Consultant Report
Securing Australia's Future
STEM: Country Comparisons

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STEM: Country Comparisons – Europe …a critical examination of existing solutions to the STEM skills shortage in comparable countries

Dr Ian R Dobson
Honorary Senior Research Fellow
School of Education and Arts
University of Ballarat

Adjunct Professional Staff Member
Monash University

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Introduction

This report represents an 'extreme' synthesisation of the myriad reports and studies on the STEM[1] disciplines that have been published in Europe since the start of this century. Given the copious flow of material and the large number of STEM studies, it has been as difficult to know what to leave out as what to include. Many of the reports describe the same or similar problems and make similar recommendations to solve those problems. Some studies provide suggestions about specific measures that might counteract young people's disinclination to persist in STEM studies and into STEM occupations, but it is extremely difficult to measure the long-term impact of any reform or group of reforms.

Many of the studies undertaken within Europe came out of projects funded by bodies such as the European Union out of which other (similar) projects evolved. As one project supersedes another, it is sometimes difficult to establish which projects are still current. Websites tend not to be dismantled once initial project funding has finished. Establishing a taxonomy of many projects has been one of the challenges in establishing what *current* practice is across Europe. Projects that seem similar in their coverage acquire funding from a range of European funding agencies under an even wider range of programmes.

Scrutiny of issues relating to the STEM disciplines of science, technology, engineering and mathematics in Europe this century (and earlier) has been intensive and continuous. Pan-European organisations based on national representation, other bodies that are discipline-based or interest-group based, and national scholarly academies have been prolific. This is also an area that has spawned many acronymic studies and programmes, such as SPICE, STENCIL and LUMA, florally-monikered projects such as ROSE, IRIS and LILY, and interestingly named projects such as Pollen and Sinus-Transfer.

A present or future shortage of STEM professionals is claimed for most European countries, some more than others. Many organisations are promoting education and training in STEM disciplines directly or indirectly, including organisations that promote a tighter focus on science education, scientific literacy and research cooperation. What follows is a summary of what has been done by way of pan-European programmes, with mention also being made of specific intra-nation projects mentioned in the various European STEM studies. Some countries have been dealt with in more detail, so some of the material in this Europe-wide report recurs in specific country reports.

Across Europe, several organisations have played a major role, some more directly than others, in promoting the STEM cause. In order to provide a backdrop, the findings and recommendations from several of the available reports have been summarised below. One reason for doing so is to highlight the overall conformity of opinion about the STEM disciplines all the way along the path from primary education up to the labour market for qualified STEM workers. Most reports speak (at least) of the shortage of STEM professionals, the need to engage students at all levels in science to boost the supply of STEM workers, the need for innovative curricula, low student motivation, improved science assessment, teachers: their quality, motivation and up-to-datedness, and the gender imbalances within schools and other levels of education and in the workforce. Later sections look at a number of the actual programmes established, and the claims made for their efficacy (where such claims have been made).

[1] The acronym STEM has been used throughout, but some reports etc. use or prefer other abbreviations or acronyms, including MST and SET.

National membership-based organisations such as the OECD, the European Commission and European Schoolnet have been the main providers of STEM-related analysis and commentary from the public domain. Discipline-based organisations have also been important, such as FEARN, the European Federation of National Engineering Associations and the national Association of German Engineers (VDI – Verein Deutscher Ingenieure e. V.). Both have been important commentators and contributors to the STEM debates. National academies (of science, etc.) have been important participants in country-by-country discussions and Europe-wide discussions via ALLEA (ALL European Academies - the European Federation of 53 national academies of sciences and humanities from 40 countries). Input from the private sector has come from the European Round Table of Industrialists (ERT), which produced a major report in 2009, and BusinessEurope with yet another report in 2011.

Perceptions about science

The negative perceptions many students and others have towards science are mentioned in one context or another in several places throughout this report. Science's image is said to influence students' decisions about persisting with science, and in particular it is said to be an unattractive study and work prospect for girls and young women. The next section includes some notes on support for inquiry-based science education 'as a possible solution to the observed lack of interest in science' (ALLEA, 2012, p10).

The European Union has funded several projects aimed at research into overturning science's negative persona. These include MOTIVATION[2], a project that aimed to establish an exchange between countries about the factors that influence the image of science; and YOSIWEB[3], to use websites to promote a positive image of science.

In some cultures, the role of parents is important in students' scholastic and life choices. Although the ROSE survey has provided evidence from secondary students that their parents and siblings are important sources of inspiration for studying science (see later text), it was not possible to unearth any research that considered parents' attitudes to science.

European education

Europe is diverse, and its education systems are equally diverse. Some figures on the uptake of STEM follow, but by way of introduction, it should be observed that there are differences between European countries on several fronts. For example, the number of years of compulsory education varies, as summarised in Table 1. It is nine years in many countries (Belgium, Finland, Sweden and parts of federal Germany and Switzerland). It is 10 years in Denmark and Norway and parts of Germany and Switzerland), 11 in one Swiss canton and 13 in the Netherlands (Eurydice, 2012a). In fact, students in most western countries stay at school for longer than the legislated minimum. In Finland, for example, only 9-10 per cent of students do not continue immediately beyond the ninth year, but many eventually continue and complete school-based or pre-tertiary vocational studies.

