculum; authentic experience of Maori language, knowledge and culture
    - kuru kaupapa Maori (KKM) schools (tend to be small; students emerge proficient in te reo Maori and with extensive Maori knowledge)

- School-community links: Healthcare Heroes (secondary schools and the Pasifika Medical Association)
- Vision 20:20 school outreach program (run by the University of Auckland; includes: Maori and Pasifika Admission Scheme; Certificate in Health Sciences; Whakapiki Ake Project)

RUSSIA – high participation and performance system; historical focus on mathematics and science

CHARACTERISTICS

- Russia inherited from the Soviet era – which finished two decades ago - an education system and economy geared for high levels of mathematics and science.
- High value is placed on education (e.g. higher education is seen as the norm).
- High performance in mathematics and science (TIMSS) (but PISA results are below the international average). This suggests that Russian students are strong in knowledge, memorizing standard tasks, but weaker in application and failing in reasoning/integration).
- Mathematics is compulsory to the end of school.
- Some specialist schools focus on higher learning in mathematics and physics; however these are small in number.
- Teachers hold a high level of teacher qualifications.
- Very high participation in higher education (59-77% of age cohort).
- Gender disparities, particularly in some STEM disciplines in higher education, and in most STEM R&D.

LESSONS FOR AUSTRALIA

- There is an emphasis on project-oriented and inquiry-oriented learning.
- There is an emphasis on enhancing senior secondary school science and mathematics within the curriculum.
- There are a variety of programs to strengthen research in universities, stimulate commercialization and technology transfer and encourage interaction between universities and industry for innovation in business.

POLICIES, STRATEGIES AND PROGRAMS

- Russian government political document establishes the goal that by 2020, Russia will have a leading position (5-10% of global markets) for high technology products and intellectual services
- Science and Technology Policy (but no coherent, consistent or loosely focused educational policy on STEM)
- Presidential Program (retraining for 15,000 engineers working in Russia or abroad; increased per-capita funding for university engineering, medical and science enrolments)
- Presidential target for world class universities (established target of no less than five institutions in the top 100 by 2020; increasing expenditure on R&D)
- Development of R&D (strengthen research in higher education institutions; stratification of institutional landscape; 'excellence programs'; mergers of regional institutions to concentrate regions resources; commercialization and technology transfer; interaction between universities and industry; development of innovation in business; attract leading researchers; world class laboratories)
- Concept of development of mathematics education in Russia (basis of analytical data of state of the art mathematics education)
- Support for gifted children (competitions – 'Olympics'; festivals at national, regional and municipal levels; national database of gifted children and their support; establishment of a center of support for gifted children at federal universities; distance education schools at several federal and national research universities)
- Supplementary education at secondary level (network of institutions for supplementary, extra-curricular education)
- Specialist schools of advanced study in mathematics and science (residence establishments associated with universities, and some non-residence programs; graduates progress to be researchers in higher education – for economy and military sector)

CHINA – deep commitment to education; high participation in STEM; booming economy

CHARACTERISTICS

- Deep commitment to education (i.e. self-cultivation; instrumental role).
- The education system is government-driven, teacher-centered, theory focused, national examination-oriented, and homework supplemented.
- There is compulsory participation in mathematics to the last year of school for both the science track and the arts track.
- There is compulsory participation in physics, chemistry and biology until the 2nd last year of school.
- High performance education system (i.e. student achievement on PISA, TIMSS).
- Teacher discipline specialization (i.e. teachers teach one subject; mathematics and science teachers are trained in the discipline they teach in).
- There is high participation in STEM disciplines in higher education, particularly engineering and STEM research higher degrees. Engineering is the most popular undergraduate discipline, followed by natural science. 71% of doctoral entrants are in the science/engineering/medicine disciplines.
- Universities and R&D are seen as critical to technological progress (central to the national innovation system).
- There are gender disparities in the R&D workforce.
- There is significant investment in the R&D sector with a focus on applied and experimental research and a priority on the elimination of poverty.
- Developing country with booming economy.

LESSONS FOR AUSTRALIA

- Dual focus:
  - development of scientific literacy (i.e. school and university students basic science knowledge, spirit and qualities) and
  - cultivation of science 'talents' (i.e. high achievement in STEM-disciplines, education and R&D occupations, with both basic and applied research.
- Longstanding commitment to science (including mathematics) education.
- Discipline-specialists for STEM teachers; practical preparation; continuous professional development; strong career ladder including incentives and performance requirements.
- Focus on building world-class universities (e.g. growth of Natural Science and Technology Universities).
- Curriculum and pedagogy reform including a focus on scientific literacy, inquiry-based teaching and learning, creativity – 'teach them how to fish rather than giving them the fish'.
- After-class / out-of-school activities.
- Active involvement of parents.

POLICIES, STRATEGIES AND PROGRAMS

- Science and Technology development goal (2006-2020) (agriculture, industry, high-tech and basic research)
- Ministry of Science and Technology (MOST) (program based competitive grant schemes – Basic Research Program, Key Technologies R&D Program, S&T Basic Conditional Construction Program, Spark Program, Torch Program, National New Products Program, Innovation Fund for Small Technology-based Firms, Agricultural S&T Transfer Fund, International S&T Co-operation Program and Special Technology Development)
- National Technology Transfer Centres (based at universities)
- University Enterprise Reform (relations between universities and affiliated enterprises through ownership and management reform)
- University Science Park (free land allocation, infrastructure and facility support)
- Technological Innovation Project (boosting corporate technological innovation)
- Technological Innovation Funds for High-tech Small and Medium-Sized Enterprises (enterprise-based innovations)
- Independent agencies for science and technology (all levels of government, down to counties)
- Linkages (universities, research institutes, industry)

- New Curriculum Reform, and pedagogy reform (scientific literacy, ‘science for all children’, inquiry-based teaching and learning, active learning, hands-on skills, project work, student-centred, critical skills – ‘teach them how to fish rather than giving them the fish’) (textbooks, materials, teacher preparation, professional development aligned to national curriculum/standards)
- National Mid and Long-term Education Reform and Development Framework (2010-2020) (implement new curriculum reform nationwide, all-round qualities of students; collaboration between industry, universities and research institutes; enhance basic and applied research)
- Teaching quality (teacher preparation, continuous professional development, training workshops, peer group projects, pedagogy training – active participation of students, questioning, critical thinking, creativity)
- Science Experimental Class (SEC) (special education program for talented school students to attend the International Science Olympiad; elite education, creativity, research capability, talent; specialised curriculum; interest groups; research; self-learning; group discussion; tutorials; eligible for exemption from the National College Entrance Examination) (note: decreased popularity due to concerns about skewing of original objectives towards fast-track into university)
- After-class activities (‘after-school activities’; ‘second classrooms’, including subject-related clubs, and student-interest clubs)
- Project 211 (launched 1995) (growth in research student numbers and research capacity is a priority for the higher education agenda; funding for elite universities; strengthening 100 higher education institutions; science infrastructure, laboratories; scientific research; commercialisation of research findings; staff competence)
- Project 985 (world-class research universities)
- Guidelines for Strengthening Basic Research in the Higher Education Sector (Changjiang Scholar Plan; innovative team development plan and new century talents support plan; evaluation system for basic research; attract overseas students; investment in research)
- Collaborations (universities, research institutes, companies) (drive innovation system; knowledge transfer; commercialisation; university-affiliated technology enterprises, technology transfer contracts, patent licensing, joint-authored publications, university science parks, incubators):
    - Bainbridge Program run by Royal Phillips Electronics, with Shanghai Jiaotong University – joint laboratories and projects; ‘brain-bridge’ with Zhejiang University and Technical University of Eindhoven (Netherlands); new culture of technical excellence; research in health science, IT and electronic engineering
    - Microsoft China Company (collaboration with Chinese universities; students work at Microsoft for a semester and undertake the Microsoft certification exam)
- Internationalisation of higher education (Chinese students study higher education programs abroad; transnational education programs; internationally co-operative research projects and co-authored publications)
- Science Education Reform and Practice Program (science and technology ‘talents’; evaluation of science education; co-construction of science curriculum; management of science education in universities; collaborations between universities, research institutions and industry; English-teaching science programs)
- University programs for talented students (science and engineering students; students delay decisions about specialisation until completion of generic 2 years undergraduate focused on mathematics, physics and chemistry – similar to Melbourne Model for talented students)

