Consultant Report
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STEM: Country Comparisons

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Literature Review - A selection of the work of international organizations on STEM education and STEM-related issues

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Executive summary

Education in the fields of science, technology, engineering and mathematics (STEM) is of international interest and has been explored in numerous ways by international agencies. This document was prepared by Kelly Roberts and reviews the literature produced by international agencies on STEM education and related issues.

The alphabet of performance measurement in STEM fields: PISA, TIMSS and AHELO

International organizations have their most significant role in the measurement of STEM education. Indicators from these sources are used to substantiate points throughout this document, however, the review first addresses the measurement of educational outcomes in STEM fields through an examination of international tests of student achievement. Growing participation in international testing of student achievement has become a significant component of educational accountability, policy making and planning around the world, with authority in these processes. Media coverage of results has become widespread, regularly rekindling public discussion of educational reforms, and the test outcomes are increasingly normative in national policy contexts. The two key international assessments are the Programme for International Student Assessment (PISA), and the Trends in International Mathematics and Science Study (TIMSS). PISA is a triennial programme of assessment which commenced in 2000 and is coordinated by the Organization for Economic Cooperation and Development (OECD).

By 2012, the programme has grown to assess 15 year-old school students in more than 74 countries, representing more than 90% of the world's economy. PISA assesses reading, scientific and mathematical literacy, focusing on knowledge and skills gained through education but applicable to everyday choices and the solving of real world problems. A special focus is made on one testing domain each testing cycle. Scientific literacy was a special focus of the 2009 round of testing and is defined by PISA as 'an individual's scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence based conclusions about science related issues, understanding of the characteristic features of science as a form of human knowledge and enquiry, awareness of how science and technology shape our material, intellectual and cultural environments, and willingness to engage in science related issues, and with the ideas of science, as a reflective citizen' (OECD, 2010:14). Mathematical literacy will be the focus of the latest testing cycle conducted in 2012 and is defined as 'an individual's capacity to formulate, employ, and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts, and tools to describe, explain, and predict phenomena. It assists individuals to recognize the role that mathematics plays in the world and to make the well-founded judgements and decisions needed by constructive, engaged and reflective citizens' (OECD, 2010c:4).

TIMSS is the longest running and most extensive international tests of science and mathematics learning. It is administered by the International Association for the Evaluation of Educational Achievement (IEA) and directs attention towards curriculum, rather than literacy in these fields. Students in years 4 and 8 are tested and student achievement scores are published, along with extensive survey information gathered from students, parents, teachers and policy makers in each country. Accordingly, national participants receive comprehensive and internationally comparative data on the ways in which each discipline area is taught, curricular content and student outcomes. Numerous curriculum driven learning domains are tested within TIMSS and more detailed information is provided in the body of the review. The latest results of both testing programmes place Australia among top performers, but with significant scope for improvement, particularly in mathematics.

International data on adult skills and tertiary level educational outcomes are the next, more challenging, area for international assessments. One example of this is the OECD's Assessment for Higher Education Learning Outcomes (AHELO) which had a focus on international outcomes of engineering education. This programme is still in its formulation and pilot phase and is yet to show itself to be viable, with substantial challenges such as the diversity of international tertiary offerings.

Counteracting the decline and attracting more students into STEM studies

The proportion of both upper secondary and tertiary level students choosing to study in STEM fields has declined internationally through the past decade or more. International organizations both produce the data to illustrate this trend, and have engaged in study of this issue and its potential solutions. Student choices are driven by public images of employees in STEM fields, their experiences of study in these areas in compulsory years of schooling and the quality of teaching they had at this time. Recommendations are made in the literature for the improvement of this situation, including the promotion of collaboration between interested parties, the collation of better and more detailed data, the improvement of curricula and teaching practices, and the provision of opportunities for students to meet STEM professionals and understand better what it is that they do.

Improving STEM education is an economic priority

This review explored the extent to which international organizations have taken great interest in STEM education and the development of the STEM workforce in countries around the world. Across the board, interest in STEM fields in couched in primarily economic terms, with economic growth and development the central motivators. Those not studying STEM fields, and particularly those not working in these fields after graduating from relevant study are referred to as under-utilized resources, and international tests of achievement identify this achievement as the yield of education systems.

Gender inequality in some STEM fields, creates interest in promoting the participation of women in STEM fields

Women are under-represented in STEM fields in numerous ways throughout both education and employment. The overall proportion of women in STEM fields is low, despite greater participation of women in higher education and professional employment in the past decade. There are disciplinary patterns to this gender divergence within the STEM fields. At tertiary level, men outnumber women in mathematics, statistics, science (particularly physics), engineering, manufacturing, construction and computing, while women outnumber men in the study of health, welfare, education, agriculture and life sciences, as well as in many non-STEM fields such as the humanities, arts, services, social sciences, business and law. Similar patterns can be traced back through student expectations of study and careers at age 15 years, and workforce outcomes for women, including high levels of attrition, and very low numbers of women in senior appointments. A myriad of factors contributing to this under-representation are described in the review, including elements of the nature and organization of employment in STEM fields, acculturation of young people into particular notions of what pathways are for males and females, and simple ignorance of what it is to be a STEM professional. There are also numerous reasons why inequality here is problematic, covering economic, social and quality concerns. The international literature makes a wide range of pertinent recommendations to address the established causal contributors. These include making the professions more attractive to women with better work-life balance, parental assistance, and more open work cultures. Additionally, the recommendations include strategies directed towards social and cultural barriers to female participation, including changing perceptions of STEM professions within classrooms and the community more broadly. Further, recommendations are made for policy makers and regulators to contribute to the collation of better internationally comparative gender dis-aggregated statistics on this topic and involve peak bodies, industry associations and other interested parties collaboratively in the formation of national solutions.

Engineering is the often forgotten part of STEM, but has issues of its own to deal with

Engineering is of critical importance to the world we live in: it produced the technologies we now cannot live without, and has an ongoing role in helping societies deal with challenges. However, engineering faces challenges of its own. A skills shortage in this area exists in countries internationally, including in Australia, and declining numbers of high school graduates progress onto tertiary studies in engineering. A UNESCO report on the subject finds a need for better data and indicators to inform policy makers and professionals more effectively of the challenges faced by this discipline, and monitor progress after the implementation of solutions. Similar to general recommendations elsewhere, the need for the young to engage with and better understand the profession is suggested here to boost student interest in Australia. Furthermore, student-centred, authentic, investigative, problem-based learning practices have been found to be incredibly successful and are recommended strategies where this has yet to be applied.

Understanding finance – no longer reserved for specialists

The financial crisis stirred international concern about the levels of financial literacy among populations of the developed and emerging economies. Public understanding of financial matters has been found to be low, despite the greater need for knowledge and confidence in these matters in contemporary life. Financial knowledge is centrally important to being a modern consumer, making sensible choices about investment, superannuation/pensions and even handling mortgage or other debt. Lifetime financial risk sits more now with individuals than governments, greater affluence has bestowed more possibility on average citizens, while the marketing and consumer generated demand from individuals requires them to be better able to engage in global consumption and maintain their own financial well-being throughout life.
Some international evaluations of financial literacy have been conducted, noting particularly poor levels around the world, including in Australia. Better data will be released later this year once the current round of PISA test data has been analysed.

The design and implementation of a National Financial Literacy Strategy has been recommended by the OECD and INFE to countries around the world. These strategies must be based upon a planning process that includes stakeholder collaboration and mapping of needs. Coordination of the Australian strategy fell to the Australian Securities and Investments Commission (ASIC), who have championed a number of related programmes, including the development of the information and advice laden websites known as Money Smart and Money Smart Teaching. Substantial review or evaluation of this programme is yet to be conducted.

Structuring this review

The review has selectively covered a vast amount of literature from international organisations on STEM education and STEM related issues. The document will begin with a thorough examination of the measurement of STEM through international tests of student achievement, after which several pertinent policy and research areas will be covered, including attracting students to STEM studies, women in STEM fields, engineering and financial education.

Introduction

Education in the fields of science, technology, engineering and mathematics (STEM) is of international interest and has been explored in numerous ways by international agencies. This document reviews the literature produced by international agencies on STEM education and related issues through research and policy work on: attracting students to STEM studies; women in STEM fields; engineering and financial education; as well as, a thorough examination of the measurement of STEM through international tests of student achievement.

International organisations in this review

The work of numerous international organisations is both mentioned and explored in this review. Each is identified and briefly described below to spell out the related acronyms that will be used throughout this review and provide some context to the work they have undertaken in relation to STEM education.

The European Union (EU)

The EU is an economic and political alliance between countries located in Europe. It was established as it is today in 1993, though formal European alliances that have existed since the middle of last century. The member countries include: Austria, Belgium, Bulgaria, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom. The union has enabled trade arrangements, free and unrestricted movement, and international monetary consistency in the region with the Euro. In addition, the union finances and commissions policy directed research, as well as collating data on member countries to assist national policy making and improve the well-being of European citizens.

International Association of the Evaluation of Educational Achievement (IEA)

The IEA is an international cooperative, combining the forces of national research institutions and governmental research agencies. It is independent of national governments and 'conducts large-scale comparative studies of educational achievement and other aspects of education' (IEA, 2012). The focus of this work is on numerous topics relevant to members of the organization, including mathematics, science, reading, civic and citizenship education, computer and information literacy, and teacher education. Since the organisation was founded in 1958, more than 100 countries have participated in IEA research.

International Council for Science (ICSU)

The ICSU is a non-governmental international organisation. Its aims are essentially to work to improve science for the betterment of society through numerous activities that promote science, help establish international connections and address significant contemporary issues. The organization was originally founded in 1931 and has grown to include 120 national scientific bodies and 31 international scientific unions.

Organisation for Economic Cooperation and Development (OECD)

The OECD, established in 1961, provides policy analysis and recommendations to the governments of its member countries. As a result of its centralized organizational structure, it is almost exclusively located in Paris, France where more than 2 500 people are employed in the secretariat. Member nations are significantly involved in the governance process, as well as in the planning and implementation of research programmes. The OECD's mission is to 'promote policies that will improve the economic and social well-being of people around the world' (OECD, 2012). Member countries are the developed economies of Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The organization has key partners in emerging economies Brazil, China, India, Indonesia, the Russian Federation and South Africa.

The United Nations Science, Education and Cultural Organisation (UNESCO)

UNESCO was founded in 1945 and has grown to include 195 members and 8 associate members. In its own words, 'UNESCO works to create the conditions for dialogue among civilizations, cultures and peoples, based upon respect for commonly shared values' (UNESCO, 2012). UNESCO works on matters related to quality education and lifelong learning, emerging social and ethical challenges and building inclusive knowledge societies. The organization has a particular focus on fostering an international community, sustainable development, human rights and mutual respect, peace, the alleviation of poverty and gender equality. Much of its work has been directed at achieving the Millennium Development Goals. Nearly 3 000 staff are employed in the secretariat, with work carried out in the following programme sectors: Education, Natural Sciences, Social and Human Sciences, Culture, and Communication and Information.

The World Bank

Though the name would indicate otherwise, the World Bank is not really a bank at all. Instead it is a partnership between the International Bank for Reconstruction and Development, and the International Development Association. The former has its primary role in middle-income and credit-worthy poorer countries, while the latter works on issues in the poorest countries. In essence, the goal of the World Bank Group is to reduce poverty and support development around the world. In achieving this aim, The World Bank Group is governed by 188 member countries. The World Bank was established in 1944 and has grown to employ 9 000 people in more than 100 offices around the world.

The international STEM literature

Searching for STEM

In preparing this review, keyword searches for the term *STEM* within the work of international organizations were found to be generally fruitless. It was quickly apparent in the research process that the collection of curricular fields in this term, while obviously linguistically specific to Anglophone contexts, is also not commonly used to structure policy work in international settings. Resources for this review were instead identified through a more rigorous search process for each component of STEM individually. That is, separate searches were conducted for research and other programmes that had concentrated on science, technology, engineering and mathematics education within the work of any international organization. The remainder of the review presents the outcomes of this process.

Defining STEM

References cited in this review group the STEM fields in their work in various ways, including, science alone, engineering alone, science and technology, or science engineering and technology. They also describe elements of concern from primary, through to tertiary education, and then employment related issues within research and professional careers. This review has attempted to combine these as best as possible, to draw consistent points relevant to all STEM disciplines, and has been clear about which level is being referred to, where appropriate in the text.

Being selective

The international literature related to STEM fields is vast, and so the review has been necessarily selective in terms of the material included. The presented themes represent those the author found to fit a balance of two criteria: the most pertinent to the Australian context, and the most significant literature within the international arena.

Measuring STEM: International tests of student achievement

International organizations have their most significant role in the measurement of STEM education and the production of relevant indicators. Comparative indicators quantifying social phenomena have been a critical component of the work of international organizations since the 1960s (Rutkowski, 2008). The contemporary prevalence of this type of measurement results from a combination of factors, including policy makers' preference for *concrete* evidence to inform decision making, and the work of international organizations in the promotion of indicators (Rutkowski, 2008; Smith & Baker, 2001). A selection of such indicators will be presented to substantiate arguments later in this review. Rather than covering this twice, the focus will be on the measurement of outcomes, namely, student achievement through international tests.

The most extensive and influential component of measuring STEM education is through outcomes. International organizations conduct extensive assessments of the knowledge, skills and problem solving capacities students have gained from study in related curriculum areas during the compulsory years of schooling and beyond. Accordingly, the following section will be devoted to a description and examination of these international assessments of student performance, and their resultant outcomes.

A large amount of quantitative data is now regularly produced from international tests intended to identify the level of mathematical and scientific literacy of school students, and is a pertinent example of the newfound influential role of comparative indicators as *evidence* in national policy making (Wiseman, 2010; OECD, 2010). These international achievement tests are intended to enrich the evidence produced by national tests – in terms of level and equity of performance – by putting this information into a comparative context (OECD, 2010). Wiseman (2010) additionally proposes that a shift from policy interest in educational attainment to concern with performance levels might contribute to an explanation for the increasing popularity of internationally comparative assessments. Once mass compulsory schooling has become the international norm, high levels of student performance becomes the symbol of national educational legitimacy (Wiseman, 2010).

There are two key international assessments of student performance in STEM-related knowledge and skills, both at the school level: the Trends in International Mathematics and Science Study (TIMSS) programme developed by the IEA, and the PISA programme conducted by the OECD. As the two highest profile studies, TIMSS and PISA are at the core of the debate on both the appropriateness and use of international achievement testing in national policy making (Wiseman, 2010). Both programmes will be described in detail in the following section, before the global outcomes and uses of their results are explored.

Programme for International Student Assessment

PISA is perhaps the most extensive example. The programme is a triennial international comparative assessment of educational outcomes through student performance. Originally administered in 32 countries in 2000 (OECD, 2000), PISA grew rapidly to encompass as many as 74 member and non-member countries and economies by the fourth cycle of the programme conducted throughout 2009 and 2010 (OECD, 2012c). This group of countries represents more than 90% of the world's economy. The programme has now collected data through a fifth cycle of assessments, though this data is yet to be analysed and published. The programme measures students' reading, mathematical and scientific literacy, ostensibly in order to determine if students are prepared 'to meet the challenges they may encounter in future life' (OECD, 2010:9) with the skills 'deemed to be essential' for this purpose (OECD, 2004:14). Like other OECD projects, PISA is governed through an ongoing collaborative process between the secretariat, experts and representatives of all participating countries. The central aim of this programme is to 'provide a new basis for policy dialogue and for collaboration in defining and implementing educational goals, in innovative ways that reflect judgements about the skills that are relevant to adult life' (OECD, 2010:9). Wiseman (2010) argues that this form of participatory collaboration is a particularly effective way to govern an international testing programme due to the legitimacy it provides and the increased likelihood of policy impact.

The purposes of the PISA programme were formulated in economic terms. For example, according to the programme, the assessments measure the 'cumulative yield of education systems' at the point of, or very close to, the end of the compulsory years of schooling (OECD, 2010:11, 2006:9). This view supposes the outcomes of years spent in education are quantifiable, and both apparent and measureable during youth. For another example, the aims of the programme PISA are expressed in terms of providing the quantitative measure of student performance that will not only inform policy making, but contribute to the definition of educational goals (OECD, 2010). The underlying assumptions here are, of course, that the alignment of educational goals and outcomes can in fact be measured.

Between 4 500 and 10 000 students aged 15 years from around 150 schools participate in each round of assessments in each participating country for 2 hours, producing up to 390 minutes of survey items each (OECD, 2010). This main survey includes a background questionnaire that gathers information about students and their home life. In addition, further questionnaires are administered to principals and parents to enable substantiated connections to be made between student, family and institutional factors that are then associated with a students' performance level in the main survey (OECD, 2010).

PISA takes a 'broad approach' to the measurement of the knowledge and skills students have gained from their school-level study of mathematics and science (OECD, 2004:9; OECD, 2010). Due to the international setting, it is near impossible to produce a standardized test directed at curriculum content. Accordingly, the PISA assessments focus on problem solving, and the application of mathematical and scientific knowledge to real-world experiences; understanding, 'evaluating choices and making decisions' (OECD, 2004:9; OECD, 2010). This emphasis on knowledge application allows the survey to also, in part, reveal the ability of students to continue learning throughout life. It is to this notion of *literacy* that the project attempts to adhere. Importantly, the programme documentation insists that this choice of test style is due to the importance of applicable knowledge and skills for successful adult life, as much as it is about the practicalities of cross-system testing (OECD, 2010, 2006, 2004, 2000).

Three broad domains of learning are assessed through PISA surveys: reading literacy, mathematical literacy, and scientific literacy. Reading literacy is defined by PISA as 'an individual's capacity to: understand, use, reflect on and engage with written texts, in order to achieve one's goals, to develop one's knowledge and potential, and to participate in society' (OECD, 2010:14). However, more relevant to this review, are the ways in which this programme defines literacy in science and mathematics. It is to the testing of these learning domains by PISA that this review will now turn.