There are also differences in the number of hours of instruction in mathematics and science, as shown in Table 1. Countries that spend the least time (on average) teaching mathematics and science tend to be the same in most cases, including

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2 http://cordis.europa.eu/documents/documentlibrary/118298181EN6.pdf
3 http://www.yosiweb.eu/

Belgium (Dutch and German-speaking), the Netherlands, Austria, Finland and Sweden. In terms of proportions of the school year, primary students spend from between nine per cent and 15 per cent on natural and social sciences. By the compulsory secondary years, natural and social sciences and teaching of foreign languages represented 40 per cent of taught time (Eurydice, 2012c)[4].

A detailed study on 'taught time' has been produced by Eurydice[5] and Chapter 3 and Annex 1 of the Eurydice report *Science Education in Europe: National Policies, Practices and Research* provide a detailed exposition of science as taught in primary and lower secondary schools in selected European countries.[6]

Table 1: Duration of Compulsory Education and the Proportion of Time Spent on Mathematics and Science

Country	**Years Spent in Compulsory Education**	**Mathematics**			**Science**		
		0 - < 2 Hours	2 - 4 Hours	> 4 Hours	0 - < 2 Hours	2 - 4 Hours	> 4 Hours
Austria	9	93.5	5.2	1.3	98.2	1.2	0.6
Belgium - Dutch sp.	9	90.4	6	3.6	94.7	3.7	1.6
Belgium - French sp.	9	82.8	10.8	6.4	89.3	7.3	3.4
Belgium - German sp.	9	94.6	4.5	0.9	97.4	1.6	1
Czech Republic	9	85.7	9.1	5.2	86.9	7.9	5.2
Denmark +	9	84.5	10.6	4.9	93.3	4.9	1.8
EU27		83.9	10.6	5.5	89.0	6.6	4.4
Finland	9	94.4	2.9	2.7	95.3	2.9	1.8
France	10	82.5	11.8	5.7	90.9	5.9	3.2
Germany	9-10	89.9	7.3	2.8	95.9	2.7	1.4
Italy	10	74.7	15.1	10.2	85.7	8.6	5.7
Netherlands	13	92.3	5.2	2.5	95.2	3	1.8
Norway	10	81.6	12.2	6.2	85.3	10.5	4.2
Poland	10	85.0	10.2	4.8	85.5	9.4	5.1
Portugal	12	83.2	13.2	3.6	94.2	3.8	2
Spain	10	73.6	18	8.4	84.0	10.3	5.7
Sweden	9	94.5	3.8	1.7	95.1	3.3	1.6
Switzerland #	9 – 11						
UK - England	11	89.2	6.3	4.5	89.0	5.2	5.8

Source:
Eurydice (2012a). Recommended time taught in compulsory education 2011/2012
Eurydice (2012b) Compulsory Education in Europe;
+ Denmark 10 years if compulsory pre-school is included
# Switzerland: Compulsory education varies between canton; no data for hours

It is also the case that there are differences between European countries in their students' performance in international tests. Taking the 2009 PISA tests as an example, Table 2 shows a considerable spread in relative performance.

4 http://eacea.ec.europa.eu/education/eurydice/key_data_en.php
5 Recommended annual taught time in full-time compulsory education in Europe, 2011/2012. http://eacea.ec.europa.eu/education/eurydice/documents/facts_and_figures/taught_time_EN.pdf
6 http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/139EN.pdf

Table 2: Mean Score in Mathematics & Science: PISA Results 2009 Selected Countries – Ranked according to Score in Science

Country	**Reading**	**Mathematics**	**Science**	**Variance Between Schools #**
Finland	536	541	554	7
Belgium	506	515	526	58
Netherlands	508	526	522	55
Germany	497	513	520	64
Switzerland	501	534	517	30
UK	494	492	514	30
Poland	500	495	508	17
OECD Average	**493**	**496**	**501**	**39**
Czech Republic	478	493	501	46
Norway	503	498	500	9
Denmark	495	503	499	12
France	496	497	498	
Sweden	497	494	495	20
Austria	470	496	494	60
Portugal	489	487	493	28
Italy	486	483	489	73
Spain	481	483	488	18

Source: OECD. PISA 2009 Database
Average variance in student performance in reading scores explained by school governance

Finland's performance in the PISA tests has been widely acknowledged, and if it is valid to correlate hours spent on subjects with the PISA results obtained, it would seem that Finland produces high PISA scores while being among the countries whose students spend a lower proportion of time in mathematics and science classes. As has been well publicised, Finland's PISA success seems to have come from its way of handling school education, with its single system of comprehensive schooling for all, no assumption that raising student achievement will come out of making schools and teachers more accountable, and there are no external tests before year 12. In addition, there is a culture of trust and 'distributed moral leadership', with continual adjustment of schooling to the changing needs of individuals and society (Sahlberg, 2009).