JAPAN – R&D&T power recovering from 2003 ‘PISA shock’

CHARACTERISTICS

- Declining popularity of science and technology, amongst both children and Japanese society generally.
- Students are tracked in senior secondary school: science (science and mathematics) or humanities (Japanese and social studies; majority).
- Declining participation of secondary students in science and mathematics, with a significant decline in physics.
- School student performance is no longer exceptional (PISA results have fluctuated; ‘PISA shock’ in 2003 led to reforms).
- Declining participation in undergraduate enrolments in STEM-disciplines, including science and technology, whereas participation in health is increasing.
- Increasing number of doctoral graduates in science and technology alongside system-wide increases, however the actual proportion has leveled or decreased.
- Persistent gender disparity in university STEM-disciplines and the STEM workforce (i.e. ‘East Asian syndrome’: girls participate in science and mathematics at school, less so in university STEM including doctorates, low in R&D workforce, and low in STEM careers).
- Lack of primary school teachers with specialist knowledge of science and mathematics.
- Nation of scientific and commercial innovation (R&D&T power).
- Third largest R&D workforce, with significant private sector investment in R&D (70%).

LESSONS FOR AUSTRALIA

- Importance of science and mathematics at primary school and secondary school.
- Dual focus: scientific literacy (‘Science for All’) and elite STEM training (‘Science for Excellence’).
- Teaching quality: competitive pay scale for teachers; teachers are traditionally highly regarded; quality teacher training and ongoing professional development; common practice of ‘lesson study’ (i.e. share best teaching practices); emphasis on problem solving.
- University entrance examination arrangements influence senior secondary student participation patterns.
- Promotion of STEM generally, and STEM education.
- Science and Technology Basic Law (long term national goals) and Council for Science and Technology Policy (mid-term national strategies).
- Regular policy analysis and adjustments to the existing system to improve quality of education.

POLICIES, STRATEGIES AND PROGRAMS

- Science and Technology Basic Law (S&T Law) (Japanese economic and societal development and progress of global science and technology; Council for Science and Technology Policy headed by the Prime Minister; effective co-ordination of multiple agendas aligned through administrative organisation)
- 4th Science and Technology Basic Plan (increase women researchers in STEM fields; sets targets for women’s participation in science, engineering, agriculture, and health university programs (childcare, promotion of scientific careers, e.g., ‘STEM-girls’)
- Training Centers for Core Science Teachers (CST) (training of primary school science teachers; qualified STEM teachers; confidence; teacher-training and workshops; teachers to disseminate learnings to other teachers)
- Super Science High School (selected schools receive targeted funding; elite track; advanced mathematics or science curricula of mathematics or science; advanced research through collaboration with universities; enhancement of international abilities e.g. participation in International Mathematical Olympiad and International Physics Olympiad)
- Enhancement of Curriculum Guidelines for compulsory science and mathematics at primary school and secondary school (hours and content) from 2008 to reverse 1998 reduction (mathematical literacy, science literacy and problem solving for all through compulsory education) (reversal of ‘relaxed education policy’)

- Support for Development of Science and Mathematics Project (S&T honours program in undergraduate science and technology; co-operation between senior secondary and tertiary education; interdisciplinary Leading Programs in Doctoral Education)
- Transition support (transition to employment for STEM doctoral graduates and postdoctoral researchers to permanent research positions)
- Young Researchers Training Program for Promoting Innovation (internships for doctoral students)
- 300,000 International Students Plan (Asian students to Japanese research programs, including STEM disciplines)

SOUTH KOREA – government commitment to STEM, long term planning and continued economic growth

CHARACTERISTICS

- Very strong government belief that STEM and science and technology are key to economic development.
- Low student motivation to undertake STEM, even amongst successful students.
- Participation in subjects other than science is higher than science and mathematics in senior secondary school.
- The number of specialist STEM schools has increased since 2005.
- Participation in STEM-disciplines (university) has been increasing since the mid-2000s.
- The proportion of doctorates in science and engineering has increased.
- There is an increasing number of STEM-discipline graduates (university), with a sharp increase in doctoral graduates.
- Competition for entrance into teacher education programs is high.
- Persistent gender disparity, including low participation in science and technology and the R&D labour force.
- Mismatch between supply / demand STEM graduates.

LESSONS FOR AUSTRALIA

- Long term national planning for STEM.
- Curriculum content has been reduced to provide more time to focus on the curriculum, and pedagogy, including greater creativity.
- Focus on lifting motivation.
- Specialist science high schools have been established for high achievers.
- STEAM: creativity, experiential education, inter-disciplinary education, motivation.
- Life-cycle conception of science and technology.

POLICIES, STRATEGIES AND PROGRAMS

- Second Master Plan for Educating and Supporting Human Resources in Science and Technology (2011-2015) based on Special Support Act for Science and Engineering for Improving National Competitiveness (educating and supporting human resources in science and technology, with emphasis on top universities, creativity, women)
- Science, Technology, Engineering, Arts and Mathematics (STEAM) (inter-disciplinary education, creativity, artistic literacy, self-efficacy, student engagement, motivation, inquiry)
- Korea Advanced Institute of Science and Technology (KAIST) (graduate school specializing in science and engineering)
- Korea Institute for the Advancement of Science and Creativity (KOFAC) (promote science and technology-related cultural activities; science and creativity communication; classes, activities, camps, support for STEAM, talks, dinners, Science Evening Dinner with Science for adults at work)
- Comprehensive Plan for Discovering and Education Talented and Gifted Youth in Science (specialist science, technology, engineering, arts and mathematics schools for talented and gifted e.g. Science and Arts Schools for the Gifted)
- Life cycle approach to human resources for science and technology covering education, employment, research and retirement (e.g. Global PhD Scholarship available for high caliber undergraduate, doctoral, postdoctoral research)
- Women in science and engineering: Korea Advanced Institute of Supporting Women in Science, Engineering and Technology (WISET)
- Brain Korea 21 (increase human resources in science and technology; lift research indicators and university rankings)
- World Class University (WCU) Project (lift international faculty)
- Specialist science and technology universities
- Global EXCEL program (increase number of Korean institutions in 100 global universities; inter-disciplinarity and graduate education, competitive evaluation and quantitative indicators)
- Women in Engineering program (emphasized within master plans; expanding career paths)

- Women in Science and Technology program (career development of women in science and technology, policy research, online information, group activities)
- Women's Academy for Technology Changer in the 21st Century (WATCH21) (promote natural sciences and engineering to high school students; creative problem-solving; research activities)

TAIWAN – Asian Tiger committed to scientific literacy and STEM scientific research capacity

CHARACTERISTICS

- Growing economy (Taiwan is designated as one of the 'Four Asian Tigers') (i.e. very high living standards and economic growth).
- Taiwan is positioning itself as a global leader in green energy technology and intelligent living.
- Science and technology education is prioritized in Taiwan's school system.
- Mathematics and science are compulsory until the end of grade 11, then students are tracked: natural science, or social science.
- There is decreasing participation in primary and secondary education due to the decreasing birth rate.
- Very high performance in school mathematics and science (PISA and TIMSS).
- High participation in STEM disciplines in higher education, with over 50% bachelor enrolments, and 50% postgraduate enrolments in STEM; however, there has been a decline in recent years.
- There is gender disparity with respect to higher education students and staff in STEM disciplines.
- A large proportion of senior secondary teachers hold Masters degrees (47%).
- There is a shortage of academics.