Learning domains assessed in PISA: Scientific literacy

Scientific literacy was a specific focus of the PISA survey conducted in 2006, when it occupied up to two thirds of the test. Unlike assessments of curriculum content or science knowledge, a test of scientific literacy is more aligned with the needs of all students in general science topics. According to the OECD, this type of literacy, essentially a general understanding of science and technology, is a particularly important outcome of the compulsory years of education (OECD, 2006). The justification for assessing this area centres on the notion that an understanding of science and technology is central to personal, social, professional and cultural aspects of life. Furthermore, the programme attests that the level of knowledge and skills in these areas possessed by an individual can significantly influence their ability to actively engage in modern life, that is, to participate in society and the 'determination of public policy where issues of science and technology impact on their lives' (OECD, 2006:20). Interestingly, while not articulated explicitly, the importance of scientific literacy seems to be well understood by authors of the recent review of Australian science conducted by the Office of the Chief Scientist (2012), particularly in their concern over falling scientific literacy scores of the nation's students in the PISA tests conducted since 2000.

There is ample literature to support the claim that scientific literacy is increasingly important, and it is, in general, consistent with three main lines of argument. Firstly, in contemporary economic and social planning, it is increasingly acknowledged that the higher the level of scientific literacy in the majority of the general population, the greater the economic utility and strength (e.g., Hanushek & Woessmann, 2012; Post *et al*., 2011; OECD, 2010, 2006; Mullis *et al.*, 2009; Rennie *et al.*, 2001; Osbourne *et al.*, 2003). Historically, scientific and technological development has precipitated cultural, political, social and economic strength (OECD, 2010, 2006; Rennie *et al.*, 2001), and in some cases, this has arguably become a level of global dominance and supremacy. Secondly, for an individual living in a contemporary society, robust scientific literacy skills are critical for ongoing well-being and social inclusion (Post *et al*., 2011; Holbrook & Rannikmae, 2009; OECD, 2006; Osbourne *et al.*, 2003). Many problems, issues or situations that individuals encounter in the normal course of their daily lives entail some level of scientific understanding or method. In particular, these issues often relate to public discourse on policy directions, and scientific literacy can improve the ability of citizens to actively participate in informed public debate (Post *et al*., 2011; OECD, 2010; Mullis *et al.*, 2009; Rennie *et al.*, 2001). Thirdly, linear life trajectories through basic education to life long employment in a local industry or service are less common than they once were. Accordingly, education must prepare the young with broad literacies and transferable skills, such as communication skills, adaptability, flexibility, information management, high self-efficacy for ICT, and self reflective skills, so that they might be able to develop an enduring commitment to pursue lifelong learning and improvement (Rennie *et al*., 2001; Hurd, 2000; Gros, 1996). The epistemological and methodological skills associated with scientific literacy are particularly useful here.

Despite all these benefits, it seems scientific literacy remains a problem, with a persistent cultural gap between the scientific community and society as a whole. International theorists have been expressing concern about this for some time. Back in 1996, Gros wrote in the UNESCO Courier about this gap and the consequent importance of scientific literacy to twenty-first century life, making an argument for reforms to educational structures, as well as to both curriculum and pedagogy, within secondary schools and universities. Further, the author made a link between the scientific literacy and lifelong learning, that is, the development of a scientific culture or way of thinking that can be maintained throughout life and applied to future education or training. Gros (1996:19) also expressed the opinion that contemporary students are 'far more receptive to science, technology and discussion about [related] social problems than is generally believed'.

A variety of definitions are proposed for scientific literacy, however, rather than being in conflict, they differ in their level of detail. Rennie *et al.* (2001) define it as the 'extent to which people are able to use science'. The practices of a scientifically literate person include interest in and understanding of the world around them, sceptical and questioning nature about claims made by others about scientific matters, participation in discourses of and about science, ability to identify scientific questions, problem solving, evaluation of risk, investigation and drawing of evidence-based conclusions, and making informed decisions about the environment and their own health and well-being (Rennie *et al.*, 2001; Hurd, 2000). Post *et al.* (2011) define levels of scientific literacy proposed initially by Bybee (1997). The levels extend from recognition of basic terms through functional and procedural understandings of science, and on to a more advanced, broad and multi-dimensional level of literacy. Post *et al.* (2011:203-204) argue that this highest level is the most desirable educational outcome, describing it as an 'understanding of science which extends beyond the concepts [and procedures] of scientific disciplines', enabling 'connections [to be made] within scientific disciplines, and between science, technology, and the larger issues challenging society'.

The definition of scientific literacy adopted by the PISA programme is most similar to the advanced level described by Post *et al.* (2011). Scientific literacy is defined by PISA as 'an individual's scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence-based conclusions about science-related issues, understanding of the characteristic features of science as a form of human knowledge and enquiry, awareness of how science and technology shape our material, intellectual and cultural environments, and willingness to engage in science-related issues, and with the ideas of science, as a reflective citizen' (OECD, 2010:14). Specifically, the assessment questions are intended to determine students' ability to 'identify scientific issues', 'explain phenomena scientifically' and 'use scientific evidence' to form conclusions (OECD, 2006:20). It is these aspects that are thought to be most able to identify students' grasp of the 'knowledge, values and abilities today [that] relate to what is needed in the[ir] future' as citizens (OECD, 2006:20).
In the 2006 test, students were asked questions in the contexts of health, natural resources, the environment, hazards, and frontiers of science and technology, each relevant on personal, social and global levels. These questions were intended to delve into (1) students' ability to interpret scientific phenomena and draw evidence-based conclusions; (2) their understanding of science as an epistemology, or form of human knowledge; (3) their awareness of science as a human endeavour with the potential to shape material, intellectual and cultural environments; and (4) their propensity and willingness to actively engage as reflective citizens with both issues related to science, and ideas developed through scientific endeavour.

Learning domains assessed in PISA: Mathematical literacy

Mathematical literacy is also an assessed learning domain within the PISA programme, and was the major domain in the second cycle of testing in 2003, again revisited in the most recent 2012 survey. Each of these cycles understood mathematical literacy differently, and, despite maintaining enough elements for trend comparisons, they also treated the testing of this learning domain differently. The following definition was provided in 2003: 'Mathematical literacy is an individual's capacity to identify and understand the role that mathematics plays in the world, to make well-founded judgements and to use and engage with mathematics in ways that meet the needs of that individual's life as a constructive, concerned and reflective citizen' (OECD, 2004:24). Furthermore, students were asked questions intended to shed light on their ability to 'reason quantitatively and to represent relationships or dependencies', the kind of capacities deemed to be more 'apt' for the real lives of tested students than the more 'familiar textbook' style questioning (OECD, 2004:12). As in the case of PISA assessments of scientific literacy, the programme's focus in 2003 was on the relevance of mathematical skills in everyday life and the performance of citizenry responsibilities.
The draft assessment framework for the focus on mathematical literacy in the 2012 cycle of PISA testing redefined mathematical literacy to more clearly include the importance of context, more broadly capture the relevance of the tested abilities to real life, and

emphasize more clearly the active nature of the mathematical problem solving required for this test. Furthermore, the expert group consulted found it important to make mention of the 'tools' for engaging with mathematics in order to acknowledge the centrality of technology, in particular to work-related applications of mathematics (OECD, 2010c:7).

> *"Mathematical literacy is an individual's capacity to formulate, employ, and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts, and tools to describe, explain, and predict phenomena. It assists individuals to recognize the role that mathematics plays in the world and to make the well-founded judgements and decisions needed by constructive, engaged and reflective citizens." (OECD, 2010c:4)*

As in the case of scientific literacy, mathematical abilities are considered by this programme to be essential for the young to deal with the rising 'proportion of problems and situations encountered in daily life, including in professional contexts, [that] require some level of understanding of mathematics, mathematical reasoning and mathematical tools' (OECD, 2010c).

While mathematics curricular in schools around the world are usually oriented around content strands, such as geometry or algebra, the mathematics component of the 2012 PISA assessments ask questions which break these boundaries, extending questions beyond classrooms to hypothetical life situations that often may be correctly solved through the use of several alternative mathematical 'concepts, procedures, facts, or tools' (OECD, 2010c:8). Students not only were required to solve posed questions, but were often challenged to notice when mathematical skills would be useful in a given problem or situation. Furthermore, test problems required students to communicate mathematically, mathematize (that is, identify underlying variables or structures in real world situations), represent real world information mathematically, and to be able to explain and defend these answers by providing mathematically-based reasoning and argument. The programme notes that student motivation to learn mathematics can be fuelled by learning that wholly captures its relevance to the real world, and that motivation in learning is often key to student achievement (OECD, 2010c).

The 2012 assessment was planned around four content categories: change and relationships, space and shape, quantity, and uncertainty and data. However, within these categories, many more topics were covered, including but not limited to, functions, coordinate systems, measurement, estimation, samples and sampling, as well as chance and probability (OECD, 2010c). While this applied approach may be unfamiliar in mathematics classrooms internationally, this format of questioning is not completely foreign to Australian education. The PISA test questions in many ways resemble the more advanced and applied questions provided at the end of chapters of textbooks utilized in Australia, and are the essence of directed investigations, the pedagogical tools that have become increasingly popular among Australian secondary mathematics teachers in recent years.

Financial education in PISA

Another, perhaps internationally timely, component of the mathematics focus during the 2012 PISA assessment was a series of elements intended to highlight students' level of financial literacy. In the wake of the financial crisis, developed and emerging economies alike have growing concerns about financial literacy levels, which are 'now globally acknowledged as an important element of economic and financial stability and development' (OECD, 2010d:7; INFE, 2009). The INFE further argues that the crisis revealed the fact that much of the global 'population is ill-equipped to participate in the global economy because they lack basic financial skills' (INFE, 2009:7).

Given that higher levels of financial literacy have been empirically linked to improved financial well-being through life, PISA is assessing these skills in the current cycle of tests. The drafted assessment framework has adopted a working definition that covers the thinking and behavioural patterns of the financially literate, as well as the purposes for developing these skills. Financial literacy is defined as the ‘knowledge and understanding of financial concepts and risks, and the skills, motivation and confidence to apply such knowledge and understanding in order to make effective decisions across a range of financial contexts, to improve the financial well-being of individuals and society, and to enable participation in economic life’ (OECD, 2010d:13). The planned test will cover everything financial from recognition of money, to use of banking services, to the processes of borrowing and lending money. These content areas will be assessed in the context of education and work, home and family, individual and societal (OECD, 2010d). While it is acknowledged that this test will draw on students’ numeracy or mathematical literacy skills including ‘basic arithmetic’, tools for mathematical calculations are provided for this part of the test to reduce the extent to which this impacts the results (OECD, 2010d:35).

The results

The most recent data available are from the 2009 cycle of PISA testing. Overall, Australia still performs comparatively well among the countries studied, ranked 10th in science significantly lower than only 6 countries, and 15th in mathematics significantly lower than only 12 countries out of 65 participating countries worldwide (OECD, 2010f; Thomson *et al.*, 2010). However, it should be noted that Australia’s results have declined slightly in both mathematics and science areas since the first round of testing in the year 2000. The following four figures show the scientific and mathematical literacy scores achieved in all participating countries in 2009. After these, Figures 5 and 6 illustrate the gender differences between proficiency scores. There is no difference between male and female students noted in science performance. However, in mathematics, boys slightly outperformed girls on average.

Figure 1: This figure illustrates international mathematical proficiency, as determined in the PISA 2009 tests (figure sourced directly from OECD, 2010f).

StatLink http://dx.doi.org/10.1787/888932343152

Figure 2: This figure illustrates international proficiency in science, as determined in the PISA 2009 tests (figure sourced directly from OECD, 2010f).

Level 4 Level 5 Level 6

StatLink http://dx.doi.org/10.1787/888932343152

Figure 3: This figure illustrates international mathematical proficiency, as determined in the PISA 2009 tests (figure sourced directly from Thomson et al., 2010).

Country/Economy		Mean score	S.E.	Confidence interval	Difference between 5th and 95th percentile
Shanghai – China	Significantly higher than Australia	600	2.8	595 - 606	336
Singapore		562	1.4	559 - 565	342
Hong Kong – China		555	2.7	549 - 560	313
Korea		546	4.0	538 - 554	292
Chinese Taipei		543	3.4	537 - 550	342
Finland		541	2.2	536 - 545	270
Liechtenstein		536	4.1	528 - 544	286
Switzerland		534	3.3	527 - 540	326
Japan		529	3.3	522 - 536	308
Canada		527	1.6	524 - 530	286
Netherlands		526	4.7	517 - 535	287
Macao – China		525	0.9	523 - 527	281
New Zealand	Not significantly different from Australia	519	2.3	515 - 524	316
Belgium		515	2.3	511 - 520	340
Australia		**514**	**2.5**	**509 - 519**	**308**
Germany		513	2.9	507 - 518	319
Estonia		512	2.6	508 - 517	265
Iceland	Significantly lower than Australia	507	1.4	504 - 509	300
Denmark		503	2.6	498 - 508	286
Slovenia		501	1.2	499 - 504	314
Norway		498	2.4	493 - 503	283
France		497	3.1	491 - 503	331
Slovak Republic		497	3.1	491 - 503	311
Austria		496	2.7	491 - 501	312
OECD average		**496**	**0.5**	**495 - 497**	**300**
Poland		495	2.8	489 - 500	290
Sweden		494	2.9	489 - 500	304
Czech Republic		493	2.8	487 - 498	308
United Kingdom		492	2.4	488 - 497	287
Hungary		490	3.5	483 - 497	303
Luxembourg		489	1.2	487 - 491	319
United States		487	3.6	480 -494	300
Ireland		487	2.5	482 - 492	280
Portugal		487	2.9	481 - 493	301
Spain		483	2.1	479 - 488	298
Italy		483	1.9	479 - 487	302
Latvia		482	3.1	476 - 488	259
Lithuania		477	2.6	471 - 482	290
Russian Federation		468	3.3	461 - 474	280
Greece		466	3.9	458 - 474	294
Croatia		460	3.1	454 - 466	292
Dubai (UAE)		453	1.1	450 - 455	325
Israel		447	3.3	440 - 453	343
Turkey		445	4.4	437 - 454	310
Serbia		442	2.9	437 - 448	298
Azerbaijan		431	2.8	426 - 436	207
Bulgaria		428	5.9	417 - 440	324
Romania		427	3.4	420 - 434	260
Uruguay		427	2.6	422 - 432	300
Chile		421	3.1	415 - 427	266
Thailand		419	3.2	412 - 425	259
Mexico		419	1.8	415 - 422	259

Figure 4: This figure illustrates international scientific proficiency, as determined in the PISA 2009 tests (figure sourced directly from Thomson et al., 2010).

Country/Economy		Mean score	S.E.	Confidence interval	Difference between 5th and 95th percentile
Shanghai – China		575	2.3	570 - 579	270
Finland		554	2.3	550 - 559	294
Hong Kong – China	Significantly higher than Australia	549	2.8	544 - 554	287
Singapore		542	1.4	539 - 544	342
Japan		539	3.4	533 - 546	325
Korea		538	3.4	531 - 545	266
New Zealand		532	2.6	527 - 537	349
Canada		529	1.6	526 - 532	292
Estonia	Not significantly different from Australia	528	2.7	523 - 533	277
Australia		**527**	**2.5**	**522 - 532**	**333**
Netherlands		522	5.4	512 - 533	311
Chinese Taipei		520	2.6	515 - 526	284
Germany		520	2.8	515 - 526	330
Liechtenstein		520	3.4	513 - 527	286
Switzerland		517	2.8	511 - 522	314
United Kingdom		514	2.5	509 - 519	324
Slovenia		512	1.1	510 - 514	306
Macao – China	Significantly lower than Australia	511	1.0	509 - 513	251
Poland		508	2.4	503 - 513	286
Ireland		508	3.3	502 - 514	315
Belgium		507	2.5	502 - 512	340
Hungary		503	3.1	496 - 509	288
United States		502	3.6	495 - 509	321
OECD average		**501**	**0.5**	**500 - 502**	**308**
Czech Republic		500	3.0	495 - 506	318
Norway		500	2.6	495 - 505	298
Denmark		499	2.5	494 - 504	302
France		498	3.6	491 - 505	339
Iceland		496	1.4	493 - 498	317
Sweden		495	2.7	490 - 500	327
Austria		494	3.2	488 - 501	332
Latvia		494	3.1	488 - 500	254
Portugal		493	2.9	487 - 499	273
Lithuania		491	2.9	486 - 497	280
Slovak Republic		490	3.0	484 - 496	308
Italy		489	1.8	485 - 492	314
Spain		488	2.1	484 - 492	286
Croatia		486	2.8	481 - 492	276
Luxembourg		484	1.2	482 - 486	342
Russian Federation		478	3.3	472 - 485	297
Greece		470	4.0	462 - 478	298
Dubai (UAE)		466	1.2	464 - 469	344
Israel		455	3.1	449 - 461	348
Turkey		454	3.6	447 - 461	265
Chile		447	2.9	442 - 453	268
Serbia		443	2.4	438 - 447	277
Bulgaria		439	5.9	428 - 451	344
Romania		428	3.4	422 - 435	257
Uruguay		427	2.6	422 - 432	316
Thailand		425	3.0	419 - 431	262
Mexico		416	1.8	412 - 419	254

Figure 5: This figure illustrates international gender differences in performance of students in mathematics, as determined in the PISA 2009 tests (figure sourced directly from OECD, 2010f).