Table 3 also provides an indication of the variability between schools within each country identified in PISA 2009. For example, in Finland, the differences between schools (explained by school governance) explain only seven per cent of the variability in performance in reading. This is a reflection of the equitable nature of Finnish schooling and the relative homogeneity of its schools. Finnish schools, for example, also provide students with a prepared lunch, and help ensure that all students receive appropriate medical and dental treatment during their school years. As noted in the PISA 2009 report for Finland, 'The commitment to education and to the well-being of children has deep roots in Finland's culture, and provides the bedrock on which the comprehensive school movement rests… The underlying belief… was that all children could be expected to achieve at high levels, and that family background or regional circumstance should no longer be allowed to limit the educational opportunities open to children' (OECD, 2010b, p. 129).

Norway and Denmark also had relatively 'homogenous' schools across their school systems. At the other extreme are countries such as Italy, Germany and Austria, where much higher proportions of performance differences between schools can be explained by differences between schools.

Teachers, curriculum and inquiry-based science education

Teachers, what they teach and how they teach it are important variables in European education. Across Europe, teachers are required to have undertaken both academic studies and ‘education’ studies to provide them with theoretical and practical skills. The two models under which this knowledge is acquired are the concurrent model, and the consecutive model. Under the former, the ‘education’ components are provided at the same time as the subject study components. Under the latter, the academic components are usually completed before the ‘education’ training (Eurydice, 2012c).

Most European systems provide pre-primary and primary education according to the concurrent model, and upper secondary school education according to the consecutive model. Lower secondary school education can be one or the other, depending on which country one is in. For example, ‘the concurrent model is the only possible option in Belgium, Denmark, Germany, Slovakia and Turkey. However, in Estonia, Spain, France, Italy, Cyprus, Luxemburg and Hungary, the consecutive model is the only available pattern of training’ (Eurydice 2012c, p. 109).

The level of qualifications required of teachers varies from one country to another. For pre-primary teachers, at least a bachelor’s degree (ISCED[7] Level 5) is required, but in some countries (including Germany), the minimum qualification is ISCED 3 or 4. Primary teachers must have at least a bachelor’s degree, but ten countries, including Germany and Finland, require teachers to hold a master’s degree (Eurydice, 2012c).

Lower secondary school teachers must have a master’s degree in about half of European countries/regions. Upper secondary teaching requires a master’s degree in most countries however, in 11 countries or regions a bachelor’s degree suffices. Prospective teachers must also undergo a period of induction in 13 countries or regions (Eurydice, 2012c).

Some European countries face current or future teacher shortages. It has been reported, for example, that many students in some countries ‘are being taught in schools where teaching is hindered by a lack of qualified teachers in the core subjects (language of instruction, mathematics and science). In Germany, the Netherlands and Turkey, the percentages are high not only for the core subjects but also for other school subjects’ (Eurydice, 2012c, p14). Results from PISA 2009 suggest that around about 15 per cent of 15-year-old students were taught in schools where the schools were ‘hindered by a lack of qualified science and mathematics teachers’ (Eurydice, 2012c, p113). However, around half of the European countries had no major problems in the recruitment, training and retention of qualified teachers. Some countries have a general shortage of teachers.

Science can be taught as an integrated subject, or as separate subjects (chemistry, physics, etc.). Across Europe, primary school science is taught within a single subject, except in the Netherlands (European Commission, 2006). By lower secondary school, separate science subjects are usually taught. Most countries prescribe science activities in the curriculum, but not the Netherlands, Belgium (Flemish community) and Sweden. These countries express science education in terms of teaching and learning objectives (European Commission, 2008). Teacher training follows these differences in the way teaching is provided in primary and secondary education.

The science curriculum for primary and lower secondary education in most countries is couched in terms of ‘science in context’, where the context refers to either the history

[7] Where enrolments or graduations are mentioned, the International Standard Classification of Education (ISCED 1997) classification has been used. The levels are: pre-primary (Level 0), primary (1), lower secondary (2), upper secondary (3), post-secondary, non-tertiary (4), tertiary, first stage (5) and tertiary, second stage (6).

of science, or contemporary societal issues (or both) (Eurydice, 2006).[8] Science curricula vary between countries in Europe, and they can be presented in different ways. For example, they can refer to the broad areas of knowledge to be covered, they can specify the specific activities to be carried out, or the learning outcomes to be achieved. All education systems have science curricula that are ultimately subject to following directives from education authorities (Eurydice, 2006).

As noted by Eurydice (2006), school science curricula are the subject of debate and reforms in the great majority of European countries. National approaches can vary, but matters such as methodological approaches and the amount of teaching time are important. In some countries, this is associated with blanket curriculum reform, including reforms concerned with methodology.

Inquiry-based science education (IBSE) is often considered in the context of curriculum reform. So far, this modality has not been embraced uniformly across Europe, but it is much discussed as a concept.