LESSONS FOR AUSTRALIA

- Science education in primary and junior secondary schools is called 'citizen education'.
- There is a focus on 'science for all' as well as 'cultivation of scientists' (i.e. scientific research capacity and skills; acquiring science-related knowledge and concepts; fostering scientific attitude).
- There is a focus on increasing students creativity and critical thinking, cultivating curiosity and scientific ethics and attitude, and research ability.
- Senior secondary technical/vocational school students completing technology-related subjects are a potential source of the STEM labour market. 70% progress to higher education.
- Curriculum transformation (i.e. focus on scientific literacy; from science elite, to science for all; from teacher-centered to student centred; from science concepts to a combination of science, technology and safety; from knowledge oriented to ability-oriented).
- Technical universities are focused on advanced training in technologies to support the manufacturing industry.
- There is industry-academic collaboration, including funding for universities; real world research problems; applied research; well-trained graduates and knowledgeable faculty; technology licensing.

POLICIES, STRATEGIES AND PROGRAMS

- Long term planning (1959 – Long-Term National Science and Technology Plan; National Long-Term Science Development Committee; 1969 – Twelve Years National Science and Development; Industry Technology Research Institute; Professional Training Golden Regulations)
- Science Parks (co-operation between universities, research institutions and industries)
- National Science Council (NSC) and Science and Technology Advisory Group (STAG) (science promotion)
- National Education 9-year Curriculum Outline (science curriculum integrated into Natural Science and Living Technology; active research and exploration; independent thinking and problem-solving abilities; use of science, technology and information; textbooks; curriculum research groups; teachers given more autonomy in delivering lessons; assessment reformed into teacher dominant assessment; abolition of uniform graduation exam; multiple intelligence and pluralistic assessments adopted)
- Senior Secondary School Curriculum Outline (compulsory mathematics and science subjects in year 11; delay of tracking to year 12; focus on science literacy rather than training specialists in science, engineering and technology; transformation from elite to 'science for

all'; curriculum development role of school and teachers, rather than government departments; transformation from teacher-centred to student-centred; transformation from science concepts to combination of science, technology and science; from knowledge-oriented to ability-oriented)

- Science teacher training and professional development (cultivation of high-quality science teachers; science teacher professional development including pre-service and in-service training; *Teacher Education Law* regarding teacher education – pre-service teacher education includes general learning, subject-related learning and internship)
- Development Plan for World Class University and Research Centers of Excellence (world-class universities and research centres; university instruction and research; human resources; university management; organizational operation; interscholastic/international research teams; focus human resources and equipment investments; develop key national research areas; integration of R&D and innovation; new curricula; annual on-site evaluation; 3 yearly review and evaluation)
- Industrial-academic collaboration (upgrading the role of universities and research institutes in fundamental R&D, incubators of new knowledge-based firms, intellectual property protection, commercialization activities; patenting; entrepreneurial technology transfer; industrial-academic research; strategies up-, mid- and downstream scientific technological development)
- Regulations Governing University Industrial-Academic Collaboration (university involvement in industrial-academic collaboration) (funding from industry for university; industrially-sponsored research; exposure to real-world research problems; intellectually challenging research problems; applied research)
- Technology dissemination (Technology Transfer Centres, Technology Trade Centres – web-based systems; incubators)
- Taiwan Technology Marketplace (integrated technology-trading platform; incubators)
- Regional Industrial-Academic Collaboration Centres (industrial-academic interchange; matching potential R&D partners; subsidies to technical colleges for technology R&D centres)
- Implementation Guidelines for the Promotion of Industrial-Academic Collaboration between Technical Colleges and Universities and Industry Parks
- Inter-disciplinary training for engineers (inter-disciplinary engineering curriculum; interface between universities and industry)
- Program for Promoting Academic Excellence of Universities and Program to Improve Public Universities' Main Graduate Schools (inter-disciplinary research groups; improvements in institution's basic facilities for PhD courses)
- University-level sandwich programs (practical training to acquire professional know-how; ½ - full year in industry)
- Ford Company and technical university (co-operative relationship; Ford technical staff teach in the technical university; students visit Ford Company)

SINGAPORE – familial commitment to high performance

CHARACTERISTICS

- Very high performance education system (i.e. student achievement on PISA, TIMSS).
- Mathematics and science are compulsory core subjects (in primary school: mathematics from grade 1, science from grade 3; in secondary school: mathematics and science compulsory).
- High participation in science and mathematics (school).
- High participation in STEM disciplines (polytechnics, Institutes of Technical Education, university).
- Specialist trained science and mathematics teachers.
- Family commitment to education. Parents are engaged in education and there is a high level of participation in out-of-school/extra-curricula activities – tutoring, competitions, mathematics learning, camps and games.
- Numerous STEM occupations are in demand including manufacturing, healthcare, finance, construction, information communication and digital media industries.
- There are high rates of employment for Institute of Technical Education (ITE) STEM graduates.

LESSONS FOR AUSTRALIA

- Kindergartens support the academic development of children (e.g. science activities for pre-schoolers are organized by the Science Centre Singapore).
- A key goal of primary school education is to help students master mathematics (e.g. mathematics and science are both compulsory core subjects in primary level).
- Engagement of parents in school education.
- Provision of both remedial and enrichment mathematics programs.

POLICIES, STRATEGIES AND PROGRAMS

- Agency for Science, Technology and Research (A*STAR) (funding for research; co-ordination of R&D in science and technology; attract scientists and industry to Singapore; support biomedical sciences, chemicals, electronics, info-communications, media and engineering; Biomedical Research Council, Science & Engineering Research Council, Exploit Technologies; resources web-portal) (manage, monitor, evaluate and organize STEM related activities and programmes)
- Science Centre Singapore (science activities for pre-schoolers; organizes and supports enrichment activities)
- Enrichment activities (Talent Search; Singapore Science Festival; recognition and reward; competitions: Amazing Science-X Challenge, National Junior Robotics Competition; Meet the Scientist; Brain Awareness Week; Science in the Café; Star Kits to explore science; Discover Science Resources; Science Buskers Festival; Science in the Mall; Singapore Science & Engineering Fair; Sony Creative Science Award; Tan Kah Kee Young Inventor's Award; National Science Challenge; DNA Learning Academy)
- Collaborations between universities (Singapore and international, around bioinformatics, information science and medical technologies) (e.g. Singapore – MIT Alliance for Research and Technology – SMART: innovative engineering and life science education and research collaboration)
- Institutes of Technical Education (ITEs) have established partnerships with schools, training partners under Industry-based Training Schemes, corporate and industry partners (and VET institutions internationally)
- Improving university rankings (many programs in STEM related fields in high performing universities)
- STEM-related community based projects (students from universities, polytechnics and Institutes of Technical Education)
- ICT Master Plans (ICT skills and knowledge; creativity; innovation; student learning environment; self-directed and collaborative learning through effective use of ICT)
- Parent Support Group (PSG) (orientation courses; extra tutoring classes; events to acknowledge teachers; talks)