Girls
perform
better

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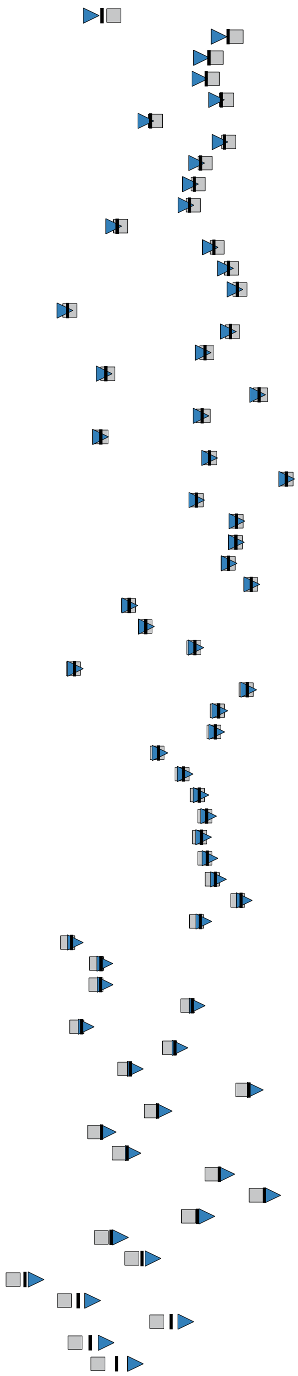
Figure 6: This figure illustrates international gender differences in performance of students in science, as determined in the PISA 2009 tests (figure sourced directly from OECD, 2010f).



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Change in PISA performance

Now that multiple tests have been conducted as part of the PISA programme, the performance of Australian students can be compared over time. The change in performance of students in PISA in mathematical literacy can be compared between 2003 and 2009. During this period, the average scores attained by Australian students decreased 10 points (OECD, 2010g; Thomson *et al.*, 2010) (see Figure 7). More Australian students performed below level 2 of 5 proficiency levels in 2009 compared to 2003, while there were significantly less top performers. Decreases in average scores similarly occurred in Iceland (8 points), and in Ireland, Sweden, France, Belgium, the Netherlands and Denmark by between 11 and 16 score points (see Figure 8). The most significant decrease can be observed in mathematical performance by students of the Czech Republic (OECD, 2010g) (see Figure 8).

During the same period, some countries increase student performance in mathematical components of the PISA tests. For example, Mexican student scores climbed 33 points, Brazilian students improved by 30 points, while students in Turkey, Greece and Portugal gained more than 20 score points, and students in Italy and Germany gained 17 and 10 score points, respectively (OECD, 2010g) (see Figure 8).

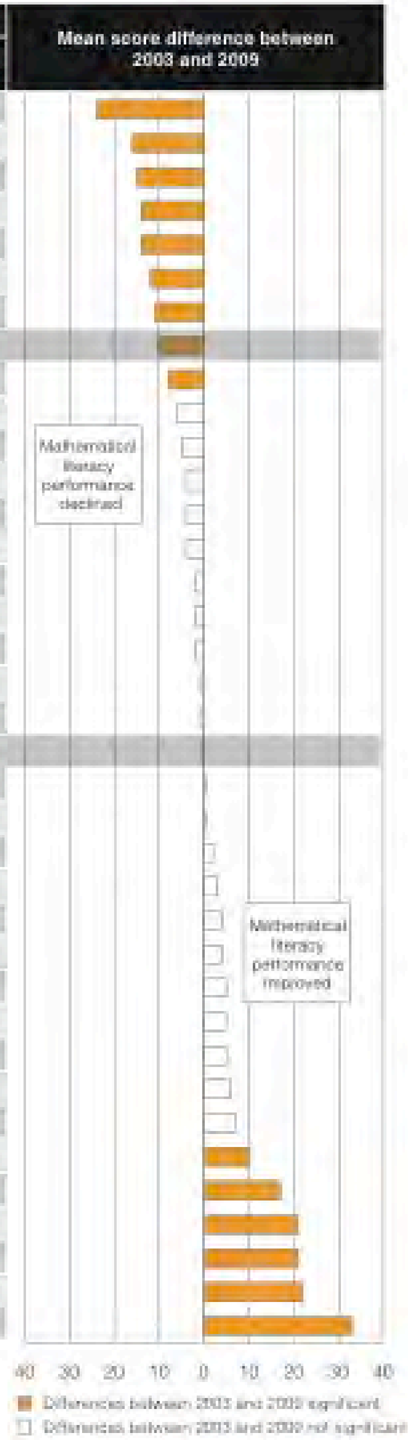
Figure 7: This figure illustrates international mathematical proficiency, compared between PISA tests in 2003 and 2009 (figure sourced directly from OECD, 2010g).

3 37 46 47 48 74 97 97 98 92 78 76 67 58 28 10 27 36 7 0 1 1 5 0 0 0 0 0

Figure 8: This figure illustrates international mathematical proficiency, compared between PISA tests in 2003 and 2009 (figure sourced directly from Thomson et al., 2010).

Table 5.15 Mean mathematical literacy scores for PISA 2003, PISA 2006 and PISA 2009, and differences in performance between cycles by country

Country	PISA 2003		PISA 2006		PISA 2009	
	Mean score	S.E.	Mean score	S.E.	Mean score	S.E.
Czech Republic	516	3.5	510	3.6	493	2.8
Ireland	503	2.4	501	2.8	487	2.5
Sweden	509	2.6	502	2.4	494	2.9
France	511	2.5	496	3.2	497	3.1
Belgium	529	2.3	520	3.0	515	2.3
Netherlands	538	3.1	531	2.6	526	4.7
Denmark	514	2.7	513	2.6	503	2.6
Australia	524	2.1	520	2.2	514	2.5
Iceland	515	1.4	506	1.8	507	1.4
Canada	532	1.8	527	2.0	527	1.6
Japan	534	4.0	523	3.3	529	3.3
New Zealand	523	2.3	522	2.4	519	2.3
Luxembourg	493	1.0	490	1.1	489	1.2
Finland	544	1.9	548	2.3	541	2.2
Macao – China	527	2.9	525	1.3	525	0.9
Spain	485	2.4	480	2.3	483	2.1
Slovak Republic	498	3.3	492	2.8	497	3.1
Latvia	483	3.7	486	3.0	482	3.1
Russian Federation	468	4.2	476	3.9	468	3.3
OECD average-28	500	0.6	497	0.6	499	0.6
Hungary	490	2.8	491	2.9	490	3.5
Liechtenstein	536	4.1	525	4.2	536	4.1
Thailand	417	3.0	417	2.3	419	3.2
Norway	495	2.4	490	2.6	498	2.4
Korea	542	3.2	547	3.8	546	4.0
Hong Kong – China	550	4.5	547	2.7	555	2.7
United States	483	2.9	474	4.0	487	3.6
Uruguay	422	3.3	427	2.6	427	2.6
Poland	490	2.5	495	2.4	495	2.8
Serbia	437	3.8	435	3.5	442	2.9
Switzerland	527	3.4	530	3.2	534	3.3
Germany	503	3.3	504	3.9	513	2.9
Italy	466	3.1	462	2.3	483	1.9
Portugal	466	3.4	466	3.1	487	2.9
Greece	445	3.9	459	3.0	466	3.9
Turkey	423	6.7	424	4.9	445	4.4
Mexico	385	3.6	406	2.9	419	1.8



At this stage, PISA performance in scientific literacy can only be compared between 2006 and 2009. This short time span is, of course, unlikely to be a helpful comparison. Accordingly, Australian students exhibit no significant change in their performance levels, nor in the distribution of proficiency levels in their results (OECD, 2010g; Thomson *et al.*, 2010) (see Figure 9). Some countries did manage to achieve positive change. Turkish students increased their performance on average by as many as 30 score points, or nearly half a proficiency level OECD, 2010g) (see Figures 9 and 10). Portugal, Korea, Italy, Norway, the United States and Poland each achieved increases of between 10 and 19 score points. Scientific literacy was recorded lower in 2009 than in 2006 in five of the tested countries. For example, the performance of students in the Czech Republic decreased on average by 12 points, while in Finland and Slovenia they fell by 9 and 7 points, respectively (OECD, 2010g) (see Figures 9 and 10).

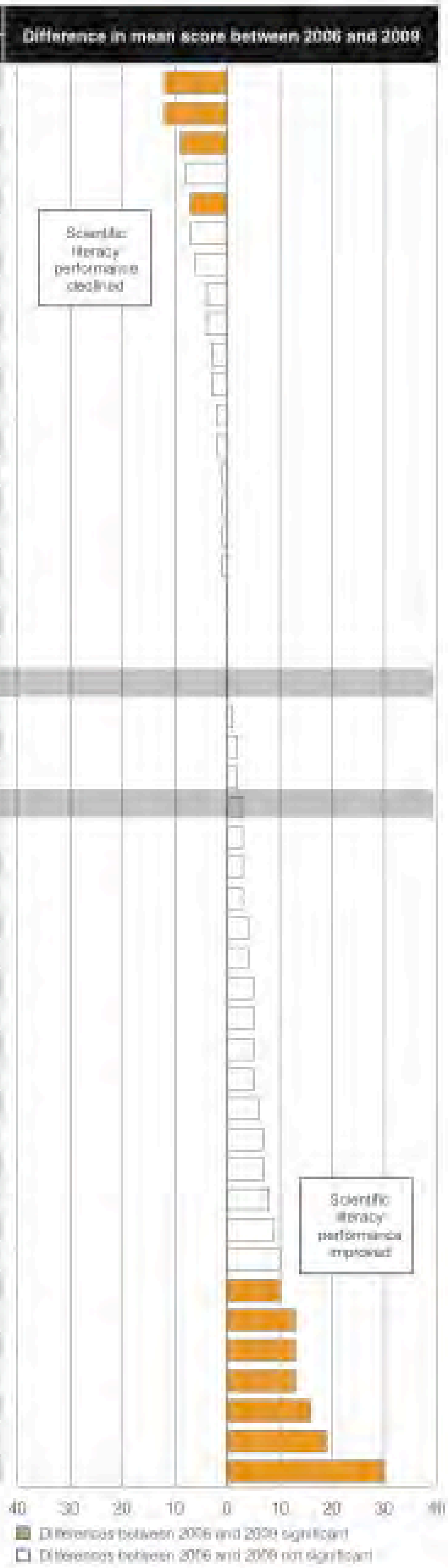
Figure 9: This figure illustrates international scientific proficiency, compared between PISA tests in 2006 and 2009 (figure sourced directly from OECD, 2010g).

Republic 2

Figure 10: This figure illustrates international scientific proficiency, compared between PISA tests in 2006 and 2009 (figure sourced directly from Thomson et al., 2010).

Table 6.15 Mean scientific literacy scores for PISA 2006 and PISA 2009, and differences between performance in cycles by country

Country	PISA 2006		PISA 2009	
	Mean score	S.E.	Mean score	S.E.
Czech Republic	513	3.5	500	3.0
Chinese Taipei	532	3.6	520	2.6
Finland	563	2.0	554	2.3
Sweden	503	2.4	495	2.7
Slovenia	519	1.1	512	1.1
Croatia	493	2.4	486	2.8
Canada	534	2.0	529	1.6
Belgium	510	2.5	507	2.5
Estonia	531	2.5	528	2.7
Greece	473	3.2	470	4.0
Netherlands	525	2.7	522	5.4
Luxembourg	486	1.1	484	1.2
Liechtenstein	522	4.1	520	3.4
Hungary	504	2.7	503	3.1
Russian Federation	479	3.7	478	3.3
United Kingdom	515	2.3	514	2.5
Uruguay	428	2.7	427	2.6
Ireland	508	3.2	508	3.3
Spain	488	2.6	488	2.1
Macao – China	511	1.1	511	1.0
Australia	527	2.3	527	2.5
Israel	454	3.7	455	3.1
New Zealand	530	2.7	532	2.6
Slovak Republic	488	2.6	490	3.0
OECD average-33	498	0.5	501	0.5
France	495	3.4	498	3.6
Denmark	496	3.1	499	2.5
Lithuania	488	2.8	491	2.9
Thailand	421	2.1	425	3.0
Latvia	490	3.0	494	3.1
Germany	516	3.8	520	2.8
Iceland	491	1.6	496	1.4
Switzerland	512	3.2	517	2.8
Bulgaria	434	6.1	439	5.9
Mexico	410	2.7	416	1.8
Hong Kong – China	542	2.5	549	2.8
Serbia	436	3.0	443	2.4
Japan	531	3.4	539	3.4
Chile	438	4.3	447	2.9
Romania	418	4.2	428	3.4
Poland	498	2.3	508	2.4
United States	489	4.2	502	3.6
Norway	487	3.1	500	2.6
Italy	475	2.0	489	1.8
Korea	522	3.4	538	3.4
Portugal	474	3.0	493	2.9
Turkey	424	3.8	454	3.8



Trends in International Mathematics and Science Study

Despite the ascendancy of PISA in recent years, there are other major international tests measuring the knowledge and problem solving skills of school students in the areas of science and mathematics. The International Association for the Evaluation of Educational Achievement (IEA) has been conducting international tests of student achievement for many years, cementing for itself an instrumental role in the development of education policy internationally (Mullis *et al.*, 2012). Twelve countries participated in the IEA's First International Mathematics Study conducted between 1963 and 1967 (Drent *et al*., 2012). Their more contemporary, institutionalized programme, known as Trends in International Mathematics and Science Study (TIMSS), has grown to encompass 69 educational systems from 63 countries since it began in 1995 (Mullis *et al.*, 2012; Drent *et al*., 2012; Mullis *et al.*, 2009). TIMSS is now the largest, most extensive and longest running international tests of science and mathematics learning.

Like PISA… but, distinctly TIMSS

The TIMSS assessments are similar to PISA in many ways, but exhibit some key differences. In regards to content, the TIMSS programme is a more curriculum-oriented test of mathematics and science learning, rather than the *literacy*-oriented focus of the PISA programme on general knowledge and skills for life and work (Mullis *et al.*, 2009). The TIMSS assessments are for students at fourth and eighth grade (four and eight years, respectively, beyond ISCED level 1 across countries), both younger than the 15-year-old students tested through the OECD's PISA programme (Mullis *et al.*, 2012; Mullis *et al.*, 2009). In addition, while the current iteration of TIMSS is, like PISA, in the midst of its fifth cycle, the tests have been conducted every four years and so span a slightly longer period of time (Mullis *et al.*, 2012; Drent *et al*., 2012; Mullis *et al.*, 2009). Furthermore, the education systems engaged in the cycles of TIMSS assessments are economically, as well as geographically diverse, meaning that there is great variation amongst participants in measures of health and well-being, such as life expectancy and infant mortality, and often significant disparity in the funds available for education between their countries (Mullis *et al.*, 2009).

Perhaps the largest distinction between the two assessment programmes is between their aims. Rather than intending to inform national policy making with comparative evidence of educational yield (OECD, 2010), the IEA's TIMSS programme is directed more towards 'help[ing] countries improve teaching and learning in mathematics and science' (Mullis *et al.*, 2012:3). The IEA's 'mission is to provide high quality information on student achievement outcomes and on the educational contexts in which students achieve' (Mullis et al., 2009:1-2). TIMSS expressly intends to 'provide valuable information that helps countries monitor and evaluate their mathematics and science teaching across time and across grades' (Mullis et al., 2009:14). This is distinctly in contrast with the OECD's purpose in the PISA programme.

There are, of course, key similarities between these two well-known testing programmes. Like PISA, the TIMSS programme is governed through a similar collaborative approach that includes iterative consultation and systemic review among country representatives and experts (Mullis et al., 2009). Key elements of the design of the TIMSS survey are dictated by the need to maintain consistency with previous tests. However, both programmes engage in continual review processes that are conducted by representatives of participating systems, experts and other interested parties. Methodologically, the TIMSS assessments sample similar numbers of students in each system. Around 4 000 students from 150-200 schools participate in TIMSS from each country or system.

Participating countries and systems receive a comprehensive set of internationally comparable data on the ways in which mathematics is taught, the curricular content and student outcomes in fourth and eighth grades. This data reveals for them not only the performance levels of their students over time, but enables countries to identify ways in which students learn best elsewhere, allowing them to engage in national or system level policy review and productive reforms on the basis of evidence (Mullis et al., 2009).

Reasons to assess student learning outcomes in science and mathematics

The need for international assessment of science and mathematics knowledge and skills is justified by the IEA TIMSS programme on the basis that the study of these topics, particularly during the primary years (1) 'prepares children to succeed in future educational endeavors and eventually in daily life and the workforce'; and (2) allows students to fully engage in their society, to 'make informed decisions about personal health and finance, as well as about public policy concerning such issues as the environment and economy' (Mullis *et al.*, 2009:7). Again, like PISA, the TIMSS tests emphasize the central importance of the knowledge and skills tested to the future lives of the students (Mullis *et al.*, 2012, 2009). For example, in their description of the mathematics component on the assessment framework for the latest cycle of TIMSS assessments, Mullis *et al.* (2009:19) note the 'increasing awareness that effectiveness as a citizen and success in a workplace are greatly enhanced by knowing and, more important, being able to use mathematics'. They claim that 'the number of vocations that demand a high level of proficiency in the use of mathematics, or mathematical modes of thinking, has burgeoned with the advance of technology, and with modern management methods' (Mullis *et al.*, 2009:19). Finally, they recognize the importance of students appreciating mathematics 'as an immense achievement of humanity' (Mullis *et al.*, 2009:19). In justification of the science component, scientific literacy is described as 'imperative if citizens are to make informed decisions about themselves and the world in which they live' (Mullis *et al.*, 2009:49). Further, this IEA programme argues that the scientific modes of thinking generated through science study assist individuals to deal effectively and productively with the 'barrage of information' they now meet in daily life (Mullis *et al.*, 2009:49).

Learning domains assessed in TIMSS: Mathematics

The fourth grade students' mathematics component of the test quizzes students on three content areas:

- Number: This includes comparison and computation (or basic arithmetic), and number sentences, as well as units of measurement, fractions and decimals, and patterns and relationships.
- Geometric Shapes and Measures: This includes points, lines (for example, length) and angles, as well as two and three dimensional shapes (for example, perimeter, area and volume).
- Data Display: This includes reading and interpreting presented data, as well as choosing how to represent or display information in tables and graphs.

The eighth grade students' mathematics component of the test assesses these students on four content areas (which differ in complexity where they overlap):

- Number: This includes whole number, fractions and decimals, integers, as well as ratio proportion and percentage.
- Algebra: This includes patterns, algebraic expressions and equations, formulas and functions, as basic level algebra is studied in most countries by the time students reach the eighth grade. These can be examined in questions that require students to 'solve real world problems using algebraic models' (Mullis *et al.*, 2009:32).