The ALLEA report (2012)[9], assembled by the group representing Europe's learned academies, has been particularly prominent in its promotion of IBSE. The starting point of the ALLEA report is acknowledged as being the *'Rocard report'* commissioned by the European Union. The Rocard Report: 'described inquiry-based science education (IBSE) as a possible solution to the observed lack of interest for science. Yet, it must be recognised that the positive aspects of IBSE pilot experiences made by students, teachers, parents and communities do not easily translate into a general and systemic change of school pedagogy' (ALLEA, 2012, p. x). ALLEA note that apparent successes with IBSE cannot be correlated with scores achieved by students in international tests, but they note that IBSE strengthens creativity and critical reasoning, and that 'it typically transcends traditional disciplinary divisions, as IBSE teachiung units are problem centred' (ALLEA, 2012, p. 10).

European Union funding for research into IBSE has enabled several projects to be undertaken. For example, the INQUIRE project[10], which, starting from the fact that IBSE is not practised in most European classrooms, sought to provide training to teachers to try IBSE methods in their everyday teaching.

Sums devoted to research into IBSE and IBSME when mathematics is included, tend to attract considerable funding. The Fibonacci project was funded with a grant of €4.7 million from January 2010 to February 2013, to look into the large scale dissemination of IBSME. This project built on other studies and arrangements, such as POLLEN and SINUS-Transfer (See country report on Germany).

Another EU-funded project (€780,000) was 'Mind the Gap'[11], which ran between April 2008 and March 2010. Its aim was to gather, exchange, develop and disseminate ideas of good practices in IBSE.

Yet another on-going project is PRIMAS[12] – Promoting Inquiry in Mathematics and Science Education (< €3 million, January 2010 to December 2013): This project aims to effect a change across Europe in the teaching and learning of mathematics and

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8 http://www.kidsinnscience.eu/upload/file/Eurydice_Science_teaching_in_schools_in_Europe.pdf

9 http://www.allea.org/Content/ALLEA/WG%20Science%20Education/ALLEA%20Report_A%20renewal%20of%20science%20education%20in%20europe.pdf

10 http://cordis.europa.eu/search/index.cfm?fuseaction=proj.document&PJ_RCN=11687770

11 http://uv.uio.no/english/research/projects/mindingthegap/index.html

12 http://www.primas-project.eu/servlet/supportBinaryFiles?referenceId=6&supportId=1247

science by supporting teachers to develop inquiry-based learning pedagogies so that, in turn, students gain first-hand experience of scientific inquiry'. The goal is to train 20 in-service trainers in each of the 12 participating countries.

STEM uptake

The ultimate test of the success of STEM policies is whether or not the education and training systems produce enough skilled people to meet future overall labour force needs. Without having exact details of future vacancies (and perhaps a crystal ball), numbers of graduates in STEM areas provide at least a statistic to help compare European nations.

The European Union comprises over 502 million people in 27 countries (Wikipedia, n.d.). Table 3 provides figures on population and the labour force of selected countries, plus Norway and Switzerland, which are not members of the European Union. With a population of nearly 82 million, Germany has rather more people than the other countries shown (France has a population of about 61 million and the United Kingdom 59 million). The countries shown will lose around 20 per cent of their current labour force over the next 15 years, with Finland likely to lose a higher proportion than other countries.

The labour forces of the countries shown have a slightly different distribution between agriculture, industry and services. Those countries with a higher industry base are likely to need a more technically knowledgeable workforce than those with a higher proportion in services. Of course, many 'services' also require a strong base in technology. If these assumptions are true, Norway and Finland might need to ensure a higher throughput of technically strong workers than some of the other countries.

Table 3: Population and Labour Force - Selected Countries 2010

	Belgium	Denmark	Finland	Germany	Netherlands	Norway	Sweden	Switzerland
Total Population 2010 (millions) #	11.0	5.6	5.4	81.8	16.7	4.9	9.4	
Age Group #								
50-54	7.1%	6.6%	7.0%	7.6%	7.2%	6.5%	6.2%	
55-59	6.4%	6.3%	7.1%	6.7%	6.5%	6.1%	6.1%	
60-64	5.9%	6.5%	7.5%	5.7%	6.6%	5.9%	6.5%	
Size of Labour Force (millions) +	5.2	2.9	2.7	43.6	7.8	2.6	5.0	4.9
Labour Force Composition +								
Agriculture	0.7	4.5	3.0	0.8	2.7	2.6	1.8	1.3
Industry	21.7	19.1	29.2	28.6	24.2	39.7	27.3	27.5
Services	77.6	76.4	67.8	70.6	73.1	57.7	70.9	71.3

Source:# Eurostat
+www.cia.gov

Table 4 provides an indication of the relative uptake of STEM disciplines by reporting the number and proportion of tertiary graduates (from course levels ISCED 5 and 6) for 2010. The table shows that there is considerable variability within Europe. From the countries reported here, the proportion of STEM graduates varies from almost one-third (Finland), down to one-sixth (the Netherlands). The EU (27 countries) proportion is 21.3 per cent.