- Career Services Centre of ITE (career counseling, talks and fairs, industry visits, job matching/placement, online recruitment service, career talks, career fairs, information resources)
- Science Mentorship Programmes (teachers as mentors; scientists as mentors; cultivate 'the spirit of inquiry'; science fair projects; encourage problem-solving; promote scientific R&D; nurture positive attitudes towards scientific inquiry)
- Scientists as mentors programs (Applied Science Programme, Biotechnology Programme, Defence Science Programme, I2R Mentorship Programme, IHPC Mentorship Programme, Computer Mentorship Programme, Science Mentorship Programme, Science Exploration Programme) (enrichment; investigations and inquiry in science; stimulate interest; interaction with scientists and teachers; motivate by Mentorship Attachment/Project Work and Youth Science Conference)
- A*STAR undergraduate scholarships (scholarships for STEM disciplines)
- A*STAR research scholarships (PhD scholarships for STEM disciplines; research attachments with A*STAR Research Institutes, Singapore universities or universities abroad)
- Singapore Academy of Young Engineers and Scientists (SAYES) (support STEM education; youth science movement; resources accessible from Science Centre Singapore including field trips, lectures by Nobel Laureates, scientists, training programmes and peer group activities)
- Integrated Programme (route for high performance students to university)
- Vocational Programme (vocational education in schools, rather than specialised vocational/technical schools)
- Workforce Skills Qualifications (WSQ) (competency based training and recognition for adult workers)
- Teach Less, Learn More / Thinking Schools, Learning Nation (engage learners; less dependence on rote learning, repetitive tests and instruction; student engagement; discovery; lifelong skills)
- Teaching quality (nurture teaching talent: recruitment, training, compensation, continuous professional development, performance appraisal, career development, leadership selection and training)
- Training school leaders (assess young teachers for leadership potential; develop leadership capacity; mentoring)
- Specialised independent schools (National University of Singapore High School of Mathematics and Science, and School of Science and Technology)
- TE21 (Teacher Education for the 21st Century) (the 'thinking teacher')
- Singapore Science Park (promote STEM)
- Biopolis and Fusionopolis (research facilities; shared research equipment, services and supplies)
- Pedagogy (encourage focus on student-centred learning and problem solving)

BRAZIL – growing economy nurturing access to, and quality in, education

CHARACTERISTICS

- Growing economy.
- Increasing investment in education.
- There is a focus on addressing low levels of education (i.e. education access: children, young people and adults; and education quality), rather than an explicit focus on STEM.
- Poverty reduction and social inequality: there is a concern with people in less socially and economically developed states and municipalities, including remote and 'hard-to-reach' populations in the Amazonia forest.
- There is low but growing participation in STEM-disciplines in higher education.
- There are issues regarding the education system including classroom infrastructure; low-level qualifications for teachers; pedagogy; and high attrition.
- There is a shortage of STEM qualified people, particularly engineers.

LESSONS FOR AUSTRALIA

- Programs for students and adults in rural areas, including young people and adults, such as rural farmers.
- Programs for indigenous students and adults, including affirmation of identities, recovery of historical memories, native languages and knowledge of indigenous people.
- Focus on redressing disparities for people in rural areas, and indigenous people.
- Problem based learning (i.e. critical thinking, proactivity, team work).

POLICIES, STRATEGIES AND PROGRAMS

- Science Without Borders (scholarships to undergraduate and postgraduate students; international mobility of undergraduate and graduate students and researchers – mostly in STEM; research and teaching quality; entrepreneurship)
- New methodology for engineering courses (Problem Based Learning in computer science and other engineering fields)
- Scholarships (FIES: higher education students; PIBID: internships for higher education teacher education students; PROUNI: fellowships for post-graduate students in private higher education institutions; REUNI: increase access to and retention in higher education)
- Education for the countryside (higher education for rural farmers; monthly grants to farmers to support education participation in degrees)
- Quilombola education (higher education for slave communities; training of teachers for Quilombos, school infrastructure, pedagogic materials)
- Sequential courses (for people who do not have access to higher education; 2 year courses; practical skills)
- Distance education (technological innovation in educational processes and learning; techniques and pedagogy; public school focus)
- Indigenous school education (National Curriculum Guidelines for Indigenous School Education; 'indigenous school education as a right, characterised by the affirmation of ethnic identities, recovery of historical memories, valorization of native languages and knowledge of indigenous people; school infrastructure; food for pupils; specific pedagogic materials
- Indigenous university and community education (quota system at universities for indigenous students; train children, teenagers and adults engaged in community projects for improvement of life conditions and reinforcement of ethnic identities)
- Bolsa familia program ('Brazil without poor'; financial support for poor families; education and training programs)
- Education Development Plan 2011-2020 (teaching training; redefined national exam; pre-service teacher training; recruitment of new teachers; teacher career paths)
- More Education Program (increasing educational offerings at public schools; optional activities; pedagogy support)
- Fundescola (quality of education; focus on less developed regions)
- STEM Brazil (cognitive skills development; targeted public schools with lower SES students and ethnic minorities; contextual mathematics and science project-based learning emphasizing academic and practical employability skills; teacher training; critical- and

creative-thinking; bonds between teachers/students; connecting science and mathematics curriculum to engineering and technology sectors of economy)
- Digital inclusion program (computers and multi-media laboratories in all public schools; multimedia digital content for learning activities; educational holodeck/simulator for pre-K to middle school campus of Colegio Atual)
- Technical and vocational programs (voucher program for participation in technical and vocational training for young people and adults)
- Basic Education Quality Improvement Program (equity and quality of education services; in-service and continuing teacher development; academic qualifications of teachers; teaching practices; non-formal early childhood development; accelerated programs for over-age students; televised educational programs; accessibility for dropouts, parents and young workers)
- Contextualised Education (funded technical assistance, consulting services, teacher training, teaching learning materials, evaluation/administrative expenses; school autonomy strategies; school re-organisation; impact evaluations; social participation and mobilization)
- Sao Paulo Basic Education Quality Improvement Project (education quality; curriculum reform; learning materials; teacher content mastery tests/performance pay; partnership with universities)
- Reference schools (partnership with groups of companies to improve schools)
- Jovem de Futuro (education quality; school autonomy; results-based management; school improvement strategy; choose interventions – incentives for teachers, new computers, building upgrades, learning materials, extracurricular cultural activities, reinforcement classes)
- Municipal approaches (address grade repetition and attrition; schooling reinforcement; special mathematics and reading reinforcement)
- TELECURSO programs (over-age students; specially trained teachers; video/DVD programs; accelerated learning courses across all subjects)
- Se Liga 'Get Connected' (mastery of reading and mathematics for children in early grades)
- Bolsa Escola (School Grant) and Bolsa Familia (Family Grant) (the grant is conditional on school attendance; part of broader anti-hunger program)
- Creative programs for children in rural areas (address disparity for rural children; home-based models of education e.g. Acre – isolated communities in tropical forest with intense rains/difficulty fording rivers: curriculum applied in modules; classes taught by single teacher; aim to reduce poverty and increase schooling)
- ProUni (expend access of low SES students to higher education)
- Financing Students in Higher Education (financial support for higher education students)
- Embraer Institute School Access and Scholarship Fund (quality of high school education; scholarships/loans for university education)
- Tax reduction to philanthropic private universities (and scholarships for low-income university students)
- Open University of Brazil (distance learning programs, with focus on teacher education programs)
- National Service of Industrial Learning (national centre of knowledge creation and dissemination aimed at industrial sector; distance education professional development; mathematics education)
- Private education distance learning programs (teacher training through satellites/franchises of private education institutions 'viewing centres')
- Expansion of technological courses at universities
- Bolsa Universidade program (University Scholarship Program)
- Restructuring and Expansion Plan for Federal Universities (REUNI) (access to, and retention in, higher education; increasing places in evening courses; increasing student mobility; university teacher-learning methodologies; modalities for undergraduate education; articulating undergraduate/postgraduate with primary and secondary schools; infrastructure; human resources)
- Racial quota (the Supreme Court of Brazil approved the adoption of a racial quota policy for higher education institutions; % of places for students of African and/or indigenous)

ARGENTINA – biotechnology driven industrial development

CHARACTERISTICS

- Focus: quality of life, social development and education.
- Low participation in school science (i.e. physics, chemistry and biology) and mathematics.
- Low participation in higher education STEM disciplines (i.e. engineering).
- Gender disparity in both education and the labour market.
- Worsening conditions for teachers.
- Shortage of university academics.
- Industry specialisation in molecular biology, genetic engineering and biotechnology.
- Increasing investment in R&D, particularly including biotechnology.

LESSONS FOR AUSTRALIA

- Government industry investment strategy in STEM field (i.e. biotechnology; incubators; technology parks).