- Geometry: This includes geometric shapes (for example, angles and theories like Pythagoras' theorem), measurement, and location and movement (for example, locating points on a Cartesian plane and translating, reflecting or rotating two dimensional shapes).
- Data and Chance: This includes data organization and representation (including spread and tendency), data interpretation (including predictions and evaluation of given interpretations), and chance (including probability and determining the likelihood of a given outcome).

The questions directed at both fourth and eighth grade students are designed to examine each of the following cognitive domains:

- Knowing: This includes simple 'familiarity with mathematical concepts' (Mullis *et al.*, 2009:41), recall, basic computation or measurement.
- Applying: This includes the straight forward application of knowledge to often familiar contexts though *routine* problems. While these are set in real world situations, more often they resemble the more abstract, 'textbook style' mathematical questions.
- Reasoning: This includes questions that allow students to exhibit their 'capacity for logical, systematic thinking' (Mullis *et al*., 2009:45). Often the test elements draw on inductive reasoning that can reach solutions for non-routine problems, requiring students to undertake analysis and synthesis.

Given the international diversity in the use of technological tools to support learning, there are no test elements within TIMSS requiring calculator or computer use. Calculators have been permitted for the tests within some countries since 2003 simply to avoid depriving students of a familiar tool (Mullis *et al.*, 2009). Comparison of the results between these and past tests identifies little impact on achievement (Mullis *et al.*, 2009).

Learning domains assessed in TIMSS: Science

The fourth grade students' science component of the test quizzes students on three content areas (in order of the proportional representation in the test):

- Life Sciences: This includes the characteristics and life processes of living things, life cycles (for example, comparisons between different types of living things), reproduction, and heredity, interaction with the environment (for example, basic behavioural patterns), ecosystems (such as, an understanding of the interdependence of things and the importance of biotic and abiotic factors), and human health (including a rudimentary knowledge of nutrition and disease).
- Physical Sciences: Though not complex at fourth grade, this includes the classification and properties of matter (for example, solid, liquid, gas), sources and effects of energy (such as, 'heat, temperature, light, electricity and magnetism' (Mullis et al., 2009:57)), and forces and motion (such as, gravity and the balancing of forces on an object).
- Earth Science: This includes earth's structure, physical characteristics, and resources (for example, commonly known geographical features like mountains, lakes, ocean, and deserts, and knowledge of both uses and the conservation of our planet's resources), earth's processes, cycles, and history, and earth in the solar system.

The eighth grade students' science component of the test assesses these students on four content areas (which differ in complexity where they overlap):

- Biology: This includes characteristics, classification (for example, taxonomy of species), life processes of organisms, cells and their functions, life cycles, reproduction, and heredity, diversity, adaptation, and natural selection, ecosystems (including the interdependence of organisms), and human health (such as, knowledge of nutrition and its role in the body, and causes of disease, infection and disease spread.
- Physics: This includes the physical states and changes in matter (that is, changes in state, movement of particles), energy transformations, heat, and temperature, light and sound (including interaction of light with matter), electricity and magnetism (for example, a basic understanding of circuits and the basic uses of the main types of magnet), and forces and motion (for example, simple forces and the workings of machines).
- Chemistry: This includes classification and composition of matter (including the ability to classify substances according to their physical properties), properties of matter (such as, separation of substances, dissolving, and acids and bases), and chemical change (as distinct from physical change).
- Earth sciences: This includes earth’s structure and physical features (for example, the crust, mantle and core, as well as key processes like volcanoes and earthquakes), earth’s processes, cycles, and history (including the water cycle, geological events, and climatic variation across geographical locations), earth’s resources, their use and conservation (for example, the sustainability of resources, and environmental challenges like pollution, climate change, deforestation, and desertification, as well as knowledge of common agricultural methods and modes of obtaining fresh water such as desalination), and earth in the solar system and the universe. Earth sciences is tested despite not being taught as a separate subject in all participating countries and systems.

Mullis *et al.* (2009) explain that the TIMSS assessments recognize science as a methodology, that is, a way to understand the world, and not simply a curriculum or academic area of study. Accordingly, the test emphasizes the process of scientific inquiry and attempts to test this through the cognitive domains knowing, applying and reasoning.

Supplementary to the test: Background and curriculum questionnaires

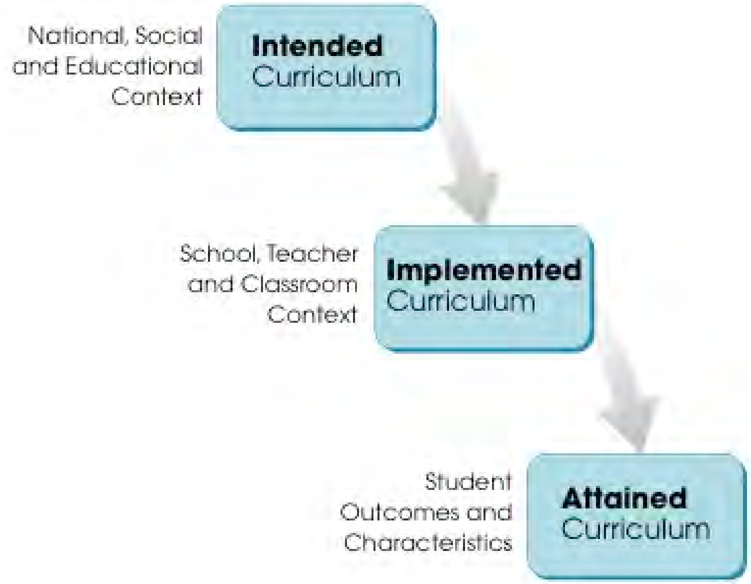
In recognition of the ‘numerous contextual factors that affect students’ learning’ (Mullis *et al.*, 2009:93), TIMSS conducts additional questionnaires with students, teachers and principals. This information is used to enrich the analysis of test data, similarly to the PISA programme but with more of a focus on pedagogy and curriculum. The questionnaires gather data on:

- National and community contexts: This includes demographics and resources, organization and structure of the education system, and mathematics and science curricula.
- School contexts: This includes information about the school itself, including size, location, and characteristics of the student body, organization of instruction, learning climate, teaching staff, resources, and parental involvement.
- Classroom contexts: This includes teacher education and development, teacher characteristics (such as, attitude, motivation, and self-efficacy), instructional materials and technology, the taught curriculum, pedagogy and assessment.
- Student characteristics and attitudes: This includes demographic information and details related to the students’ home background, as well as their attitudes towards learning mathematics and science.

While it is well known that the demographic and socio-economic profile of students influences their achievement, their motivation and enjoyment of the topics is an even greater influence, ‘important [for learning] in the present and for future careers’ (Mullis *et al.*, 2009: 116). Drent *et al*. (2012:2) also explain that ‘the information from the TIMSS supplementary questionnaires provides an invaluable and deep insight into the diversity of the characteristics of education systems all over the world’.

A particularly interesting and pertinent supplementary element of TIMSS is their Curriculum Questionnaire, which seeks information on local science curricula, school organizational approaches, and instructional practices. Essentially, its role is to enable the results of the test to be contextualized in terms of the student’s ‘opportunity to learn’, such that the achievement data can be used productively (Mullis *et al.*, 2009:11). The Curriculum Questionnaire is administered to teachers, and is meant to explore their own ‘reports about their preparation, experience, and attitudes; the mathematics and science content actually taught to the students assessed for TIMSS; the instructional approaches used in teaching mathematics and science; and the resources available in classrooms and schools to support mathematics and science teaching and learning’ (Mullis *et al.*, 2009:11). Through the TIMSS programme, the IEA has developed a Curriculum Model to illustrate the project’s understanding of the interrelationships between the different levels of actors within education. This model is illustrated in Figure 11 and informs the analysis of the supplementary background and curriculum questionnaires administered to students, teachers and parents.

Figure 11: The TIMSS Curriculum Model, highlighting the perspectives of multiple actors within education (figure sourced from Mullis et al., 2009:10).



The results

Due to their alignment with curricula areas, the results of TIMSS are particularly rich. The summary data is presented here to illustrate Australia’s overall performance. Four graphs are shown, revealing that in 4th grade, Australia ranks 19th in mathematics and 24th in science, though remains above the average in both curriculum areas (see Figures 12 and 13). In 8th grade, Australia ranks 12th in both science and mathematics, but only achieves a combined score above the international average in science (see Figures 14 and 15).

Figure 12: International distribution of mathematics achievement at 4th grade in TIMSS 2011 international tests (sourced directly from Mullis et al., 2012a).

.1: Distribution of Mathematics Achievement

TIMSS 2011 Mathematics 4th Grade

Figure 13: International distribution of science achievement at 4th grade in TIMSS 2011 international tests (sourced directly from Mullis et al., 2012b).

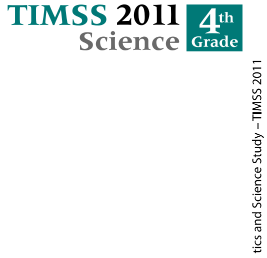


Figure 14: International distribution of mathematics achievement at 8th grade in TIMSS 2011 international tests (sourced directly from Mullis et al., 2012a).

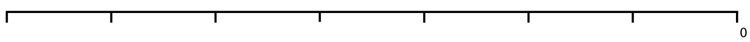


Figure 15: International distribution of science achievement at 8th grade in TIMSS 2011 international tests (sourced directly from Mullis et al., 2012b).

Measuring learning in tertiary level engineering: AHELO

Since the success of the organization's PISA programme, the OECD has explored the possibility of establishing other broad scale surveys of educational outcomes and skill levels. Planning for the Assessment for Higher Education Learning Outcomes (AHELO) programme began in 2008. The programme's feasibility study is still in progress and formal testing is yet to commence. The preliminary conceptual documents state the project's intention to 'assess learning outcomes' of tertiary students, providing an international standard of achievement and a base from which to ascertain the quality of tertiary offerings (OECD, 2011:7). There are two key elements to the motivation and justification for this programme. Firstly and simply, there are no existing international assessments of tertiary outcomes (OECD, 2010-2011). Secondly, and the more complex element of their reasoning, relates to the significant pressures currently experienced by the tertiary sector, as a result of contextual change (OECD, 2011). The programme document cites the following *contextual pressures*: Universities must play an increasing role in the development and maintenance of knowledge-intensive economies, they must foster diversity created by student mobility, and shift teaching from 'knowledge-oriented' to

‘learner-oriented’ styles, all while dealing with complex management and organizational reforms (OECD, 2011:11). Within this context, the programme argues that learner outcomes are ‘becoming increasingly important or of serious interest to those involved in higher education’ (OECD, 2011:11). AHELO concludes from this that an international achievement test would be an ideal way to monitor outcomes within this context, particularly making it easier to transition towards *learner-oriented* teaching.
The diverse nature of learning among tertiary students according to their programme, institution and national culture has relegated the program to first tackle: (1) ‘generic skills or transferable competencies’; (2) economics students; and (3) engineering students (OECD, 2011; Ewell, 2012). Seventeen countries are currently involved in the development phase of the project, including Australia, which participated in the testing for the engineering strand of the feasibility study conducted early in 2012 (Ewell, 2012; OECD, 2010-2011). The programme explains that engineering is the ‘interface between scientific and mathematics knowledge and human society’ (OECD, 2011:13). The field is further defined as ‘the profession that deals with the application of technical, scientific and mathematical knowledge in order to use natural laws and physical resources to help design and implement materials, structures, machines, devices, systems, and processes that safely accomplish a desired objective’ OECD, 2011:13).

Several challenges are acknowledged. The non-standard nature of engineering programmes internationally is particularly challenging. However, international agreements, such as the Bologna Process, have made it easier to engage in comparisons. The extent to which a test like this may influence the design and running of tertiary programmes is also acknowledged in the preliminary conceptual framework, and caution is expressed in relation to maintaining academic independence and authority in course design (OECD, 2011). The AHELO feasibility study encountered numerous practical issues including translation of tests, creation of internationally meaningful questions, and students’ interest and motivation to participate in the assessment (Ewell, 2012). Unlike school age testing, it is more difficult to mandate participation. Cultural differences in motivation to participate have also proved to be a key hurdle (Ewell, 2012).

International achievement tests: Outcomes, impact and critics

Growing participation in international testing of student achievement in mathematics and science has contributed to them becoming not only a ‘hallmark of educational accountability and planning in many countries’, but also ‘taken-for-granted components of the landscape of national education policy making’ (Wiseman, 2010:xiii-xiv). However, joining a testing programme is ‘quite an enterprise in terms of effort, time and costs’ (Drent *et al*., 2012:2). One might assume then that governments are very calculated and deliberate about their decision to be involved in such tests before committing their resources. For example, in return for investment in TIMSS, participating countries receive significant information about their educational system, including student’s knowledge in science and mathematics, the system’s progress over time, and its comparison with richly characterized education systems around the world (Drent *et al.*, 2012; OECD, 2010; Mullis *et al.*, 2009). Another example is the case of PISA, where in return for their investment, countries can access a breadth of information on the level and equality of student performance in their own and other participating systems. Furthermore, they can compare this with collected information on student, school, teacher and parental factors that may be associated with student achievement in the test.

In recent years, political leaders worldwide have not only agreed to participate in more international tests of mathematics and science, but have also increasingly taken their outcomes seriously. There are a number of complicated reasons for their interest in such results. However, one of the most pressing of these is the demonstrated link between the outcomes of these assessments and the overall economic strength and long term growth

of national economies. In essence, a significant reason for political leaders concerning themselves with results of international tests is the economic losses that are predicted to result from comparatively poor national educational outcomes, ostensibly in both scientific and mathematical literacy (OECD, 2010b; Wiseman, 2010; Reid, 2010).
The OECD has also recently provided evidence to support the argument that human capital exerts a direct influence on long term economic growth (OECD, 2010b).

Essentially, the OECD (2004:14) defines human capital here as 'the knowledge, skills, competencies and other attributes embodied in individuals that are relevant to personal, social, and economic well-being'. In the OECD's study, student results from the PISA tests of mathematical, scientific, and of course reading, literacies were used in the analyses as evidence of cognitive ability in the population, in the absence of 'direct measures of achievement of individuals in the labour force' (OECD, 2010b:14). The importance of cognitive ability for OECD countries was attributed in large part to the finding that populations with a higher average cognitive skill level tend to 'innovate at a higher rate than those with less' (OECD, 2010b:10).

Economic modelling has consistently identified a link between population levels of educational attainment and historic gross domestic product (GDP) growth (Barro, 2001; OECD, 2010b; Sianesi & Reenen, 2003; Krueger & Lindahl, 2001). Educational attainment falls short as a proxy for human capital as it measures only quantity not quality (OECD, 2004). The international evidence further reveals that educational quality, as measured by tests of cognitive skills, primarily in the fields of science and mathematics, exerts even greater economic benefits (Hanushek & Woessmann, 2009,2008; Hanushek & Kimko, 2000; OECD, 2010b; Sianesi & Reenen, 2003). An even more recent study by Hanushek & Woessmann (2012) describes their model, which has now grown to encompass a particularly large base of evidence (including international tests conducted over many decades by both the IEA and OECD), while their main conclusion remains unchanged.

The PISA impact

The outcomes of PISA and its impact on policy have been examined and reviewed. There is consensus that this assessment programme has become an embedded, and in many ways authoritative, 'global standard' of student performance, exerting a clear normative effect on national policy making in education (Breakspear, 2012:5). While this ascendency has taken place over a decade, it has been concentrated at the national governmental level, specifically on policy makers, rather than being influential on actors and stakeholders in local governments or individual schools (Breakspear, 2012). Of course, participation in the PISA programme does itself 'represent a commitment by governments to monitor the outcomes of education systems through measuring student achievement on a regular basis and within an internationally agreed common framework' (OECD, 2010:9). The rich and extensive data collected by the PISA programme is used by the OECD itself to describe, analyse and inform policy through the connection of measured outcomes with structural, personnel, curricular and pedagogical factors.
Whenever a new set of performance data is released, the PISA programme makes a particularly large splash in international media, often rekindling public discussions on school reform in countries around the world. Through an examination of European responses to the outcomes of the first two rounds of PISA testing in 2000 and 2003, Grek (2009) identified three types of reaction. In some cases, countries experienced 'PISA-surprise'. For example, the Finnish were pleasantly surprised by their success in the assessment and by the international interest they garnered through this result (Grek, 2009:34; Breakspear, 2012). Elsewhere, the results created national consternation, described by Grek (2009:34) as 'PISA-shock'. This occurred, for example, in Germany in 2000 and Japan in 2003, when students from these countries performed at a level below the results that were generally expected (Breakspear, 2012; Grek, 2009). This experience

triggered national debates about education and contributed to subsequent reform efforts that were then monitored through ongoing PISA performance, as well as nationally observed benchmarks. Kingdon (1995) argues that when an *external shock* like this occurs, a *policy window* is generated during which time it is politically possible to enact large scale reforms. The third type of reaction was termed 'PISA-promotion' by Grek (2009:34) and is typified by countries such as the United Kingdom, where the media was primarily disinterested in early cycles of PISA. The national results were not comparatively poor and so the government attracted attention to the student's achievement scores later essentially to gain political mileage from touting the strong outcomes as evidence of the success of British education.

Accordingly, no reforms were generated in this process (Breakspear, 2012; Grek, 2009). These last two types of reaction, shock and promotion, illustrate well the importance of the media's interpretation of the results from international tests of student performance (Wiseman, 2010). Breakspear (2012) argues that all three of these reactions differ due to the balance between expected and actual test outcomes, providing another two examples. In New Zealand, students' high performance level in the test reinforced existing positive feelings about recent reforms, while in the United States, the below average results achieved by students was similarly consistent with expectations. In both cases, no reforms were proposed.