Table 4: Tertiary Graduates in All Fields and Science & Engineering (ISCED Levels 5 & 6), 2010 – Ranked, by Science & Education % of Total

Country	All Fields	Science & Engineering #	
	Total	No.	% of Total
Finland	50,977	16,212	31.8%
Austria	57,538	16,739	29.1%
Sweden	61,217	16,490	26.9%
France (2009)	628,089	164,374	26.2%
Germany	572,928	146,630	25.6%
Portugal	78,609	19,551	24.9%
Spain	336,810	83,108	24.7%
Czech Republic	102,898	24,081	23.4%
Ireland	58,837	13,650	23.2%
Italy	214,965	48,591	22.6%
United Kingdom	709,880	158,668	22.4%
European Union (27 countries)	3,848,444	818,020	21.3%
Switzerland	84,965	16808	19.8%
Denmark	54,271	10,488	19.3%
Belgium	102,693	16,562	16.1%
Norway	37,844	6,054	16.0%
Poland	624,799	98,324	15.7%
Netherlands	131,545	18,426	14.0%

comprises the fields of science, mathematics & computing and engineering, manufacturing & construction
Source: Eurostats

The next table also provide measures of the uptake of STEM, but the numbers show variability between countries in part because of the differences in school structure.

Finland and several other countries, for instance, has an education system in which students reach a decision point after nine years of compulsory schooling. Some students then go into an upper secondary stream as the precursor to higher education, whereas other students undertake vocational secondary studies. The graduates of this vocational stream are then labour market ready as trained professionals and paraprofessionals. This organisational form is therefore suited to the provision of statistics about school 'graduations'. Nonetheless, it serves to show that some countries seem to fare better than others in the quest for a better prepared technical workforce.

Table 5 is ranked according to the proportion of vocationally trained workers prepared for labour markets in 2010. On the basis of these figures, some countries seem to have a relatively high proportion of vocationally-trained STEM workers coming through.

Comparing Tables 4 and 5 provides an opportunity to see which European countries seem better provided with a supply of both tertiary graduate and vocational STEM workers. Again, Finland would seem to be one of the better placed, with 31.8 per cent of its tertiary graduates being in STEM fields of study, and 34.2 per cent of its vocationally trained graduates. Several other countries have more than a quarter of their tertiary graduates AND more than a third of their vocationally trained graduates in STEM areas: Sweden, France, Germany and the Czech Republic. Some other countries are relatively low in the number of tertiary graduates, but relatively high in vocationally trained graduates: Switzerland, Denmark, Norway and Poland. These patterns are summarised in Figure 1.

Table 5: Upper Secondary and Vocational Graduations in All Fields and Science & Engineering, 2010

Country	Upper secondary education (ISCED Level 3) - pre-vocational and vocational programme orientation			Post-secondary non-tertiary education (ISCED Level 4) - pre-vocational and vocational			Upper Sec. & Post-Sec Voc.
	All FoS	Science & Engineering		All FoS	Science &		
		No.	% of Total		No.	% of	% of
Norway	23,395	12,218	52.2%	5,828	1,538	26.4%	47.1%
Poland	207,468	104,038	50.1%	76,350	10,996	14.4%	40.5%
Switzerland	69,236	25,562	36.9%	4,835	4,105	84.9%	40.1%
Sweden	57,761	22,810	39.5%	3,856	1,016	26.3%	38.7%
Denmark	31,590	11,158	35.3%				35.3%
Germany	456,017	157,902	34.6%	121,675	42,901	35.3%	34.8%
France	527,075	182,937	34.7%				34.7%
Finland	61,671	21,508	34.9%	5,298	1,418	26.8%	34.2%
Czech	74,754	30,992	41.5%	24,780	2,354	9.5%	33.5%
Spain	191,644	60,239	31.4%				31.4%
EU 27	2,715,951	856,211	31.5%	410,435	98,422	24.0%	30.5%
Austria	77,839	22,540	29.0%	27,331	6,418	23.5%	27.5%
Netherlands	179,009	37,397	20.9%	1,766	1,246	70.6%	21.4%
Belgium	94,322	15,940	16.9%	28,436	6,908	24.3%	18.6%
Ireland	40,203	1,193	3.0%	6,834	3,574	52.3%	10.1%
Portugal	39,770		0.0%	3,926	1,601	40.8%	3.7%
UK (2008)	163,848		0.0%				0.0%

Comprises the fields of science (FoS), mathematics and computing and Engineering, manufacturing and construction