POLICIES, STRATEGIES AND PROGRAMS

- Ministry of Science, Technology and Productive Innovation (MINCYT) (policy for sustainable industry sector with high tech goods and services)
- Technical Education Act 2006 (restored the integrated model of secondary technical education, funding for education and science, netbooks)
- Government funds:
    - Technological Fund of Argentina (FONTAR) (technological modernization and innovation: services, assistance and training entrepreneurial incubators, technology parks)
    - Scientific and Technological Research Fund (subsidies to public and private non-profit R&D institutions)
    - Trust Fund for Promotion of the Software Industry (FONSOFT) (software development) Sectoral Fund (FONARSEC) (subsidies for upgrading R&D capacities)
- Biotechnology policy and programs (National Programme of Biotechnology, Biotechnology Multi-Year Plan for Science and Technology, Strategic Plan for Science, Technology and Innovation 'Bicentennial', Promotion of Production and Development of Modern Biotechnology Act, Argentinean Chamber of Biotechnology)
- National Agency for the Promotion of Science and Technology
- Bicentennial Strategic Plan (2006-2010) (researchers, investment in innovation and modernization, scientific base and technological capacity)
- Medium-Term Strategic Plan in Science, Technology and Innovation (2005-2015) (quality of life and social development, responsible use of natural resources, innovation and agricultural production, science and technology capabilities and infrastructure)
- National Institute of Teacher Training (STEM teaching quality, review of teaching techniques)
- Quality University Program (2001) and Project for the Improvement of Teaching Engineering Programs (PROMEI) (2005) (university compliance with engineering degree accreditation requirements, engineering academics)
- Strategic Plan for Engineering Education (2012-2016) (promote engineering, target: one engineer per 4000 inhabitants by 2016, engineering scholarships, transitions from school to university)
- RAICES program (Argentinean Researchers and Scientist Network Overseas) (2003, 2008) (re-expatriate scientists who emigrated overseas, Bicentennial Scholarship Program for Scientific and Technical Careers to support low-income students)

PORTUGAL – stagnant economy; lagging STEM participation and performance

CHARACTERISTICS

- Stagnant economy.
- Portugal lags behind other OECD countries in terms of participation and performance measures.
- There is standardised science and mathematics curriculum in primary and upper secondary education.
- Participation in higher education STEM disciplines is increasing, from a low base (30% enrolments in engineering).
- STEM occupations are amongst the highest paid and fastest growing.
- There is gender disparity in university STEM disciplines.

LESSONS FOR AUSTRALIA

- Dual focus of government policy, on both scientific literacy for all students; and increasing participation in higher education STEM disciplines and STEM careers.
- School mathematics focus (i.e. teacher professional development, resources).
- School science focus (i.e. experimental science teaching, student engagement, more time for science content).
- Information technology in schools (i.e. infrastructure, focus on ICT throughout curriculum, ICT internships, ICT academies in schools).
- Teaching quality (i.e. teacher education, professional development, centres to improve STEM teaching, STEM-qualified teachers).
- Collaborations in the higher education sector between research centres, industry, internationalisation and networking.

POLICIES, STRATEGIES AND PROGRAMS

- Government commitment to science and higher education sector reform (rather than STEM-specific focus)
- National Agency for Scientific and Technological Culture (Ciencia Viva) (promotes scientific culture in schools and to the public; work experience placements in research laboratories, Science and Technology Week, experimental teaching methods, science in the summer, the Robotics Open Festival, MIT professors go to school, the ORION amateur scientific association, debates with scientists, Census Viva, the LONGEVA project, ethnomathematics, the FORUM ciencia viva, Champimovel Project, Assocation Ludus and 17 ciencia viva interactive science centres)
- Technological Plan approved by the Portuguese Council of Ministers (2005) (high speed internet access in schools, IT equipment, school portals for sharing digital resources, certification of ICT skills, access to laptops and learning resources; Virtual School; Mobile School distance learning project).
- Mathematics Plan – mathematics projects for 5^{th} and 9^{th} grade students and teachers (professional development, database of resources, revision of mathematics textbooks, teacher education programs) (reached 460,000 students/50,000 teachers)
- National Action Plan for Science – experimental science teaching in elementary school (first 3 years of compulsory schooling) (teacher education, student engagement)
- Enrichment activities (Olympiad STEM competitions encompassing National Physics Olympiad and National Chemistry Olympiad)
- Curricular reform (additional time allocated for school science education; use of ICT throughout curriculum)

ISRAEL – innovation-driven high-technology Start-Up Nation

CHARACTERISTICS

- ‘Start-Up Nation’ (i.e. innovation-driven high-technology economy; large venture capital sector) (‘Silicon Wadi’ cluster).
- Weak input - strong output.
- School education is compromised (e.g. weak infrastructure; high student-to-teacher ratios; small budgets).
- Mandated partitioning of school education system: national secular, national religious (low priority science education) and independent system primarily Ultra-Orthodox (shun science education).
- High performance in academic research, industrial and military R&D, high-technology innovation.
- Ultra-Orthodox (15-17% of population) do not participate in STEM education or workforce.
- STEM track is ‘interjected’ with compulsory military service (minimum 2 years – women; minimum 3 years – men) (i.e. students do not transition directly from school to higher education).
- High participation in tertiary education (STEM priority fields; growth in absolute number of STEM students).

LESSONS FOR AUSTRALIA

- Government legislation, policy and sponsorship provide the dominant force behind STEM (Government policy supports science, technology, education, R&D and innovation).
- STEM pipeline conceptualised as kindergarten to lab pathway.

POLICIES, STRATEGIES AND PROGRAMS

- Policy spans jurisdictions of various ministries (no comprehensive national science and technology innovation plan or strategy; absence of cohesive governmental leadership on STEM matters; Government policy supports science, technology, education, R&D and innovation)
- Government legislation (Encouragement of Industrial Research and Development Law; Law for the Encouragement of Capital Investment; regulation through the National Council for Research and Development)
- Science and Technology Administration (an agency within the Ministry of Education) (sets STEM education goals; STEM curriculum and related pedagogies; supports introduction of ICT into classrooms; monitors achievement in STEM subjects; leads Adapting the Education System to the 21st Century)
- Honours program for excelling students (students identified in grades 5-6; 6 year track in STEM subjects; special consideration for recruitment into military units and admission to Technion)
- STEM curricula and pedagogical tools (Matar - science and technology online: podcasts, classroom aids, books, information sources for school-level research)
- Higher Education Plan 2011-2015 (funding for the Israel Science Foundation; created I-CORE Israel centres of research excellence)
- Integrating adults from marginalized groups into the STEM-related workforce (training for special populations such as Ultra-Orthodox Jews; absorbing skilled immigrants into STEM-related professions)
- Industry-oriented government initiatives (invite foreign firms to establish business in Israel: MAGNET program, MATIMOP program; build local capacity: incubating start-ups)
- Enrichment activities (science museum programs; initiatives to build financial capacity, industrial and technological infrastructure, and business training)
- Participation in PARSEL and CORDIS (EU programs) (network for STEM teachers; forums for curricula developers, STEM school supervisors, STEM matriculation examiners and STEM teachers)
- Atuda (academic reserve) (college education in several disciplines on high school graduation in exchange for added years of military service; military training in STEM-related topics)
- Talpiot (brilliant recruits placed in academic studies of basic science integrated with R&D defense projects)

- Corporate initiatives (Intel Teach: teacher training for use of ICT to aid teaching and learning; Mind the Gap!: started by women at Google Israel, tackles gender disparity; introduce girls to STEM-related study and work; girls hosted at Google offices, sponsors visits to R&D labs, university classrooms and conferences)
- Civil society initiatives (Ilan Roth Youth Physics Centre; Israel Technology Transfer Network)
- Academic initiatives (Hemda: learning centre for high school students to matriculate in advanced science and mathematics; STEM education; labs, teachers, tutorial services; Bloomfield Science Museum)

CANADA (Indigenous) – Indigenous ways of knowing to enhance both Indigenous and non-Indigenous student achievement

CHARACTERISTICS

- 1.26 million Indigenous peoples (785,000 First Nations; 425,000 Metis; 50,000 Inuit citizens) in Canada (3.8% of population). 1/3 – ½ First Nations people live on reserves; most Inuit live throughout sparsely populated northern territories.
- While education and labour/employment are provincial responsibilities, First Nations people who live on reserves are the responsibility of the federal government, including on-reserve education (on reserve education: inequitable funding; disparities).
- Many Indigenous families and all Indigenous communities place a high value on education as a solution to poverty (e.g. 'the new buffalo' is seen as a contributor to economic progress).
- Under-representation of Indigenous people in STEM fields.
- Saskatchewan (2nd highest *proportion* of First Nations and Metis citizens in Canada - 15%; and highest proportion of school aged children – 29%).
- In Saskatchewan: decrease in overall enrolment in 'optional' science courses, despite population increases; Indigenous students' enrolments in 'optional' science courses in grades 11/12 increased 80% (2002-2011) (population increases only 45%); more to accomplish as disparities continue.