PISA has become well known in Australia. In the most recent report on the Health of Australian Science, the level of performance in PISA was referred to extensively, described and illustrated graphically to indicate student achievement in science at school (Office of the Chief Scientist, 2012). Policy-oriented academic publications also refer to PISA outcomes (e.g., Marginson & James, 2008). However, Australian representatives to the PISA programme reported in a recent study that PISA's influence in Australia was not so extensive as elsewhere (Breakspear, 2012). In the main, the results have been used throughout the past decade by policy makers in Australia to bolster arguments for change, and as benchmarks for assessment and accountability purposes (Breakspear, 2012). Specifically, for example, the Australian Curriculum, Assessment and Reporting Authority (ACARA) has used PISA performance levels as benchmarks in their Measurement Framework for Schooling. The outcomes of PISA have also stimulated interest in systems and reforms elsewhere, such as Finland, where the testing process illustrates educational success (Breakspear, 2012). Even the Melbourne Declaration on Goals for Australian Schooling noted performance in PISA and the need to improve Australia's comparative position within the coming decade (Curriculum Corporation, 2008). Australia, along with many PISA countries, reported little to no pressure from PISA outcomes to enact curriculum changes, but the tests have informed the design of national testing processes (Breakspear, 2012).

Uses and impacts of the TIMSS test series

Data from the TIMSS assessments and questionnaires has been well used, influencing policies and practices in education around the world. The information is used for international comparison and the monitoring of national achievement levels. However, as the most useful element of the results is their direct connection with curricular structures, the data is also commonly used to improve student learning in science and mathematics (Drent *et al.*, 2012). Mullis *et al.* (2012) identify reforms to policy or practice as a result of poor or falling performance in Bahrain, Macedonia, the Czech Republic, the Netherlands, Slovenia and Sweden. In addition, they claim that the data and assessment frameworks have been part of the basis for curriculum reform the world over. Furthermore, the question format and analysis techniques inspired the design of national assessments in Armenia, Chile, Ireland, Romania, and Serbia (Mullis *et al.*, 2012).

Researchers have also examined large amounts of TIMSS data, in particular to answer policy and curriculum directed questions in mathematics and science and better understand the drivers of achievement in these fields (Mullis *et al.*, 2012). Wiseman (2010) advocates this more nuanced use of the complex and copious data elements produced by TIMSS for productive development of national policy. Others, including Drent *et al.* (2012) are more focused on the classroom level applications for TIMSS data, concerned by their discovery of a paucity of studies on the primary school level students results and the curricular and pedagogical techniques that best support achievement at this level.

In Australia, TIMSS data from assessments of both fourth and eighth grade has been used extensively since the first round of testing in 1995 (Wernert *et al.*, 2012). TIMSS is one of the Australian Government's listed National Assessment Programmes and is a 'key performance measure' for the National Goals for Schooling (Wernert *et al.*, 2012). TIMSS has called attention to educational issues in Australia, such as inequality, triggering 'special efforts to reduce achievement disparities among ethnic, social, or regional groups' (Mullis *et al.*, 2012:26). Within state and territory education systems in Australia, the TIMSS data is most productively applied to 'curricular development and benchmarking', and the identification of essential teacher development (Werner *et al.*, 2012:117).

PISA and TIMSS have impacted national policy in somewhat similar ways. However, the curricular focus of TIMSS assessments has made them more influential at the classroom level. Wu (2010:96) investigated the differences between mathematics components, citing the greater emphasis on 'school mathematics' in TIMSS and 'everyday mathematics' in PISA. The differences explain score discrepancies for countries between the two tests. For example, the mean score for Hungary in the latest TIMSS test showed that it significantly outperformed Australia. However, Australian students perform significantly better than 15-year-olds from Hungary in PISA. Wu (2010) argues that it is not unreasonable to conclude that Australian students are better at using mathematics in real world scenarios, while Hungarian students are better at *classroom* mathematics, like algebra and geometry.

STEM-related research and policy work

Research and policy work in a variety of areas that has been conducted by international organisations in recent years was identified by this review. A selection of the most relevant to Australia are presented here through four key themes: attracting students to STEM, women in STEM, engineering, and financial education.

Attracting students to STEM

Declining numbers of students studying STEM

There is clear evidence that the proportion of both upper secondary and tertiary level students enrolling in STEM studies internationally has declined throughout the past decade or more (OECD, 2008, 2006a; UNESCO, 2009; EC, 2008; ICSU, 2006). Several international organizations collate and publish STEM-related data. For example, Figure 16 below is derived from World Bank data and illustrates the percentage of ISCED level 5 and 6 (undergraduate up to bachelor degree level) tertiary enrolments that are in science and science-related programmes. The aggregate figures hide the disciplinary distribution of enrolments, with stable numbers going into engineering and life sciences, and declining numbers in the physical sciences and mathematics areas (OECD, 2008). Students are also preferentially choosing computer sciences over physics (OECD, 2008). Accordingly, Figure 17 displays the field distribution of tertiary entrants in 2010.

Figure 16: Percentage of tertiary enrolments at ISCED levels 5 and 6 in science, in a selection of countries (data sourced from World Bank, 2012).

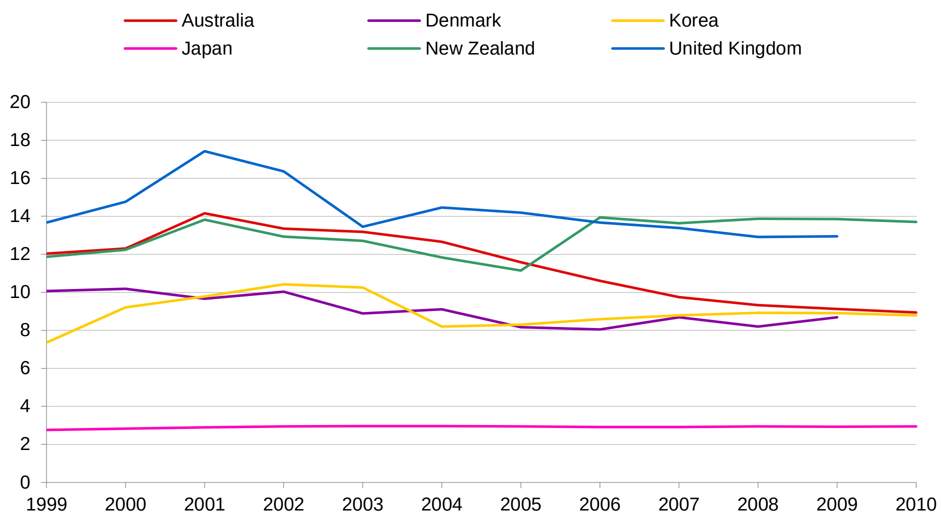
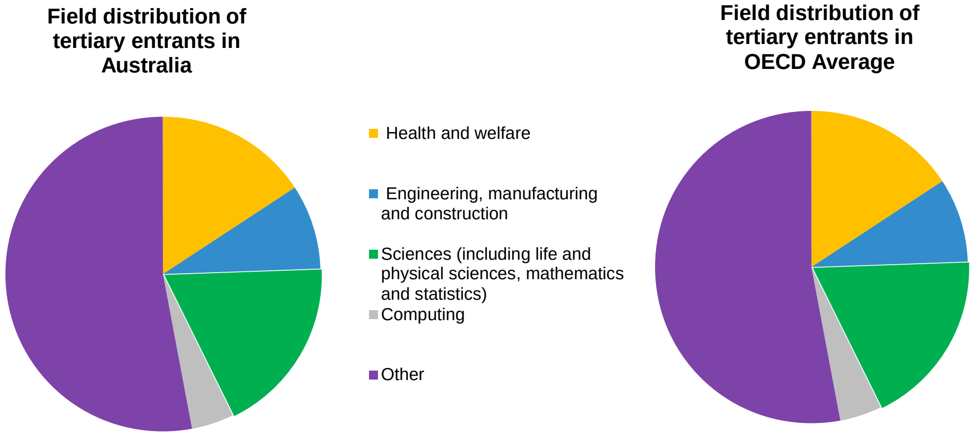


Figure 17: Distribution of tertiary new entrants, by field of education in 2010 for Australian, compared with the OECD average figures (data sourced from OECD, 2012b).



The OECD (2008) argues that student choice of study discipline is driven by three key factors. Firstly, students are influenced by the public image of the STEM-related professions, that is, what these professions are exactly, what kinds of activities are undertaken, and what kind of people choose these careers. Another influential factor is the content of STEM curricula, particularly at the compulsory level, including the relevance of topics covered to the real world or students' everyday experience. Finally, the quality of teaching in STEM subjects at all levels will significantly impact the propensity for students to engage with the subject content. Essentially, the more interesting the pedagogical practices employed, and the better the quality of student-teacher relationships, the more students will view their experiences as positive and choose to continue to study in these fields.

There are further challenges exacerbating the perceived crisis for STEM education internationally. In addition to declining numbers of enrolments and graduates, the ICSU (2006) identifies two challenges for STEM education. Firstly, there is a need to build local capacity and linkages that enable the creation of useable knowledge and contribution to national innovation systems. The second challenge, also identified by UNESCO (2009) relates to inequalities between more and less developed nations. Scientific development in the world's most wealthy nations has been a significant contributor to that wealth, as well as to their population's quality of life, through for example access to clean water, electricity, up to date technology and transportation. The ICSU (2006) recognizes a development gap between developed countries with established scientific culture and industry, and developing countries, where there is a lack of capacity and a paucity of science and technology embedded in either society or policy.

UNESCO (2007) identifies yet another challenge for the training of STEM professionals and issues of development, namely, the brain drain of talent lost to countries where the young choose to go for better jobs and a better quality of life. Many, less developed countries lose part of their investment in science and technology capacity through the persistent difficulty of keeping talent at home. They often then face the challenge of attracting back those nationals who have gone abroad for training at foreign institutions. The rapid increase in numbers of international students has exacerbated this issue. Current data indicate that about one third of qualified scientists and engineers who were born in developing countries move to developed nations to work. In the United States, for example, up to 10% of the total workforce in science and technology fields originated elsewhere. In Australia, this figure is as high as 25%. Reasons for the brain drain vary, but generally include poor working conditions: such as a lack of basic instrumentation and technical support; insufficient access to high-level research networks; highly uncertain socioeconomic conditions for the future; and a weak integration of basic science and technology or research and development with public or private enterprises.

Attitudes to STEM: An economic priority

This review has explored the extent to which international organizations have taken great interest in STEM education and the development of the STEM workforce in countries around the world. The reasons for this interest have yet to be unpicked and so are summarised here. Across the board, interest in STEM fields is couched in primarily economic terms. For example, the economic imperative appears to be the central motivator of OECD interest in declining numbers of students in STEM fields, as well as the gender related issues. A report from the OECD (2006a:3) Global Science Forum notes that ‘the economy is increasingly driven by complex knowledge and advanced cognitive skills’ and claims this to be the driver of OECD and ministerial interest in the area. In relation to the need to include more women, the report described women not currently involved in STEM fields as a ‘resource’ (OECD, 2006a). UNESCO (2007:45) similarly uses this terminology, referring to women and minorities under-represented in STEM fields as a ‘resource’ or ‘pool of talent’ that is necessary for achieving development goals. The EU has a similar view, expressing concern about declines in participation in STEM fields due to the ‘strategic importance’ of ‘innovation and knowledge in science and technology’ for the maintenance of ‘economic growth’ (EC, 2008:16). The same research described the under-representation of women, attrition in particular, as essentially the *under-utilization* of available and qualified human capital. Furthermore, the EC (2008) advocates urgent action in order to boost quality and international competitiveness in innovation – a primarily economically driven concern.
Yet another example of the economic perspective on the enhancement of STEM education can be seen in the OECD’s work on PISA. This international testing programme expresses its intent as the measurement of ‘cumulative yield’ from the quantitative examination of educational outcomes (OECD, 2010:11, 2006:9). Moreover, UNESCO (2010:337) notes the importance of engineering education for the economy by describing them as a ‘foundation for the development of society’. Without a thriving engineering profession, UNESCO (2010) claims that development, production and economic growth would suffer. The reasoning being that engineering drives innovation, and innovation drives the economy through the exploitation of new markets.

This focus on economic development may seem to be the province of international organizations whose work is anchored to the wealthier, more developed countries. However, others with greatest concern for the issues of developing countries, including the World Bank and ICSU, are similarly preoccupied with the economic benefits of excellence in STEM fields, though in this case the attention is directed towards sustainable development. For example, excellence in STEM ‘plays an important role in promoting long-term economic growth, and in building a base for a science-based knowledge society’, as well as in establishing a sustainable development trajectory within developing economies (UNESCO, 2007:27). UNESCO (2010:7) also refers to the role of science and technology capacity as being ‘critical drivers for achieving sustainable development and gaining access to the knowledge economy and society’. The outcomes of this being both societal improvement and economic growth. In relation to women in science, the report explains that any discrimination reducing the engagement of women, limits growth and the reduction of poverty in developing countries (UNESCO, 2007).

Recommendations

International recommendations for dealing with this issue are vast. However, a selection of the most relevant for the Australian context are presented in the table below from work by each international organisation.

Table 1: A selection of key recommendations for ways to attract more students to STEM study and careers.

ORGANIZATION	RECOMMENDATIONS
OECD (2008, 2006a)	• Governments ought to take steps to better understand students' choices and how this may impact on the overall economy and society. • It is important to recognise the need to measure and predict demand and supply of skills in STEM areas to meet future needs. • Collaboration between all stakeholders and parties interested in declining participation in STEM on creating and implementing solutions. • Students need to be provided with credible and accurate information about STEM subjects and careers. • Student contact with professionals in STEM fields needs to be encouraged to improve students' understanding of what it is to be employed in STEM fields and the breadth of people in these professions. This contact could be extended to teachers, and teacher trainees, so that they can have a better appreciation for STEM fields, contemporary research practices, and what it is really like to gain employment here. • A number of specific curricular changes are also recommended by the OECD. These include more flexibility, allowing students to re-enter STEM pathways later. Furthermore, a redesign of content is recommended to better reflect the nature of modern STEM careers, accurately reveal the contribution of these fields to society, exposes students to the most recent discoveries, concentrates on concepts rather than the retention of information, and a curriculum that attempts to humanize these fields and highlight the relevance of this work to the everyday lives of students. • Create teacher networks that promote better practice and share techniques and materials. • Cross disciplinary studies and professional skills should be promoted, both in upper secondary and throughout tertiary training to avoid putting students off with intense sub-disciplinary specialization. • Great improvement is required in terms of the data and indicators used internationally for understanding issues in STEM education and employment. Definitional issues remain, and there is scope for further international level evaluations. Data related to STEM studies needs to be effectively linked with workforce data to successfully monitor pathways, and survey data, including PISA needs to be better capitalized upon. Also long-term study of student motivations and choices could be studied.
UNESCO (2009, 2007)	• Curriculum changes are required to convey the notion that science is a process or method, rather than a product or discipline area. • Teaching needs to focus on building on students' prior knowledge, promoting deep learning, providing layers of context, encouraging inquiry models of learning and engaging students in meta-cognitive practices. • Teacher education should be improved so as to deal with STEM fields better outside the senior science classroom. • Employ strategies to improve access of women/girls, and other minority groups to STEM study. • Promote both scientific literacy and career progression in general science study, allowing students to change their mind about which they prefer to pursue. • Involve actors and stakeholders from outside the school system in learning.
ICSU (2006)	• International collaboration between organizations, policy makers, professional bodies, educational institutions (particularly tertiary level) and other interested parties. • Need better data to facilitate monitoring of progress. • Special attention should be given to the issues surrounding brain drain from less developed nations. • The provision of good quality teaching materials would assist teachers.

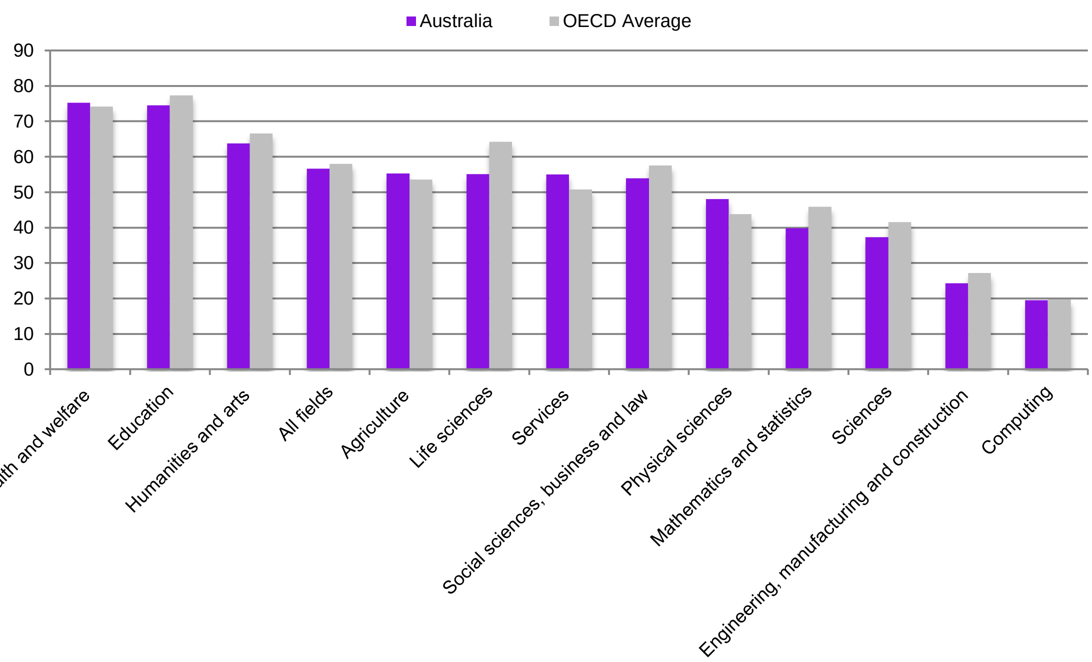
Women in STEM: A consistent theme

What is the problem?