Source: Eurostats

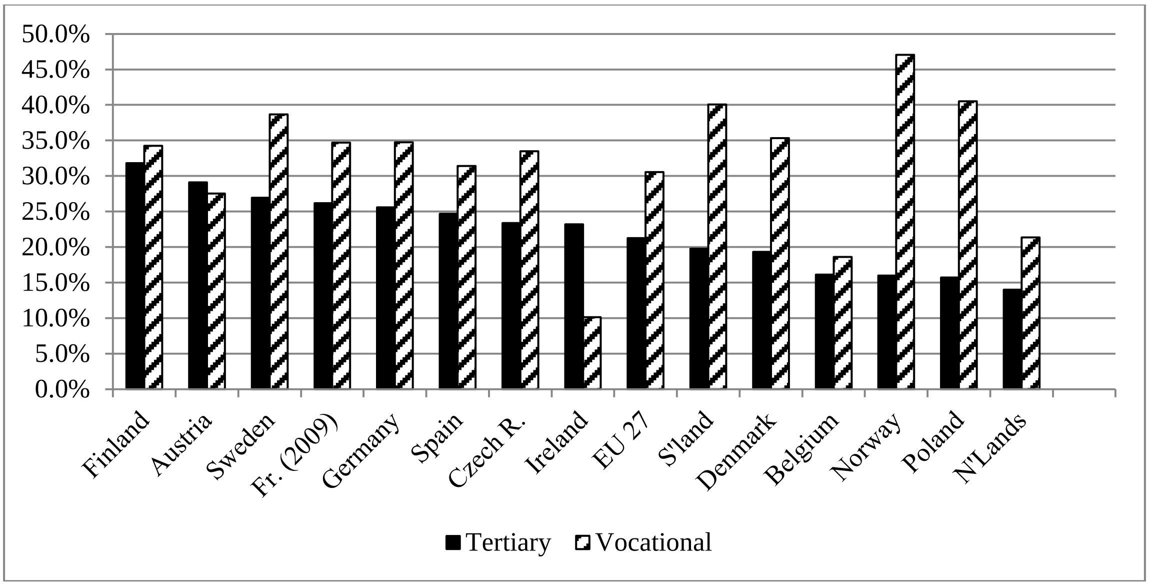


Figure 1: Tertiary and Vocational Education Graduates – 2010

It is possible that a high number of tertiary graduates might compensate for fewer vocational graduates, but countries such as the Netherlands, Belgium and Ireland seem to be producing lower proportions of graduates in both categories than other countries.

Although the tables and graphs above show the relative positions of selected European countries in snapshot year 2010, they did not indicate anything about change over time. Tables 6, 7 and 8 summarise the situation for graduations at ISCED Levels 3, 4 and 5/6 (upper secondary, post-secondary, non-tertiary and tertiary), respectively. There is at least one aberration in the tables, however: not all countries are represented in statistics in both 2002 and 2010. And therefore, the figures for benchmark-providing European Uninio 27 countries re not s full reflection of reality Taking Table 8 as an example, the increase in tertiary science and engineering graduates for Germany exceeds the total increase for the European Union 27. However, some countries (France and Greece, for example) are not represented in 2002 figures.

At ISCED Level 3, nearly 2.8 million students completed their studies in 2010. There was an overall growth in the European Union 27 countries of nearly 423,000 or 18.4 per cent. Science and engineering graduates numbered over 856,000 in 2010, about 31.5 per cent of graduates in all fields. The number increased by 16.5 per cent, slightly less that the increase overall. Within countries, there have been both expansions and contractions. In Germany, there was a decline of 19.9 per cent of graduations at this level overall, and 18.2 per cent in science and engineering. Perhaps this indicates a reduction of uptake of STEM studies in Germany. There has also been a rapid increase in Sweden, from a low base.

Table 6: Graduations 2010 and Growth 2002 – 2010 – ISCED Level 3 Upper Secondary

Country	All Fields			Science & Engineering		
	Graduations - 2010	Growth 2002-10		Graduations - 2010	Growth 2002-10	
		No.	%		No.	%
EU27	2,715,951	422,603	18.4%	856,211	121,467	16.5%
Belgium	94,322	20,830	28.3%	15,940	-1,916	-10.7%
Denmark	31,590	-4,641	-12.8%	11,158	92	0.8%
Germany	456,017	-113,607	-19.9%	157,902	-35,216	-18.2%
Netherlands	179,009	60,960	51.6%	37,397	2,348	6.7%
Finland	61,671	14,313	30.2%	21,508	5,459	34.0%
Sweden	57,761	26,068	82.3%	22,810	14,573	176.9%
Norway	23,395	418	1.8%	12,218	1,248	11.4%
Switzerland	69,236	17,831	34.7%	25,562	6,614	34.9%

Source: Eurostat

Table 7 looks at post-compulsory education of people completing ISCED Level 4 qualifications. There were fewer of these (about 410,000 in the European Union 27 countries) than for ICSED Level 3 (more than 2.7 million), and ISCED graduations in science and engineering represented about 24 per cent. Most countries reported here had few graduations at this level, the exception being Germany. Although the number of graduates in all fields of study for Germany increased by 8.0 per cent, the increase in the number of science and engineering graduates declined by 0.3 per cent, indicating a reduction in the overall proportion of science and engineering graduates. From the figures for Switzerland it would seem that there has been a change in the way education is arranged. Science and engineering graduates made up about 85 per cent of all graduates at this level in 2010, but the number of graduates at this level in all fields of education was 70.6 per cent between 2002 and 2010, and by about 51 per cent in science and technology.