LESSONS

- Poverty, more than any other single factor, is a barrier to student achievement (Euro-Canadian privilege, racism, intergenerational economic oppression).
- The incorporation of Indigenous knowledge (Indigenous ways of living in nature) in mathematics and science is beneficial for Indigenous and non-Indigenous students (Eurocentric-based STEM and Indigenous knowledge are complementary).
- Teaching methods and learning environments that actively engage students intellectually, physically, emotionally and sometimes spiritually.
- Culturally valid student assessment and evaluation strategies (give feedback to students; build on students' cultural assets to encourage achievement).
- Culture-based interpersonal communication (convey respect, humility, a sense of caring, firmness in guiding student behaviour, encouragement to forge relationships among students, faith in students' autonomy and responsibility, and high expectations of academic achievement).

POLICIES, STRATEGIES AND PROGRAMS

- Joint Task Force on First Nations and Metis Education and Employment (established in Saskatchewan in 2011) (goals: increase First Nations and Metis people's participation and success in advanced education and the labour force; particular attention to STEM)
- Bioenergy centre (Meadow Lake Tribal Council, confederation of nine First Nations) (green energy project)
- Treaty Land Entitlement Agreement (signed 1992 by the Federation of Saskatchewan Indian Nations, the federal government and the provincial government; money to purchase land
- Canadian ministries and departments of education have revised, or are revising, education policies to attract more Indigenous students to school science and mathematics to encourage them into STEM-related post-secondary programs
- Incorporation of indigenous knowledge (Indigenous ways of living in nature)
- Turtle Island's Native Science Academy (represents scholarly of Indigenous students in US and Canada; promotes inclusion of Indigenous knowledge in school science)
- Saskathchewan's Ministry of Education science curriculum renewal project (Grade 1-9 science program: curriculum content specified Indigenous knowledge to teach; supportive teaching materials – science textbook series developed for schools; Indigenous Elders and educators identified Indigenous knowledge for curriculum content; Indigenous knowledge integrated into each unit of study)
- Textbooks (Ministry of Education with Pearson Education Canada; series of science textbooks which integrate Indigenous knowledge throughout science topics including: interviews with Elders, descriptions of Indigenous knowledge; end-of-section questions;

experiential activities; inquiry projects; Indigenous Elders decided what content would be included in a science unit, and they controlled how content was described)

- Indigenous knowledge is place-based (valid for one place), therefore school systems must initiate contact between teachers and local Elders or Knowledge Keepers or Holders
- Teacher professional development (support science teachers in developing relationships with local Indigenous people so that teachers can learn the local content to be taught, and often, how to teach it)
- Curriculum: culturally responsive science teaching:
    - student learning, with specific attention to the needs of Indigenous students (cultural perspective)
    - Indigenous knowledge integrated into science classes
    - teaching strategies and methods (culturally appropriate pedagogy)
    - student assessment (culturally valid)
    - culture-based patters or styles of classroom interpersonal communication
    - learning environment (holistic integration)
- Culturally responsive science learning:
    - Learning ultimately supports the wellbeing of the self, the family, the community, the land, the spirits, and the ancestors.
    - Learning is holistic, reflexive, reflective, experiential, and relational (focused on connectedness, on reciprocal relationships, and a sense of place)
    - Learning involves recognizing the consequences of one's actions
    - Learning involves generational roles on responsibilities
    - Learning recognizes the role of Indigenous knowledge
    - Learning is embedded in memory, history, and story
    - Learning involves patience and time
    - Learning requires exploration of one's identity
    - Learning involves recognizing that some knowledge is sacred and only shared with permission
- Scientific and Indigenous knowledge integrated in science classes
- Teaching strategies and methods (culturally appropriate instructional strategies and teaching methods to engage Indigenous students in content; methods that harmonize with or enhance students' cultural identities; story-telling; talking circles; observing followed by emulating; diverse visual sensory ways of gaining information; scaffolding; students writing exit notes; reflective journaling; community support; collaboration in effective group work; Elders or Knowledge Keepers/Holders as visitors; teaching out of doors in the land; field trips to Indigenous cultural events; teaching directed towards community well-being; getting students to make significant, responsive and autonomous choices; actively engage students intellectually, physically, emotionally and sometimes spiritually)
- Culturally valid student assessment (exit comments; reflective journal entries; portfolios; experimental problem-based reports; clearly written open-ended test questions; teacher takes into consideration students' home language and their cultural values, beliefs, experiences, communication patterns, and recurrent learning strengths)
- Culture-based interpersonal communication (patterns or styles of teacher-student interactions and student-student interactions; convey respect, humility, a sense of caring, firmness in guiding student behaviour, encouragement to forge relationships among students, faith in students' autonomy and responsibility, and high expectations of academic achievement)
- Saskatchewan mathematics curriculum (includes Indigenous perspective on the world drawing upon Indigenous artefacts to teach some mathematical concepts)
- Saskatchewan Institute of Applied Science and Technology (SIAST) Aboriginal Services department (support for Indigenous students: Summer Transition Support Program; Emergency Bursary program; Aboriginal Activity Centre – social interaction and support services; access to Elders and cultural advisors)
- Saskatchewan Indian Institute of Technologies (SIIT) (trades and industrial programming for First Nations peoples offered at the community level; work-skill development; apprenticeship and industrial programs)
- Dumont Technical Institute (DTI) (serves Metis Nation in Saskatchewan; skilled Metis workforce that meets local, regional and national labour market needs: adult upgrading; essential skills; practical nursing; computer sciences)
- Indigenous teacher education programs:

- Indigenous Bachelor of Education Programs (prepare First Nations and Metis teachers; teachers encouraged to return to their communities to be role models for Indigenous achievement)
  - Indian Teacher Education Program (prepare mostly elementary school First Nations teachers; based at the University of Saskatchewan, satellite course offerings at selected reserves)
  - Saskatchewan Urban Native Teacher Education Program (SUNTEP) (Bed. for Metis students)
  - Northern Teacher Education Program (NORTEP) (off-campus program for northern residents)
- School outreach projects:
  - university personnel visit on-reserve schools and northern schools to encourage Indigenous students to attend university;
  - science professors travel to a school to talk to science classes;
  - Wildlife CSI – school visits; authentic activities that interpret real evidence, Western and Indigenous knowledge systems, builds STEM capacity for Indigenous and non-Indigenous students in rural and Indigenous communities including isolated northern communities;
  - Science First, now SCI-FI Science Camps – hands-on science, technology and engineering experiences to school-aged youth in a fun way; camps, community programs, science clubs, satellite campus in northern communities; Discover Engineering to interest girls in engineering)
- First Nations University of Canada (FNUC) (on-going relationship with on-reserve schools and their communities; culturally rich connections; formally organised outreach project)
- Science Ambassador Program (outreach project; university STEM people building strong relationships with remote Indigenous students and their science teachers; ambassadors live for 5-6 weeks in a remote community; honorarium; peer mentors and role models; engagement in science) (successful program)
- Transition programs (from high school to university entrance) (offered by technical and profession institutions and universities; target - young adults not meeting eligibility criteria; First Nations University of Canada program – community-based STEM program: instructors travel to the reserve; life skills for surviving in a city; academic reading/writing/mathematics; success-based courses that extend mathematics and science skills to introductory university level; completion certificate)
- Undergraduate Indigenous student support (Aboriginal Students' Centre at the Saskatchewan Institute of Applied Science and Technology and University of Saskatchewan – promotes mental, emotional, physical and spiritual well-being; academic skills workshops, information sessions, support programs on- and off-campus, traditional teachings, pipe ceremonies, Sweat Lodges, access to traditional Elders, Pow-Wow Indigenous celebration ceremony, mentorship programs, social functions)
- Aboriginal Student Achievement Program (ASAP) at the University of Saskatchewan College of Arts and Science (financial support; organised as a community of learning; focus on biology but will expand to most STEM first-year courses; triad classes; mentors and advisers; on-campus, Indigenous, STEM community)
- Indigenous STEM-related programs:
  - Canadian universities and Indigenous nursing programs or Indigenous teaching programs (Cape Breton University's award winning Integrative Science Program that brought together scientific worldviews and Mi'kmaw First Nations worldview in a series of four courses)
  - National Aboriginal Lands Managers Association (national certification program; professional education in Indigenous land management; face-to-face format on campus plus a home-study distance format in the student's community; connects academic achievement with students' community employment)
- Pedagogy (STEM educators should choose scientific and mathematics content based on its relevance to students, rather than solely promote the canonical content that has always been in a curriculum or the canonical content that university science, engineering and mathematics departments invariably prescribe; content constructed around students' cultural relevance, which motivates their engagement in learning)
- AREVA Resources Canada (company focused on exploration and mining of Canadian uranium deposits); various projects:
  - STEM skills training

- participates in the Science Ambassadors Program
- pre-employment program for Indigenous northern Saskatchewan high school graduates without academic background for employment: literacy, mathematics and science skills; partnerships with post-secondary technical institutes and colleges; continual contact with a student's family and community
- mill operator program for fully qualified high school graduates from northern Saskatchewan: mill operator training on-site using AREVA trainers and contracted trainers; leads to basic certification as a mill operator
- informal community-based outreach program; Elders and school educators identify students with strong interests or high potential in science and mathematics; mine site visits; shadow workers; create a strong image of themselves in a STEM-related career

- Cameco (uranium producer, named one of Canada's 'Top 100 Employers'); various projects:
  - Bernard Michel Scholarship (support for a Saskatchewan Indigenous student entering BSc degree in geology, toxicology, chemistry; or BA in geography land use and environmental studies; $5,000 pus summer work terms at Cameco's operations;
  - Cameco Scholarships in the Geological Sciences (course costs for geological sciences; summer employment)
  - Scholarships: Cameco Scholarship in Engineering, Cameco Saskatchewan Institute of Applied Science and Technology Centennial Merit Scholarship, Cameco Northern Scholarship Program, Cameco Employee's Dependent Children Scholarship, Cameco Geological Technology Scholarship, Cameco Mining and Mineral Process Engineering Scholarship, Russell W. Thompkins Memorial Award in Mining Engineering)
  - Math & Science Bursary Program (for First Nations, Metis and northern students access on-line mathematics and/or science classes)
  - Cameco Access Program for Engineering and Science (CAPES) (administered by a group of university engineering and science faculty; local educational initiatives including Rekindling Traditions integrating science content into local Indigenous knowledge, guided by Elders; outreach projects: SCI-FI Science Camps and Science Ambassadors Program)
- Federation of Saskatchewan Indian Nations (FSIN) (annual province-wide science fair for on-reserve students in grades 6-12, featuring Indigenous knowledge projects and Eurocentric science projects)

UNITED STATES (Indigenous) – strategies to enhance Indigenous people's participation

CHARACTERISTICS

- Disparities for United States Indigenous peoples representation in STEM education and careers.

LESSONS

- Equitable access to premium education.
- Address issues facing struggling students, and excellence, simultaneously.

POLICIES, STRATEGIES AND PROGRAMS

- Solutions proposed by Plucker, Burroughs and Song:
  - Make closing the excellence gap a national and state priority (supporting students other than the brightest to achieve at high levels)
  - Acknowledge that both minimum competency (struggling students) and excellence must be addressed simultaneously
  - Set realistic goals to close the gaps
  - Determine the appropriate combination of local, state and federal policy interventions to best promote high levels of achievement and shrink excellence gaps (ability groups, academic acceleration, dual credit programs, Advanced Placement, International Baccalaureate programs)
  - Incorporate advanced student performance in discussions about common standards (data collection; track performance of high achievers; state and local education agency accountability)
  - Identify policies at state level that may help or hinder the promotion of high achievement in K-12 schools
  - Research on advanced learning and talent development (high end learning)
- Higher education partnerships (scholarships; mentoring; peer mentoring; internships; supplemental instruction; bridge programs; preparation for pre-requisite mathematics and science courses prior to enrolling)
- Project Lead The Way (National Action Council for Minorities in Engineering [NACME] and National Academy Foundation project – national network of open enrolment, high school level engineering academies for mathematics/schools skills necessary for college-level STEM courses)
- National Science Board recommendations:
  - Intentional, co-ordinated and sustainable interventions at both formal and informal levels to develop students' potential for learning through STEM disciplines (accommodation student learning in ways that allow for talent, interests and capacities; elicit engagement, intellectual curiosity, creative problem-solving
  - Wider-range talent assessments at multiple grade levels and among all demographics of students (train educators to recognize potential, particularly those who have not been able to transform potential into academic achievement)
  - Community support for excellence and innovative thinking (educational professionals, parents, peers, students)
- Building Engineering and Science Talent (BEST) (public-private partnership; identified STEM programs that are effective for under-represented groups in Pre-K – 12, higher education, workplace). The design principles for effective programs:
  - defined outcomes drive the intervention (goals, desired outcomes, data collection, research and continuous improvement)
  - sustained commitment (proactive leadership; sufficient resources; steadfastness in the face of setbacks)
  - personalization (the goal of the intervention is the development of students as individuals) (student-centred teaching and learning; mentoring; tutoring; peer interaction; recognize individual differences, uniqueness and diversity)
  - challenging content (curriculum clearly defined; real-world applications; goes beyond minimum competencies; reflects local/state/national standards; academic remediation available)

- engaged adults (educators play roles as teachers, coaches, mentors, tutors and counselors; teachers develop quality interactions; active family support sought)

- Meyerhoff Scholars Program at the University of Maryland-Baltimore County targeted at under-represented, high achieving undergraduate minority students interested in doctoral study in sciences or engineering (social and academic integration; student perceptions of the STEM disciplines; extra-curricular supports/environments; knowledge and skill development; support and motivation; monitoring and advising; promotes active learning; analytical thinking; learner-centred environments mindful of students' cultural orientations; mentors in STEM fields; counseling and peer-group support; assesses student learning; classrooms as communities by promoting intellectual and social cohesion)
- National Consortium for Graduate Degrees for Minorities in Science and Education (GEM)
- Leadership Alliance
- Compact for Faculty Diversity and Preparing Future Faculty
- Holistic approach in programs (substantive knowledge and technical skills; comprehensive support network; formation of networks; extensive and intensive professional socialization; tracking program participants internally and externally (including mentors); bridge experiences between one educational milestone and the next)

SOUTH AFRICA – legacy of Apartheid continues (Apartheid abolished 1994)

CHARACTERISTICS

- Ranked 3rd on financial market development; 132nd on health and primary education.
- Triple issue of poverty, inequality and unemployment.
- Focus on redressing the injustices of the past; achieving faster economic growth, higher investment and employment; improving education, health and social protection; strengthening links between economic and social strategies; developing effective and capable government.
- High performance in formerly White schools; low performance elsewhere (long tail of underperformance). Overall, the disparity is decreasing.
- There are disparities for African, Coloured, Indian students compared to White students at both school and university; also gender disparity.
- Shift towards STEM disciplines in university enrolments.
- There has been a decline in the vocational education and training sector (VET students from impoverished communities).