Women are under-represented in STEM fields in numerous ways throughout both education and career. In education, gender based inequality has been masked by growing numbers of female students enrolling in, and graduating from, universities (Bell, 2010; OECD, 2008; UNESCO, 2007), and increasing absolute numbers of enrolments in the fields of science and technology (OECD 2006a; OECD, 2008). The international data show that women have been participating equitably in tertiary education for some time. In fact, the percentage of tertiary type-A qualifications (mainly undergraduate bachelor degrees) and advanced research degrees awarded to women in Australia has remained steady at around 56% since 2000 (OECD, 2012b). The OECD average actually increased slightly over the same period from nearly 54% in 2000 to 58% of awarded qualifications in 2010 (OECD, 2012b). From these figures it would seem that inequality for women in education no longer exists. However, an examination of the disciplinary distribution of tertiary students reveals a gendered pattern of participation that is internationally consistent and aptly concerning to international organizations. Bell (2010:7) refers to this varied distribution as 'horizontal segregation', as does UNESCO (2007).

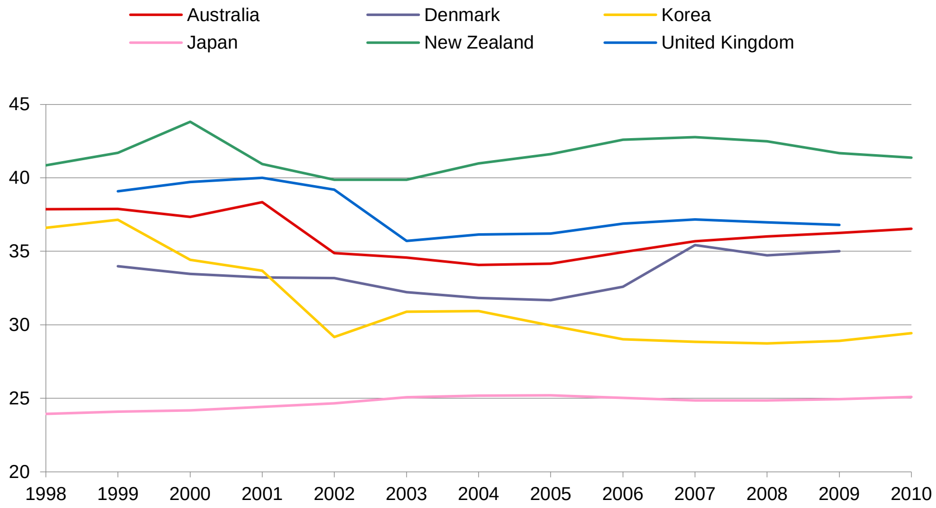
At the tertiary level, men outnumber women in mathematics, statistics, sciences (particularly physics), engineering, manufacturing, construction and computing, while women outnumber men in the study of health, welfare, education, humanities, arts, agriculture, life sciences, services, social sciences, business and law (Bell, 2010; OECD, 2012b; OECD, 2008; European Communities [EC], 2004). Similar patterns are apparent internationally (UNESCO, 2007). Figure 18 below illustrates tertiary qualifications awarded to women by field of education in 2010, highlighting the gender-based disciplinary divergence. While OECD data reveals that the numbers of women studying in these fields has increased somewhat in Australia, and in many OECD countries since the year 2000, the numbers are still well below half.

Figure 18: The percentage of qualifications awarded to women in tertiary-type A and advanced research programmes, by field of education, in 2010 (data sourced from OECD, 2012b).



At the tertiary level, women accounted for 56% of European tertiary graduates by 2001, while at the same time representing only 41% of science majors and as few as 21% of students in engineering, manufacturing and construction (EC, 2004). At the postgraduate level, the figures were 40%, 36% and 21%, respectively, although growth was noted (EC, 2004). An examination of more recent international data from the OECD and World Bank on this topic bear a similar story of gender disparity. Figure 19 draws on data from the World Bank (2012) to illustrate the percentage of enrolments in tertiary level science programmes that are female. The chart highlights a significant lag in female enrolments in science related courses (OECD, 2013, 2012; Bell, 2010). An OECD (2006a) report on the Global Sciences Forum notes that improvements have mainly been seen in countries where greater inequality had persisted, with a seemingly unsurpassable glass ceiling holding female enrolments in science and technology fields at around 40%. Aside from New Zealand's slightly better performance, the World Bank data in Figure 19 would seem to support this theory. Countries in other regions have varied levels of female enrolment in tertiary level science programmes, from 82% in the United Arab Emirates, to 45% in Egypt, 20% in Taiwan and 8% in Djibouti (UNESCO, 2007). The disciplinary distribution of males and females is consistent in these other global regions. For example, in South Africa, women feature prominently as graduates from the life sciences, but are substantially outnumbered by men in computing and engineering degrees (UNESCO, 2007).

Figure 19: Percentage of female enrolment in tertiary level science programmes, in a selection of countries (data sourced from World Bank, 2012).



The employment of tertiary graduates from science-related fields also illustrate gender differences (OECD, 2012b). Australia performs fairly well here, with figures a little above the OECD average and a similar difference between men and women (see Figure 20). The best performing countries (with least gender disparity) shown here are Estonia, Iceland, Mexico, Poland and Turkey. It is interesting to note that greater inequality occurs in some of the economies with the more developed/established science research traditions. A similar pattern is noticeable worldwide. UNESCO (2011) provides extensive data on the number of female researchers as a proportion of the total number of people working in research and development in countries around the world, including in developing regions. It seems that women have gained the most significant involvement in research within the countries that are still in the process of developing, including Venezuela (where 54.5% of researchers are women) and other Latin American countries (48-52%), Latvia (54.7%), Tunisia (47.4%) and the Philippines (52.3%) (UNESCO, 2011). In contrast to the entrenched barriers to women's entry to research employment seen in more developed economies, it may be that the lack of an established research culture in these countries opens up this sector to women.

A comparison of disciplinary study choices by males and females in upper secondary and vocational education finds an essentially identical pattern to that in tertiary level studies. A smaller proportion of females chose to study in engineering, manufacturing, construction, sciences (life and physical sciences, mathematics and statistics), or computing, while they were over-represented in health, welfare, and other (mostly social science) fields not stated (see Figure 21) (OECD, 2012b). While the data in this figure are an average of OECD member countries, the Australian data is closely aligned.

Figure 20: Number of science-related tertiary graduates among 25-34 years-old in employment per 100 000 of this cohort by gender, in OECD 30 countries (data sourced from OECD, 2012b).

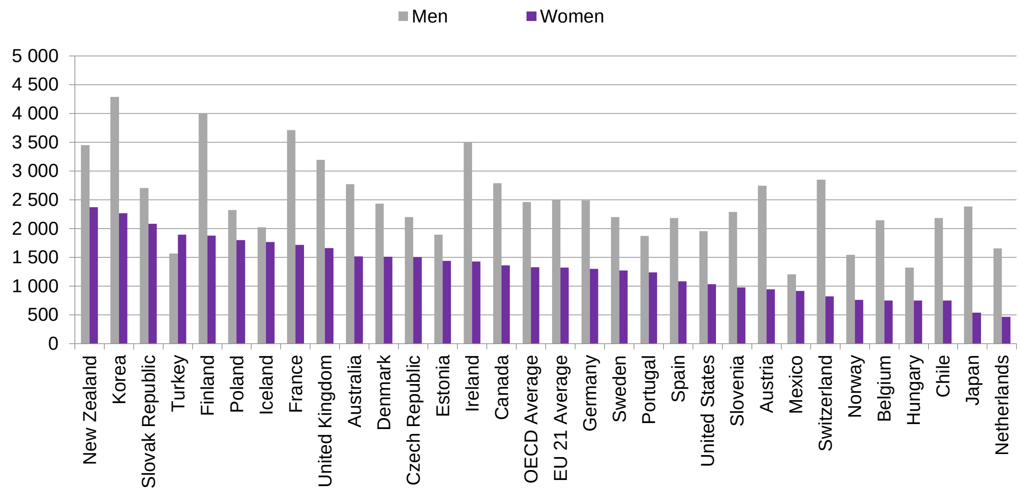
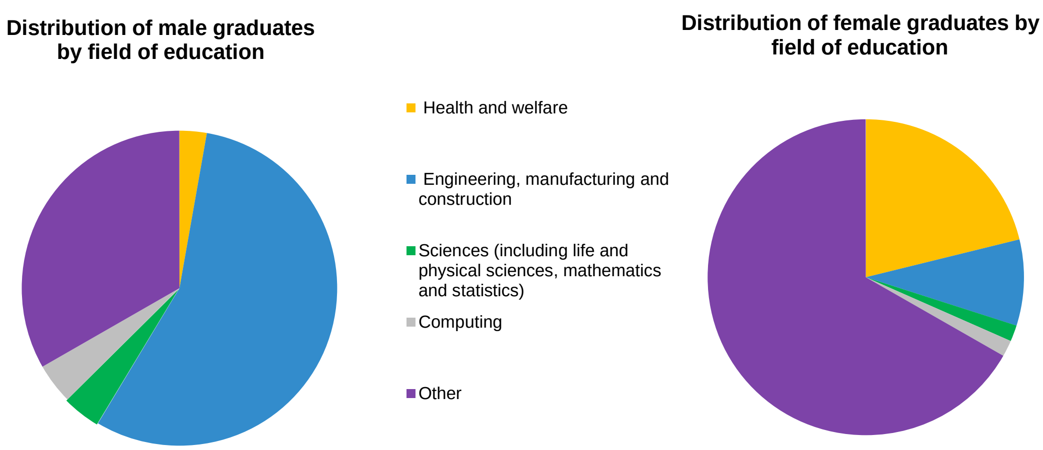
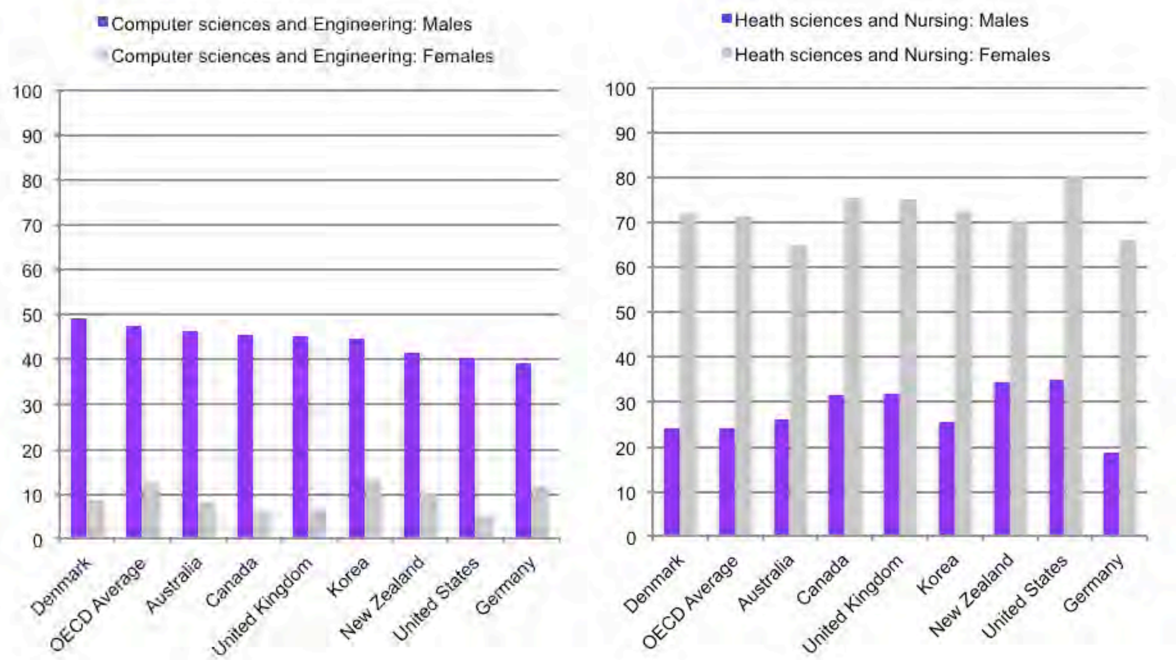


Figure 21: OECD average distribution of upper secondary and vocational graduates, by field of education and gender in 2010 (data sourced from OECD, 2012b). Australian data tracks closely with the OECD average. Note that the year of reference for Australian and Canadian data within the average is 2009.



International patterns of participation in STEM fields of study at tertiary level can be traced back through the expectations of students prior to the curricular choices they make in upper secondary school. In addition to testing students' level of mathematical and scientific literacy, the OECD's Programme for International Student Assessment (PISA) surveys 15 year-old students, collecting a range of data, including their expectations of science careers. The 2006 round of international testing found that in Australia, as many as 28.7% of the female and 27% of the male participants reported an expectation of being in a science-related career by 30 years of age. This is comparatively higher than the OECD average figures, especially for males. However, when the data are divided into two discipline-based categories – computer sciences and engineering, and health sciences and nursing – the gendered distribution becomes more distinct (see Figure 22). The most striking difference illustrated here is in student expectations of careers in computer sciences and engineering. As many as 46% of the boys tested in PISA 2006 indicated an expectation of a career in one of these fields, compared with only 8% of girls, which highlights a slightly greater divergence between genders than is exhibited internationally through the OECD average. Of the countries shown in Figure 18, Australia has the lowest number of 15 year-old girls expecting careers in health sciences and nursing at 64%, while close to the average number of boys (22%) expect careers in these fields. Again, a predictable pattern of gender disparity. A study of secondary participation in sciences in Australian education found that this is, indeed, a critical factor in determining engagement in tertiary level science courses. This research found that almost three quarters (74%) of students who studied two science subjects in their final year of secondary school continued on to study science-related areas at university (Ainley *et al.*, 2008).

Figure 22: The percentage of participating 15 year-old students expecting a science-related career by 30 years of age, by field and gender, in PISA 2006 (data sourced from OECD, 2010e).



International studies centred on research careers in the sciences illustrate the extension of gender inequality throughout STEM careers. UNESCO (2007) identifies this pattern around the world, regardless of a nation's economic strength, and the European research highlights the phenomena within the developed world. In the mid-2000s, an average of 30% of researchers in EU-15 countries were women. This is comparatively poor within the labour market as a whole because, in the same year, women accounted for 44% of all employed persons and 46% of all professionals (Reust-Archambault *et al.*, 2008). Women's under-representation was particularly acute at more senior levels (EC, 2004), with women 'concentrated in lower-level positions' (Bell, 2010:5) and accounting for only 13% of EU-15 professors in 2004 and 15% in 2008 (Reust-Archambault *et al.*, 2008; EC, 2008, 2004). Women tend to also be absent from 'decision-making scientific boards' (EC, 2008:3, 2004), and experience a gender wage gap, the largest of all male dominated professions in Europe (Reust-Archambault *et al.*, 2008; EC, 2004). Almost all European countries have declared their solidarity with this issue, creating offices or ministries with responsibility for gender equality, or adding to the responsibilities of existing ones the promotion of STEM careers for women, particularly in the sciences. But, while equal opportunity legislation in most major economies has all but eliminated blatant discrimination, under-representation still remains (EC, 2004).

The international literature also identifies an undesirably low proportion of women employed in STEM fields in Australia. In a report on women in science in Australia conducted for the OECD, Bell (2010) highlights the extent of inequality in STEM employment. In 2008, the participation of women in science, technology and engineering jobs was 45.1%, a small 2.8% increase from 42.3% in 1992. For comparison, during the same period, the percentage of women employed in the traditionally female dominated sector of government administration and defence grew 18.8%, from 37.1% in 1992 to 55.9% in 2008. Even more significant, the percentage of women employed in several other traditionally male dominated fields, while lower overall, also increased more than in STEM fields. For example, a 5.7% rise in women employed in mining was recorded, from 9.5% in 1992 to 15.2% in 2008. The gendered patterns of disciplinary distribution that occur during upper secondary and tertiary education are mirrored in the workforce, with female researchers more concentrated in biology, agriculture and health, rather than engineering, physics or computing (Bell, 2010).

Not only is female participation in STEM education and employment low, the attrition rate is particularly high, with women leaving science and other related disciplines in disproportionate numbers at each stage of the career cycle. This happens in highest volume at the post-doctoral level, despite the large amount of time invested in education prior to employment (EC, 2004). Only a quarter of female science and technology graduates in the United Kingdom actually gain employment in science, engineering or technology sectors (UNESCO, 2007). Others work in 'related jobs, such as sales and marketing in the sector', or pursue totally unrelated careers (UNESCO, 2007; OECD, 2008). Data on the United States and Australia mirror this trend. The attrition phenomenon in STEM research careers has been described by many as the leaky pipeline (Reust-Archambault et al., 2008; EC, 2004; Bell, 2010; Tytler *et al.*, 2008). Bell (2010:14) explains that this *leaking pipeline* notion, like the metaphor of a *glass ceiling*, was first used in the 1980s and has since been found to be somewhat lacking, failing to 'convey the complexities women encounter in their academic and research careers'. Instead, Bell (2010) promotes a *labyrinth* metaphor for the career paths of women in science, that is, an ongoing path of twists and turns both unexpected and expected. The notion of the *labyrinth* was put forth by Eagly and Carli (2007).

What causes are identified?

There are a myriad of factors that contribute to the under-representation of women in STEM education and employment. UNESCO (2007:15) note a number of drivers excluding women and girls from STEM study, including 'aspects of their legal, institutional, political and cultural environments'. Coverage of these in the international literature can be summarized as follows through three main areas: demand-side factors, supply-side factors, and policy or regulatory factors.

Demand-side factors are defined here as those related to employer policies and/or strategies. The first of these, is simply the nature of STEM fields, particularly in research. These areas are thought to be a large part of the cause of gender inequality, with cultural change on behalf of employers and within the sector as a whole the logical solution. Careers in STEM fields are often characterized by the requirement for long periods of prior qualification, high levels of insecurity, and the need to be internationally mobile (Reust-Archambault *et al.*, 2008; EC, 2004).