Table 7: Graduations 2010 and Growth 2002 – 2010 – ISCED Level 4 Post-secondary, Non-tertiary

Country	All Fields			Science & Engineering		
	Graduations - 2010	Growth 2002-10		Graduations - 2010	Growth 2002-10	
		No.	%		No.	%
EU27	410,435	30,523	8.0%	98,422	3,644	3.8%
Belgium	28,436	7,064	33.1%	6,908	1,446	26.5%
Denmark	:				0	
Germany	121,675	9,059	8.0%	42,901	-125	-0.3%
Netherlands	1,766			1,246	1,246	
Finland	5,298	2,295	76.4%	1,418	815	135.2%
Sweden	3,856	3,493	962.3%	1,016	808	388.5%
Norway	5,828	3,487	149.0%	1,538	466	43.5%
Switzerland	4,835	-11,599	-70.6%	4,105	-4,248	-50.9%

Source: Eurostat

The largest group of graduates are tertiary graduates: over 3.8 million in 2010, up by about 440,000 or nearly 20 per cent from 2002. Table 8 shows the relative decline in the uptake of science and engineering. Although the number of graduates increased by 67,208 between 2002 and 2008, this represented an increase of 9.0 per cent, compared with an increase of 19.9 per cent in the number of graduates in all fields of study. This pattern was not uniform across Europe, however. Germany and Finland show considerable growth overall, and in the case of Finland the proportion of tertiary graduates made up by those from science and technology has increased relative to the total of graduates in all fields of study. As well as Finland, the proportion of all tertiary graduates made up by science and engineering graduates increased in Denmark and Norway. All the other countries identified in Table 8 showed an increase in the number of science and engineering graduates, but the proportion declined. The rate of growth in science and engineering graduations was considerably lower in Belgium, the Netherlands, Sweden and Switzerland.

Table 8: Graduations 2010 and Growth 2002 – 2010 – ISCED Level 5/6 Tertiary

Country	All Fields			Science & Engineering		
	Graduations - 2010	Growth 2002-10		Graduations - 2010	Growth 2002-10	
		No.	%		No.	%
EU27	3,848,444	639,579	19.9%	818,020	67,208	9.0%
Belgium	102,693	29,754	40.8%	16,562	2,819	20.5%
Denmark	54,271	11,590	27.2%	10,488	2,412	29.9%
Germany	572,928	279,008	94.9%	146,630	69,932	91.2%
Netherlands	131,545	45,727	53.3%	18,426	4,867	35.9%
Finland	50,977	12,354	32.0%	16,212	5,118	46.1%
Sweden	61,217	15,685	34.4%	16,490	1,956	13.5%
Norway	37,844	8,192	27.6%	6,054	1,504	33.1%
Switzerland	84,965	27,266	47.3%	16,808	3,346	24.9%

Source: Eurostat

STEM and the workforce

Whether a country has poor prospects for the continued existence of highly qualified STEM workforce is dependent on the numbers entering and progressing through STEM education, and the rate at which the workforce is ageing: how many retirements will there be in years to come. Although Europe in general is relatively ‘old’, some countries might be better off than others.

Table 9 provides a comparison between selected countries with regard to employment in science and technology as a proportion of the economically active population in the age group 25-64. This table aggregates those who have either successfully completed education in a STEM field of study or are employed in an occupation where such education is normally required. The seven countries that are the focus of further analysis in this report were ranked in the top eight in 2011.

Table 9: Human resources in science and technology as a share of labour force – Selected Countries and Years Total % - Ranked, 2011

	2000	2005	2010	2011
Norway	45.3	48.0	51.5	54.8
Switzerland	46.9	49.4	53.7	54.7
Finland	48.0	48.0	50.6	52.6
Netherlands	45.4	49.3	51.9	52.2
Sweden	44.5	47.3	50.8	52.2
Denmark	42.7	49.1	51.0	51.5
United Kingdom	36.9	41.2	45.1	51.2
Belgium	41.7	46.2	49.3	49.6
Ireland	32.4	39.1	45.9	48.8
France	34.7	40.2	43.8	48.1
Estonia	39.8	44.8	45.0	47.0
Germany	41.5	43.1	44.8	44.9
Slovenia	30.6	37.3	40.8	42.4
EU (27 countries)	34.0	37.8	40.5	42.3
Austria	31.4	37.9	39.2	40.5
Czech Republic	31.5	34.5	37.8	36.0
Slovakia	27.7	30.7	33.5	34.1
Greece	25.3	29.3	32.4	33.6
Portugal	17.3	21.5	23.9	27.0

Source: Eurostat

Table 10 also demonstrates that some countries, Finland in particular, have been relatively better at producing top experts in STEM. The table shows students participating in the second stage of tertiary education in science and technology fields of study, as a percentage of the population 20-29 year old. This includes the students in tertiary programmes which lead to an advanced research qualification (ISCED Level 6), in the educational fields *Science, Mathematics and Computing*, and *Engineering, Manufacturing and Construction*. All countries with at least 0.4 per cent of the age cohort population are shown. No equivalent data were available for Germany or the Netherlands.