LESSONS FOR AUSTRALIA

- Mathematical literacy is a compulsory unit for the National Senior Certificate.
- Focus on quality education to address longstanding disparities.

POLICIES, STRATEGIES AND PROGRAMS

- National Development Plan of the National Planning Commission (redress the injustices of the past effectively; achieve faster economic growth, higher investment and employment; improve education, health and social protection; strengthen links between economic and social strategies; develop effective and capable government; promote collaboration between the private and public sectors; foster leadership from all sectors in society)
- South African Agency for Science and Technology Advancement (SAASTA) and South African Association for Science and Technology Education Centres (SAASTEC) (advance and promote science and technology)
- White Paper on Science and Technology (1996) (address inequalities that have excluded black women and men from the mainstream of South African society; conditional grant mechanisms to promote science awareness; National Research Foundation funds for young researchers, studentships and grants to researchers; public communication of science and technology)
- Focus Schools project - Dinaledi Schools (resources for previously disadvantaged black communities)
- National Senior Certificate (mathematical literacy one of the four compulsory subjects for senior secondary school students)
- Curriculum 2005 and Revised Curriculum Statements (transformation of primary and secondary school curriculum; learner-centred and activity-based approach rather than content-led didacticism and rote learning)
- Students and Youth into Science, Technology, Engineering and Maths (SYSTEM) (second chance for science and mathematics Senior Certificate examinations students to obtain mathematics exemption to go to higher education)
- Strategies for improving school science and mathematics and STEM (participation and performance of historically disadvantaged learners; high-quality science, mathematics and technology education for all; human resources capacity to deliver science, mathematics and technology education; in-service training in mathematics and science to address subject knowledge; increase the number eligible for university study by increasing participation in, and pass rate for, Year 12 physical science and mathematics; promote racial transformation of the public research organizations; research and support staff; management and the control boards)
- Teaching quality (teaching qualifications; qualifications automatically linked to salaries; teaching training; Advanced Certificate in Education or National Professional Diploma for Educators; subject content knowledge development provided by non-governmental organizations such as PROTEC, Sediba, Thinthana, CASTME, RADMASTE)

- Southern and Eastern Africa Consortium for Monitoring Education Quality (SACMEQ) (international non-government organization of 15 ministries of education of the region; assessment of performance in reading and mathematics of grade 6 students)
- Annual National Assessments (draw on SACMEQ, TIMMS and PIRLS; statements concerning reading and mathematics performance of grade 3 and 6 students)
- Enrichment activities (national Science Week, science camps, winter classes, educational materials through print, DVDs, radio and television channels)
- Minister of Higher Education target for VET (goal of enrolling 5 million students in VET by 2030)
- R&D Strategy (2002) and Department of Science and Technology initiatives (enhanced tax incentives for R&D; competitive grant funding; specifying intellectual property rights arising from public funding; Research Chairs Initiative, Centres of Excellence, Centres of Competence in universities; Big Science bid for Square Kilometre Array radio telescope with Australia)
- Ten Year Plan (technological innovation output; graduates, researchers and technicians)

INTERNATIONAL AGENCIES – international testing regimes for comparative analysis

POLICIES, STRATEGIES AND PROGRAMS

- Programme for International Student Assessment (PISA) (triennial international comparative assessment of educational outcomes through student performance; conducted by the Organisation for Economic Cooperation and Development [OECD])
- Trends in International Mathematics and Science Study (TIMMS) (curriculum-oriented test of mathematics and science learning; conducted by the International Association for the Evaluation of Educational Achievement)
- Assessment for Higher Education Learning Outcomes (AHELO) (assess learning outcomes of tertiary students; being developed by the Organisation for Economic Cooperation and Development [OECD])
- Recommendations from various international agency reports:
  - understand student choices
  - measure and predict demand and supply of STEM skills to meet future needs
  - collaboration between stakeholders (including international collaboration between organisations, policy makers, professional bodies, educational institutions, interested parties)
  - information about STEM subjects and careers to students
  - student contact with STEM professionals
  - curricular changes: flexibility; allowing students to re-enter STEM pathways; reflect modern STEM careers; expose student to recent discoveries; concentrate on concepts rather than retention of information; humanize these fields; highlight relevance to everyday lives; science as process or method rather than product or discipline
  - teacher networks
  - cross-disciplinary studies and professional skills
  - data and indicators for understanding issues in STEM education and employment
  - teaching: build student's prior knowledge; promote deep learning; layers of context; inquiry; meta-cognitive practices; good teaching materials
  - teacher education: deal with STEM fields better outside senior science classroom
  - girls and women, and other minority groups: employ strategies
  - promote scientific literacy and career progression in general science study
  - involve actors and stakeholders from outside the school system in learning
  - brain drain from less developed nations
- Women and girls:
  - career and course counseling services (better materials)
  - mentoring programmes
  - targeted programmes that prioritize opportunities for women
  - European Network of Mentoring Programmes (for women in academia and research; link between professors and PhD and post-doctoral level women;
  - address: work culture; work-life balance; flexible working hours; child care provision; support for family mobility; maternity and paternity leave; conditions for currently employed; rethink teacher training, curriculum and context/environment; attractiveness of STEM studies and careers; interdisciplinary design of courses within STEM areas; female role models; image of science, engineering and technology in community; dispelling myths/combating ignorance; procedural transparency; system-wide targets and quotas; equity legislation; financial incentives; engagement; scholarships/fellowships for women; visibility and influence of women;
  - policy of gender mainstreaming: systemic commitment to gender equality in STEM education and careers through combination of elements including political will, legislation, greater understanding of gender issues, mandated involvement in decision-making bodies and to senior appointments, more appropriate human resource processes and funding systems; sincere commitment from scientific leaders;
  - more and better quality gender dis-aggregated statistics and indicators related to women's participation in STEM fields of study and work
  - Professional Opportunities for Women in Research and Education (POWRE), ADVANCE program and Athena Project (improve career prospects for women scientists in university sector; guidelines for best practice for STEM departments in the UK)
- Financial literacy:

- International Network on Financial Education (INFE) (network of countries and public bodies interested in financial education and financial literacy)
- Financial literacy strategies (developed by many countries)
- Money Advice Service (UK) (unbiased advice with financial issues)

LITERATURE REVIEW: STUDENT IDENTITY – the centrality of student identity and engagement

- Teaching qualifications (mathematics teachers' qualifications).
- Professional development (combined professional development, in-school lesson evaluation and co-teaching).
- Teachers (gender profile for mathematics teaching profession, particularly in primary school).
- Pedagogy (learning outcomes-based approach, greater autonomy for teachers to support/be responsive to learners, active problem-based learning, real-world contexts, context-based contemporary societal issues, collaborative learning activities, key competencies approach to science education, participatory inquiry, active and co-operative learning activities, critical thinking about science, reflection on meaningfulness in everyday life).
- Perceptions (contest negative cultural stereotypes, active participation with 'experts' in the classroom, promote scientific culture, knowledge and research, raise girls interest in science, education to help educators, families, students and others value science, promote accurate/updated image of science as interesting and attractive activity, more realistic and humane images of scientists and science professions).
- Assessment (project based, portfolio, ICT or self/peer-based assessment).
- Partnerships (school science partnerships with science-related professions).
- Enrichment activities (initiatives designed to tap into students' interests in personally relevant and meaningful science and science-related career aspirations including school-based seminars, excursions, hands-on projects, secondary school-university mentoring programs, internships, science-related work experience, promotional campaigns, science-in-the community).
- Targets and monitoring (targets, monitoring systems).