The ways in which employers organize the work itself are also potential contributory factors. For example, researchers often note in surveys that it is particularly difficult to balance their work with family life (Bell, 2010; Reust-Archambault *et al.*, 2008; OECD, 2008; EC, 2004). These obstacles include, for example, that (1) funding is sourced externally, with grants offered to those working full time only; (2) experiments must be conducted often outside of normal working hours; (3) the development of knowledge and changes in the field are rapid, making it very difficult to leave the work force for the time needed for women to begin a family; and (4) in the private sector, research is often undertaken in remote locations where it is near impossible to bring/raise a family (OECD, 2008; Reust-Archambault *et al.*, 2008; EC, 2004). Interestingly, of the women who stay in science research careers, fewer of them have children than their male colleagues (EC, 2004). Social isolation within the workplaces of male dominated fields can also act to exacerbate the isolation of the women who do engage careers there (EC, 2008). The few women who do pursue careers in the most inequitable STEM fields, do so within work 'environments that favour men, either deliberately or, most of the time, inadvertently' (OECD, 2008:84).

Along with the obstacles created for women by the nature and organization of the fields themselves, women can experience a series of externally generated negative feedbacks to their career advancement (OECD, 2008; OECD, 2006a). Women are, in general, less likely to apply for and be awarded grant funding, and so then less likely to progress to tenure. Furthermore, there is evidence that even peer review processes under-estimate the abilities of women, whilst over estimating performances exhibited by their male colleagues (Reust-Archambault *et al.*, 2008; OECD, 2008; UNESCO, 2007). This disadvantage in funding decisions has been attributed to social and cultural effects, such as family obligations and role stereotyping (EC, 2008; UNESCO, 2007; OECD, 2006a). The comparative lack of female appointments to academic professorial positions, senior research positions, and membership of funding bodies is another obstacle to equality downstream, through the receipt of grant funding, to the chances of success perceived by younger researchers, and the presence of role models for tertiary students (EC, 2008).

The impenetrability of existing networks is also problematic. Networking is particularly important to success in STEM careers, including to receive funding and achieve promotions. However, *old boy networks* and the existing 'predominantly male realm' of research communities creates barriers to women's entry into the field and particularly into senior roles (EC, 2008:12). Reputation, a quality determined by a scientist's peers, can alone sway the judgment of those involved in selection processes. Women can be disadvantaged in this process, as they are often the one to leave work to deal with family obligations when necessary, such as to collect children from school or child care, and this behaviour is thought to reflect on their overall reputation within the work place (EC, 2008).

Supply-side factors also contribute causally to inequality, and are defined here as social and cultural factors which influence individuals' decision to engage in STEM careers. The literature identifies a number of significant cultural barriers and negative external pressures which can affect female students or women considering STEM study or careers. Research conducted by the Communities branch of the EU identifies the masculine nature of particular STEM professions that has acculturated over time (Reust-Archambault *et al.*, 2008; EC, 2004). This masculine dominance/male culture and its related stereotypes tend to 'put women off' STEM subjects, particularly physics, engineering and computing (OECD, 2008:83). Girls tend to develop negative attitudes towards study and work in science, engineering and technology related careers fairly young, as a result of factors emanating from both inside and outside of school (OECD, 2008; EC, 2004). Furthermore, stereotypes persist within many countries that label scientists and engineers as men, by definition (OECD, 2008). The literature identifies a lack of visibility of women in scientific or engineering careers, and therefore an absence of role models to stimulate the interest and ambition of the next generation (EC, 2008; OECD, 2006a). Such cultural elements of career choice in STEM fields are driven by social memes that are able to 'turn laws and regulations into mere text, commitment into simple rhetoric, and measures into window-dressing' (EC, 2008:12).

Stereotypes are fuelled by ignorance of what exactly STEM careers entail and who scientists, engineers and other STEM professionals actually are. Research conducted on seventh grade primary students in Europe found this ignorance to be quite striking, and very easily remediated. Figure 23 below illustrates the stereotyped image of scientists held by these young school students prior to visiting a scientific research laboratory, and then their altered view afterwards. Interestingly, the age and gender of the person depicted in these illustrations changed somewhat dramatically.

Figure 23: Seventh grade student drawings of a 'scientist' before (left) and after (right) their visit to a scientific research laboratory (figure sourced directly from EC, 2008:13).

The self-perception of female students (particularly at upper secondary level), as well as students' 'self-confidence in their scientific abilities' is considered a significant driver of low female participation in STEM education (EC, 2004:173). Women, the young in particular, 'tend to undervalue their own performance' abilities, especially within science and technology studies (OECD, 2006a:7; OECD, 2008). STEM fields, particularly those in which women are notably absent, are internationally considered as academically challenging areas. Consequently, this characteristically female self doubt can easily turn women away from such studies and careers.

A third group of causally relevant factors to the gender inequality in STEM fields are labelled here as policy or regulatory factors. A lack of counter measures within national systems is characteristic of low female engagement. These measures may include the existence of a ministry or government affiliated body dedicated to the issue, or the implementation of 'targets, quotas, mentoring schemes, special funding for women in science and paternity leave' (Reust-Archambault *et al.*, 2008:8). Another important system related factor is the proportion of national research and development conducted within business enterprises, rather than that within the public service or universities. Gender inequality is particularly marked in the private sector. From this evidence, Reust-Archambault *et al.* (2008) argue that policy makers cannot simply rely on market forces to stimulate economic growth and, therefore, promote greater innovation in science and technology. Given the diversity of female engagement by economic sector, such an approach would be unsuccessful in ameliorating the gender divide in these fields.

Why is it an issue?

The underrepresentation of women in science and other STEM fields is thought to be problem for a number of reasons identified in the international literature. Arguments for change fit within five key areas, presented here in no particular order. Firstly, there is an argument regarding the concordance of the population of STEM researchers with the general population. When the gender balance is aligned with the real world, it is more likely that the research will, accordingly, be better aligned, and so more productive and relevant to the real world applications of the work (EC, 2008; UNESCO, 2007). Secondly, there is an argument for quality in STEM research. Diversity of participation enables greater creativity and reduces potential bias, which both improve research quality (EC, 2008). Another potential argument is for social justice, fairness and human rights. If all people are equal, then all should be able to experience equal opportunity, including the circumstances that enable them to engage successfully in STEM education and careers (EC, 2008). The fourth argument is economic or utilitarian in origin. STEM research is considered to be of particular 'strategic importance' to national economic strength and growth, as well as international competitiveness, through its connection with innovation and knowledge, particularly that in science and technology (Reust-Archambault *et al.*, 2008:16; OECD, 2006a; UNESCO, 2007). Women are a significant under-utilized 'resource' that have the potential to boost the labour force in this sector and provide a larger talent pool within which to search for the best and brightest (OECD, 2006a:6; EC, 2008). Furthermore, the human capital of those women who have undertaken training in one of these fields and left their career prematurely has not been effectively maximized. For the developing world, UNESCO (2007) argues that the engagement of women and girls in STEM fields is critical to achieving sustainable economic (and social) development. Finally, there is an argument for more women in STEM fields for the sake of the common good. Research attempts primarily to address the common needs and issues facing the population and is financed by common funds such as tax revenues. It, therefore, makes sense to involve all sub-groups of the population (EC, 2008).

Recommendations: What can be / has been done about it?

The need to improve the representation of women in STEM fields of education and employment is an ongoing agenda and recommendations are made by several international organizations. The education and work environment itself will need to change to attract more women into STEM professions. Recommended strategies to improve female participation in STEM education include, revived career and course counselling services with materials adapted to better attract young women, the implementation of mentoring programmes and similar initiatives designed to encourage and support girls and women in these fields, and the creation of targeted programmes that prioritize opportunities for women (OECD, 2008, 2006a; EC, 2004). Mentoring programmes, and other direct supports for women in STEM fields can empower women to engage more effectively in research careers. Examples of this approach have been successful across Europe, through the European Network of Mentoring Programmes, directed at women in academia and research, and in Norway. Here, linkages have been systematically established between professors and PhD or post-doctoral level women. Reported evaluations of this endeavour have been particularly positive.

To make the professions themselves more attractive to women, a number of recommendations are made in the international literature that are directed towards employers. The work culture is one element that can be improved through an integration of, and better balance between, work with employees lives outside (Reust-Archambault *et* *al.*, 2008; EC 2008, 2004). Measures such as more flexible working hours, child care provision, support for family mobility, greater periods and payments during maternity and paternity leave, and incentives to return to work after periods of time away spent with family (OECD, 2008; UNECO, 2007). Work-balance is thought to be a particularly productive approach to improving the gender balance (UNESCO, 2007). The flexibility of time commitments, particularly for parents, is an ideal place to start. In Finland, Norway, Slovenia and Sweden the contracted period of employment for researchers is simply extended according to any time taken for child birth or parental leave, with males encouraged to use this provision as well. This dual target of men and women is noted as important here. Other employer-related elements noted in recommendations include the need to raise awareness of gender issues in these fields, the introduction of female perspectives into human resources and related protocols, as well as greater transparency in funding procedures, promotions and nominations for top positions (OECD, 2008; EC, 2008).

Reust-Archambault *et al.* (2008) additionally recommend that workforce or employer strategies be focussed on the sector with the worst gender performance, namely, the private sector. Initiatives that attract women to work in STEM fields here, and improve the conditions of those already in these jobs, will likely have the greatest impact. UNESCO (2007) similarly identifies the private sector as an important target for policy.
Strategies to improve gender equality directed toward women themselves and more culturally or socially oriented issues here are also warranted. Within education, the literature recommends that teacher training, the curriculum and the context or environment in which learning takes place ought to be re-thought. Further change aiming to increase the attractiveness of STEM studies and careers to young women may include the interdisciplinary design of courses within STEM areas to avoid inequality across disciplinary lines, or the development of greater self-confidence among women in STEM studies (OECD, 2008, 2006a). Strategies may also be directed at the imbalance of gender equality at each level of the career cycle. The lack of female role models in STEM areas, particularly for primary and secondary school students must be addressed as the young are already learning how to value careers and making decisions that impact their own path (European Roundtable of Industrialists, 2009; Reust-Archambault *et al.*, 2008).

Perceptions of STEM studies and careers in the community are another avenue for the implementation of change strategies. The OECD (2008, 2006a) notes the need to improve the image of science, engineering and technology in the community. This may simply involve dispelling myths and combatting ignorance of what it actually means to study and work in these fields. Young people need access to STEM professionals if they are to understand what they do and who they are (OECD, 2008). Furthermore, young women in particular must have access to older women employed in STEM professions if they are to find appropriate role models (OECD, 2008, 2006a).

International organisations focus the majority of their creativity on strategies for governments and policy makers. An overall strategy of gender mainstreaming is proposed in the European literature (EC, 2008, 2004), and by UNESCO (2007). Essentially, this means that a systemic commitment is made to gender equality in STEM education and careers, through a combination of elements including political will, legislation, greater understanding of gender issues, mandated involvement of women on decision-making bodies and to senior appointments, more appropriate human resource processes and funding systems (EC, 2008, 2004). A sincere commitment from scientific leaders to tackle the issue, rather than ‘lip service’, as well as clear policy goals from national governments, are also thought to be important (EC, 2004:182). Creating authentic policy goals must be central to progress on gender equality in STEM fields. If gender equality is a true policy goal, there are measures that can be applied, including official declarations on equality made by important players, particularly influential men. For example, the European

Commission itself has made statements, initiated projects/programmes and set a good example of equality (EC, 2008). They argue that 'to gain acceptance and commitment, gender equality has to be understood as an integral part of excellence in research' (EC, 2008:35).

One avenue for policy makers is through the conception and implementation of equality legislation within national systems. Unfortunately, in some countries such legislation has not been extended to top level appointments in academia or positions on decision-making bodies, such as research councils (EC, 2008). Procedural transparency is one recommended strategy intended to improve the gender balance here. This approach lessens the influence of established *old boy networks.* Implementing standardized selection procedures, publishing position advertisements widely, headhunting highly qualified women and monitoring gender dis-aggregated data on selection and hiring outcomes, are all potential strategies. Equality-oriented searching has been utilized in Norway, for example, where committees have been established at one university that have successfully identified and recruited many qualified women.
Targets and quotas are another, well described strategy through which policy makers and governments can tackle the issue of gender inequality in STEM fields.

Reust-Archambault *et al.* (2008) recommend that system-wide targets be set to attain an equitable percentage of women in all STEM disciplines, with particular note to the proportion that are professors or in other senior positions. Targeted funding rates, uptake of paternity leave, and quotas for engagement in senior positions or participation on decision-making boards are also thought to be helpful, with the success of such measures seemingly compounded when implemented in concert (Reust-Archambault *et al.*, 2008; EC, 2008). An example is Finland, where targets and goals were arranged as part of equality plans in many universities. However, there was a distinct lack of systematic follow up or incentives based on achievement of these plans. Targets and quotas that mandate the inclusion of women are, of course, particularly direct means of achieving outcomes. Quotas are the most strict, as they require, rather than aim to achieve, a level of equality. But, the research community usually prefer to deal with targets. For example, in Sweden, political pressure from policy makers to achieve targets is strong and has effectively increased the participation of women, whilst maintaining institutional autonomy in decision making and appointments.
Potential downsides of targets and quotas include the perception of discrimination against men, neglect of cultural elements of the issue, the imposition of equality that becomes unsustainable, rather than organically and culturally instilling the practice of equality. A statistical analysis of European data found a negative correlation between countries with targets or quotas for women in science and the actual number of women employed as researchers in this field (EC, 2008). It seems that these measures are not effective in general, not effective on their own, or simply not effective yet (perhaps they take more time to influence the overall culture of participation) (EC, 2008). Or even, the quotas may not be influencing the private sector, which normally exhibits the greatest inequality.

Financial incentives are tried and tested motivators for change that are a recommended part of the arsenal to combat gender inequality in STEM fields. In Switzerland, a programme of financial incentives has been in operation since 2000 whereby universities are provided with greater national governments funds for the appointment of female professors. This has proved successful.

Engagement is a strategy strongly and frequently recommended in the international literature. Women should be actively and deliberately engaged in policy development and implementation, funding decisions and human resource processes (OECD, 2008; Reust-Archambault *et al.*, 2008; EC, 2008; EC, 2004). When implemented, this strategy can be successful. For example, the EU committed to the engagement of women in decision-making through the imposition of a target on expert group and committee membership. Since the mid-2000s, all decision-making boards were required to be composed of at least 40% of each sex, a strategy that has successfully 'led to a strong increase in the participation of women on evaluator panels for research proposals submitted' (EC, 2008:10).

Equality in research is determined in large part by access to funds granted through systemic funding selection processes. Both engagement and targets or quotas can be employed to improve the funding situation for women in research, but there are other measures, such as scholarships or fellowships specifically reserved for female students and researchers, which have also been positively correlated with the proportion of women in professorial roles (Reust-Archambault *et al.*, 2008). An existing level of concern about the under-representation of women in science seems to be a necessary pre-requisite of these strategies. Specific measures might include targeted strategic reservation of funds for women to assist their study and establish themselves as researchers, or the allocation of greater points in funding selection processes to proposed projects with balanced gender (EC, 2008). In Greece, projects receive 5% higher in their evaluations during funding selection processes for each female researcher involved, while in Spain, 5 points are added to an overall score out of 100 awarded to projects directed by a woman or with more than the average proportion of women involved in the research group applying for funds.

There is a general call from international organizations for more and better quality gender dis-aggregated statistics and indicators related to women's participation in STEM fields of study and work (UNESCO, 2011, 2007; OECD, 2008, 2006a; Reust-Archambault *et al.*, 2008; EC, 2008, 2004). For example, Reust-Archambault *et al.* (2008) found a lack of statistics and data on women's participation in science and representation in scientific fields of employment. Their study also called for internationally 'harmonised data', collected systematically, to highlight researchers pay and the balance of remunerations received by men and women in these roles. The importance of improving the quality and extent of data on women in STEM education and employment, particularly internationally comparable data, has also been recognized by UNESCO (2011). The EC (2008) recommends an ongoing international statistical monitoring of gender balance within the sector that is both comparable over time and made publically available, particularly economically driven data such as economic and direct financial costs of losing or not attracting women. The OECD (2008:108) is concerned about this issue as well, explaining the need for better 'gender-sensitive data' and well constructed indicators. They further argue that programmes and initiatives should include measureable targets, rather than 'general mission statements' (OECD, 2008:108). The improved data would assist in the monitoring of such targets.

Other strategies relate to initiatives of science peak bodies or other professional associations. For example, in the United States, the National Science Foundation has made valuable efforts to 'increase the prominence, visibility and influence of women in all fields of academic science and engineering', as well as to 'improve the institutional climate, and the recruitment and retention of women faculty' in these fields, through several important initiatives (Bell, 2010:5). These include the Professional Opportunities for Women in Research and Education (POWRE) programme, and the ADVANCE programme (Bell, 2010). In the United Kingdom, a similar programme was established in 1999, known as the Athena Project, which aimed to improve the career prospects of female scientists employed in the university sector (Bell, 2010). In response to results from surveys conducted to better understand the causes of gender inequality in the STEM workforce, the Athena Project helped establish guidelines for best practice to be used by STEM departments in universities in the UK. The guidelines advocated, for example, for the provision of personal and professional support to women for their career development, that departmental heads be aware of the issues and challenges, and for regulatory changes or modifications to departmental culture in support of better work-life balance (Bell, 2010).

Fields of particular interest: Engineering and applied mathematics

Engineering: The forgotten STEM letter

While science, mathematics and technology are examined by international organizations, the other part of STEM – engineering – is often brushed over. Aside from the OECD's proposed measurement of tertiary level engineering outcomes and indicators of tertiary enrolment in this field (described later), there seems to have been very little work conducted by international organizations in recent years that focuses exclusively on engineering. However, in 2010, UNESCO prepared an international compendium on engineering and development, and while it was significantly directed at countries far less developed than Australia, there remain numerous interesting points on education and training in this field that will be elaborated and summarized here.

UNESCO (2010) provides two main arguments for the critical importance of engineering in the twenty-first century. Firstly, the report explains that 'engineering has given us the world we live in' from aeroplanes to bridges to smartphones (UNESCO, 2010:16), and that it has an ongoing and central role in 'addressing the large-scale pressing challenges facing our societies worldwide', such as 'access to affordable health care; tackling the coupled issues of energy, transportation and climate change; providing more equitable access to information for our populations; clean drinking water; natural and man-made disaster mitigation, environmental protection and natural resource management' (UNESCO, 2010:5). The second argument relates to the field of engineering itself and the particular challenges that must be addressed. These include the declining numbers of students choosing this field of study and the need to promote engineering knowledge within the general community. The contributing authors (three international engineering organizations) claim engineering to be a deeply 'human and social [endeavour], as well as a scientific, technological and innovative activity' (UNESCO, 2010:16).

Declining interest on the part of young students, particularly women, in engineering education is described by the report as 'one of the most serious internal issues and challenges facing engineering' (UNESCO, 2010:308). The absolute numbers of students globally in this field has increased over recent decades, however, the growth is not sufficient to meet demand. Governments in many countries, including the United Kingdom, South Africa and Malaysia, have officially identified national shortages of engineers. The UNESCO work reports similar shortages in Australia. Globalization has created demand for engineers that extends internationally with substantially reduced barriers to mobility, and increasing numbers of relevant projects worldwide, for example those focused on poverty reduction or climate change mitigation. Educators in this field have yet to keep pace with changing demands. They must consider the balance between general and specialist knowledge, the types of institutions that should be involved and the extent of focus required on technology in all engineering sub-disciplines.

Present data sources and indicators available internationally are 'of limited use in analysing the need for, types and numbers of engineers required at national and international levels' (UNESCO, 2010:312). There is an acute need for better data on education and employment in engineering, both more indicators and better definition of terms. Policy makers require good quality evidence if they are to be able to make intelligent and informed decisions about engineering-related issues. In particular, the data need to be dis-aggregated from the sciences. In order to do this, more consistent, international definitions are required that make sense of what an engineer is exactly, as well as the economic and national requirements for these professionals for growth and the invention of solutions to pressing problems. Engineers Australia also notes a lack of data from the Australian Bureau of Statistics on engineering and engineers (UNESCO, 2010). Instead, the industry body collects and publishes its own data annually on the workforce, including salaries, conditions and number of employed people. The survey and data collection process undertaken here has identified an acute skills shortage in filling engineering jobs in Australia.

The report includes a short section with particular focus on engineering education in Australia, written by Peter Greenwood of Engineers Australia. The most significant issue for Australia is the difficulty in attracting students to science and mathematics, and then subsequently into tertiary engineering courses. The numbers in both are reported to be steadily decreasing. Consequently, a skills shortage in this field in Australia has been reported, 'exacerbated by an over-reliance on overseas recruits at a time when skills shortages were becoming a global problem' (UNESCO, 2010:326). Around 5 000 students have graduated from university engineering programmes in Australia each year for the past decade or so, while annual demand for engineers in the economy is thought to stand at around 30 000. National strategies to deal with this issue focus on attracting young, Australian students to the field. For instance, the federal government provided substantial funds to Newcastle University to put in motion a Science and Engineering Challenge in 2004. Grant money was awarded to Engineers Australia for its initiative stimulating the curiosity of primary age students in engineering pathways, and funds have been made available to boost technical education through large technical colleges for high school students unlikely to achieve the grades required for university studies in engineering. The useful skills they graduate school with may be applied through careers, or even motivate these students to strive towards university level engineering study. Last resort strategies, including encouraging tertiary students and apprentices to cut their studies short and move into work, or enticing educators to return to industry, are becoming increasingly common in Australia. Unfortunately, there is concern that this could lead to 'a growing cadre of under-trained and under-qualified people in the workforce' (UNESCO, 2010:328). The skills shortage has also prompted Australian employers to make more concerted efforts to attract and retain engineers, particularly women who are not only in short supply but exhibit a particularly high rate of attrition from the profession at a young age. UNESCO (2010:327) argues that the skills shortage in engineering should prompt the federal government in Australia to have an understanding of the 'true extent of the work done by the engineering workforce and its key role in many sectors of the economy'. Better understanding of the work of engineers on the part of school teachers and students, particularly at secondary level, would also boost the attractiveness of the profession. Many are simply ignorant of what is involved in such careers and students are easily put off what they see as years of *boring* or *difficult* study in science, mathematics and technology, and sometimes lower paid jobs than these young people might find in other professions, such as finance.

The UNESCO (2010) report provides key recommendations for engineering education. It is suggested that more student-centred approaches would be desirable for a number of reasons. Students will need to be able to deal effectively with rapid knowledge development and change throughout their careers; they will need to be equipped to innovate within competitive global environments; they will be required to possess the communicative and collaborative skills necessary to work constructively in teams, across disciplines and with other professionals, for example in the media; they must be confident to make use of ever changing technology; and they will need a broader understanding of global challenges, like climate change, to ensure they contribute to the best solutions. The report recommends problem based learning (PBL) as the mode of instruction to mould such graduates. There are three key pedagogical elements of PBL that are worth noting here. Firstly, the *learning approach* refers to the organization of learning through problems or cases, with these forming the central context for the collection of new knowledge and training in problem solving and other related skills. Secondly, the *contents approach* means that the content of courses and programmes in engineering are arranged in an interdisciplinary manner, with no boundaries and no division of theory and practice. Thirdly, the *collaborative approach* concerns the building of teams and collective ownership of learning, which takes place through social interaction, sharing and communication. This approach has been adopted in Denmark, and subsequent employer surveys indicate that they prefer graduates of PBL dominated engineering courses as they have 'proved to have better skills in team work, innovation, project management, and acquiring new knowledge', when required (UNESCO, 2010:338). The literature confirms these positive outcomes, identifying the ability of PBL and other student-centred, investigative approaches to learning to enable deep active learning, encourage critical thought, improve the extent to which learning feels authentic and meaningful, and help develop feelings of professional identity, responsibility and the ability for self-motivation and direction. The UNESCO (2010:340) report also promotes the idea of engineering education for sustainable development, where this is defined as 'encouraging changes in behaviours that will create a more sustainable future in terms of environmental integrity, economic viability, and a just society for present and future generations. Unfortunately, this type of tertiary engineering programme is yet to be comprehensively applied. However, environmental education in itself has become a significant component of engineering education that is in the process of being better integrated into these programmes worldwide.

The report from UNESCO (2010) on engineering in the international sphere concludes with a number of activities thought to be necessary in addressing the problems raised for engineering around the world. These include: development and sharing of data, information and compiled indicators; publication of effective teaching materials and course designs; greater investment in engineering education at all levels; collaboration between policy makers, employers of engineers and professional bodies; and the production of transformed educational materials and experiences.

Financial Education: Applied mathematics in the wake of the crisis

The financial crisis stirred international concern about levels of financial literacy among populations of developed and emerging economies alike (OECD, 2010d, 2008; ASIC, 2011). It seems that much of the global 'population is ill-equipped to participate in the global economy because they lack basic financial skills', an applied component of mathematics study that ought to be covered by school education (INFE, 2009:7). In fact, common levels of financial literacy are 'now globally acknowledged as an important element of economic and financial stability and development' (OECD, 2010d:7; INFE, 2009). Furthermore, higher levels of financial literacy have been empirically linked to improved wellbeing throughout life (OECD, 2010d, 2008; ASIC, 2011).

Financial literacy is a 'core skill, essential for consumers operating in an increasingly complex financial landscape' (Atkinson & Messy, 2012:13; ASIC, 2011). Financial education is defined by the OECD (2005:4) as the 'process by which financial consumers/investors improve their understanding of financial products and concepts and, through information, instruction and/or objective advice, develop the skills and confidence to become more aware of financial risks and opportunities, to make informed choices, to know where to go for help, and to take other effective actions to improve their financial well-being'. This definition is appropriate as it includes the elements of 'awareness, knowledge, skill, attitude and behaviour', and points to financial well-being as the worthy end goal (Atkinson & Messy, 2012:14). In addition to its benefits for individuals, financial literacy is nationally important, with advantages such as improved individual choices that together create greater collective wealth through ‘both investment levels and economic growth’, as well as reduced demand for financial support from governments (OECD, 2006b:113). Financially literate individuals are better at ‘budgeting, saving money, and controlling spending’, ‘handling mortgage and other debt’, ‘participating in financial markets’, ‘planning for retirement’, and ‘ultimately, successfully accumulating wealth’ (Hung *et al.*, 2012:8-9). The OECD (2005:4) identifies the need for financial education to provide a working understanding of ‘basic savings, private debt management or insurance, as well as pre-requisites for financial awareness such as elementary financial mathematics and economics’.

Following a series of international conferences in the wake of the recent financial crisis, the OECD established the International Network on Financial Education (INFE). The INFE is an international body comprising more than 80 countries and 200 public bodies with an interest in matters related to financial education (INFE, 2009). The programme is directed at the exploration of financial illiteracy and its influence on development and economic cycles, and the mitigation of future crisis events through the protection and education of consumers (INFE, 2009).

Aside from the ‘crisis effect’ raising interest in financial literacy levels, there are three other ‘tangible trends’ justifying international concern about the quality of financial education (OECD, 2010d:7). Firstly, there has been a general shift of lifetime financial risk, resting now on individuals where responsibility once fell on governments and employers (OECD, 2008, 2005; ASIC, 2011). For example, social payments, such as education and health expenses, and pension benefits have tended to be less state supported internationally, requiring forward planning on the part of the majority of individuals (OECD, 2010d, 2008). The extension of life expectancy over the last century has exacerbated this issue for many (OECD, 2006b). Secondly, increasing affluence, creative marketing and diversified financial service markets have collectively produced a wide and growing range of financial products and services, to which the majority of people have sufficient wealth to access (OECD, 2010d, 2006b, 2005). These products and services are also ‘becoming more complex’, in part through their nature, and in part through deliberately elaborate and convoluted marketing strategies (OECD, 2010d:7, 2008). Consequently, the ability to navigate this abundance and see through the subterfuge of companies pedalling their wares has become a necessary part of life, even for the young. Of course it is not one-sided, in fact, the third trend is the increasing demand individuals have for financial services, in order to participate in global consumption (OECD, 2010d). They will need a range of knowledge and skills in order to make sense of the payment options for online transactions, receive income electronically and transfer remittances around the world (OECD, 2010d).

The examination of financial literacy skills has been measured internationally. One example of this is the OECD’s international tests of student achievement in science, mathematics and reading literacy, known as PISA. The latest round of testing in 2012 had a special focus on mathematics, and given the timing, the emphasis was shifted towards financial literacy levels, as a particularly relevant field of applied mathematics. Although the results of this are yet to be released, preliminary information from the study’s framework are provided later in this review within the section on PISA. Another international examination of financial literacy was conducted by the INFE (Atkinson & Messy, 2012). Data was collected through a pilot survey of 1 000 people in each of 14 countries around the world. The questionnaire was short, but covered three elements of financial literacy, namely, knowledge (for example, understanding of simple and complex interest), behaviour (such as, the keeping of household budgets or tendency to save) and attitudes (including conscious consideration of the long term, or perception of money as existing for the purposes of spending) (Atkinson & Messy, 2012). Some interesting results emerged for the countries involved, including that more responsible attitudes and behaviours were correlated with greater financial knowledge. However, Australia did not take part in the pilot study.

Further work has been conducted by the OECD and INFE to examine gender based differences in levels of financial literacy measured internationally. While this work identifies ongoing data limitations, it concludes that there is a gap in performance in this area, with women showing themselves to be less competent in financial matters in general, and less confident (Hung *et al.*, 2012). This divergence is attributed in large part to 'differences in skills, attitudes, and traditional gender roles in household decision making and in society that affect the opportunities of women and girls' (Hung *et al.*, 2012:6).

There is consensus in the international literature that some strategic efforts to improve financial literacy through education are necessary (OECD, 2008, 2006b, 2005; OECD/INFE, 2012; INFE, 2009; Atkinson & Messy, 2012; Grifoni & Messy, 2012). In 2012, the OECD and INFE created a series of principles for the development of national strategies directed at improving population levels of financial literacy. To create a national strategy, national governments must first recognize the problem of low levels of financial literacy and the importance of financial education to deal with this; they must also establish a roadmap for action that involves key stakeholders and includes measureable objectives; and they need to provide a framework that can be used by individual programmes for effective integration within the national strategy (OECD/INFE, 2012). OECD and INFE (2012:9) recommend beginning the process with preparatory steps including 'assessment, mapping, consultative and communication processes and preparatory surveys', plus some form of campaign for national awareness. Grifoni & Messy (2012) argue for national assessments at this stage, through examinations, surveys, consumer complaints and international comparisons. Governance should be coordinated either by an existing public body, or the creation of a new authority and cooperation with existing stakeholders and financial institutions is also recommended (OECD/INFE, 2012; Grifoni & Messy, 2012). Involvement of interested parties and incorporation of industry sectors is important, while success rides on strong governmental leadership (Grifoni & Messy, 2012). A variety of delivery methods and clear goals are also appropriate. The OECD (2008:142) recommends that approaches are targeted to particular demographic groups (by age, those who are less educated or vulnerable), led by government and enriched by 'a wide range of social partners', including industry groups. An example of age targeted programmes may include risk training directed towards the younger, more risk averse, or superannuation and pension planning for middle aged adults. Key issues in the development of national strategies include buy-in, consistency of definitions and information, diversity of existing programmes to capitalise upon (noted as particularly pertinent in Australia), competing political priorities and the availability of resources to make theses programmes and initiatives successful (Grifoni & Messy, 2012). OECD (2008) also recommends that consumers are educated about the need for financial education and are provided with a better understanding of their own knowledge and skills in this area. Financial education should be realistic, easy to understand and come through a variety of media from diverse sources.

Many individual countries have found international interest in financial literacy to be pertinent to their own national concerns and, consequently, have established their own national programmes and research strategies to deal with the issue. The table below lists the countries around the world where national strategies for financial education have been devised in recent years.

Table 2: This table identifies where national strategies on financial literacy have been undertaken in some way, by stage of its development. These strategies may not be systemic or well conceived, but in these countries the issues are recognised and some effort has been made (table sourced directly from Grifoni & Messy, 2012).

National Strategy	Count	Countries
1) Countries that have designed and implemented (implementation date)	15	Australia (2011),Brazil (2010), Czech Republic (2010), Ghana (2009), India (2006/2010), Ireland** (2009), Japan (2005), Malaysia (2003), Netherlands (2008), New Zealand (2008, 2010), Portugal (2011), Slovenia (2011), Spain (2008), United Kingdom (2003), United States (2006, 2011)
2) Countries that have started considering and/or designing a NS (but not yet implemented it)	21	Canada, Colombia, Estonia, Indonesia, Kenya, Latvia, Lebanon, Malawi, Mexico, Peru, Poland, Romania, Serbia, South Africa, Sweden, Tanzania, Turkey, Uganda, Russian Federation, Thailand, Zambia

*** The information is updated as of February 2012. Denmark does not have a NS as such and it is not considering designing one due to budgetary constraints, however it established a national board with responsibilities for financial education. ** Ireland on the other hand has an approach based on the recommendations of a steering group, but this does not include a NS. Nevertheless it has much in common with national strategies elsewhere and so is included in the following analysis.**

In the United Kingdom, for example, the Money Advice Service (originally the Consumer Financial Education Body) was established in 2010. This service is free, independent and provides unbiased advice to anyone in the United Kingdom to help them with financial issues. Essentially the role of this consumer body is to 'enhance the nation's financial capability' through improved public awareness and understanding of financial affairs, debt advice, and financial education (The Money Advice Service, 2012).

The Money Advice Service in the United Kingdom has been evaluated, with numerous conclusions and recommendations (Ci Research, 2012). There is a large amount of anecdotal and equally non-robust evidence to suggest the programme has been effective. However, the evaluation notes the need for greater quantitative data for ongoing monitoring of the programme's impact. Ci Research (2012) makes numerous recommendations for the ways in which this programme could be improved, and important elements others might copy, including:

- The importance of targeting the population most in need and most financially vulnerable.
- Plans for long-term influence on financial behaviour through interventions for all household members of all ages.
- Information campaigns are most effective when not implemented in isolation, but instead part of an overall strategy.
- School education as an avenue to greater financial knowledge is not necessarily the most effective for the young, nor is it useful in the longer-term. The evaluation finds 'little evidence' that knowledge developed through instruction will have any useful impact on behaviour (Ci Research, 2012:9).
- Social marketing is influential on population behaviour, but must be appropriately targeted and have clear aims.
- Education in regards to finance should target the young, aged 5-12 years, as well as adults, as attitudes are shaped very early in life. Interventions targeted at parental behaviour and attitudes are thought to be most successful here (Ci Research, 2012).

Australia has also a designated National Financial Literacy Strategy, coordinated by the Australian Securities and Investments Commission (ASIC), the country's corporate, markets and financial services regulator. The national strategy in Australia was prompted by the work from OECD and INFE on financial education (ASIC, 2011), and emphasizes 'inclusiveness, engagement, diversity, knowledge and empowerment, improving outcomes, partnerships, and measurement' (Grifoni & Messy, 2012:26). The National

Strategy is built upon inclusiveness, engagement, diversity, knowledge, empowerment, improved outcomes, partnership and measurement (ongoing monitoring of progress) (ASIC, 2011). There are four key elements of this strategy: the use of *educational pathways* to improve financial literacy (notably not just classroom-based learning), the provision of information, support and useful tools, development of solutions innovated beyond education and information, and the collaborative use of partnerships with stakeholders and industry to make the best progress (ASIC, 2011). Table 3, below, usefully maps Australia's National Financial Literacy Strategy.

Two key programmes within the Australian strategy are the Money Smart website for consumers and its counter part, Money Smart Teaching, directed at educators. Like the Money Advice Service in the United Kingdom, Money Smart provides Australian consumers with copious information to assist people with numerous financially relevant elements of modern life, including to understand insurance, debt management, savings, investment, superannuation and avoid scams (ASIC, 2012). This site took over the role of previous programmes, FIDO and Understanding Money.

Table 3: A map of Australia's National Financial Literacy Strategy (sourced directly from ASIC, 2011:10).

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