Table 10: Doctoral students in science and technology fields – Total % of the population aged 20-29 – Selected Countries and Years

Country / Year	2000	2005	2006	2007	2008	2009	2010
Finland	1.30	1.33	1.36	1.38	1.36	1.30	1.29
Czech Republic	0.45	0.79	0.68	0.72	0.81	0.81	0.84
Switzerland		0.73	0.75	0.75	0.75	0.78	0.81
Sweden	0.77	0.87	0.83	0.79	0.74	0.72	0.71
Austria	0.71	0.47	0.49	0.54	0.53	0.55	0.69
Ireland	0.28	0.35	0.34	0.35	0.38	0.45	0.58
Estonia	0.23	0.39	0.42	0.46	0.51	0.53	0.56
Greece		0.85		0.53	0.52		0.55
Slovakia	0.32	0.43	0.46	0.45	0.43	0.43	0.50
Norway	0.05	0.35	0.37	0.41	0.43	0.46	0.49
Portugal	0.22	0.38	0.40	0.40	0.38	0.40	0.49
Denmark	0.25	0.27	0.30	0.27	0.38	0.45	0.48
France			0.36	0.40	0.41	0.43	0.44
Belgium	0.22	0.26	0.26	0.25	0.34	0.40	0.43
Slovenia		0.17	0.17	0.21	0.22	0.26	0.43
United Kingdom	0.47	0.52	0.50	0.51	0.40	0.39	0.40

Source: Eurostat

STEM and gender

All data indicate that women predominate among tertiary enrolments and graduations, but are in the minority in the STEM disciplines, particularly engineering and information technology. This is amply demonstrated in Figure 2, which shows all (female and male) STEM graduates as a proportion of tertiary graduates in all fields of study, compared with the proportion of female STEM graduates to female tertiary graduates in all fields of study. For example, about

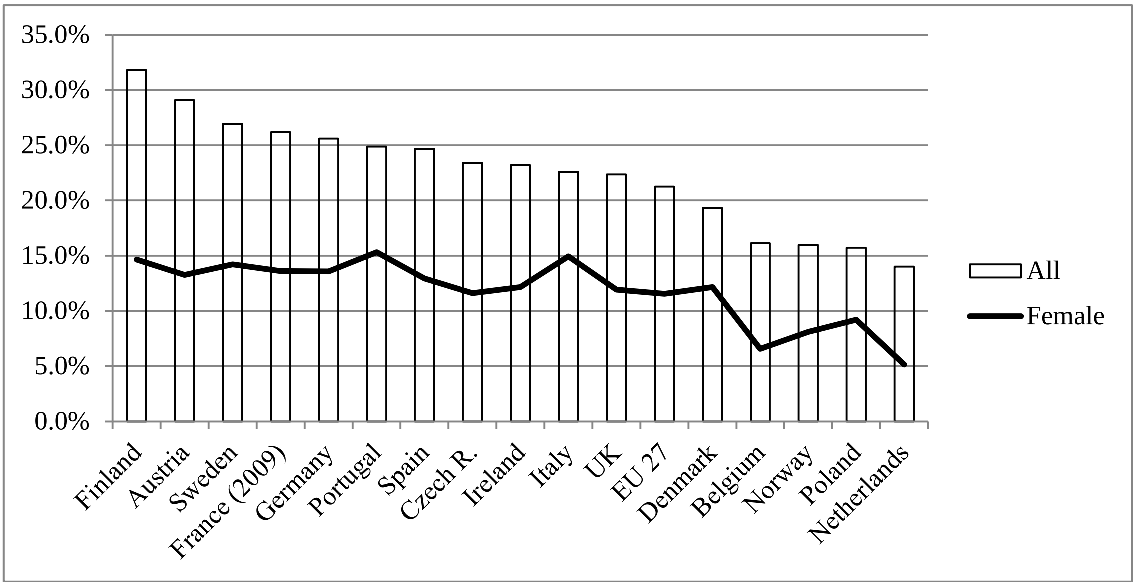


Figure 2: Tertiary Graduates – 2010 – STEM graduations (female and male) as a proportion of tertiary graduations in all fields of study; STEM graduations by women as a proportion of female graduations in all fields of study.
Source: Derived from Eurostat

Thirty-two per cent of tertiary graduates in Finland are in STEM fields, but less than 15 per cent of female tertiary graduates are. Naturally, the lower the overall proportion of tertiary STEM graduates, the lower will be the proportion of female STEM graduates. Data are shown here for a single year (2010), but the OECD has reported '… that the situation has changed only slightly since 2000, despite many initiatives to promote gender equality …' (OECD, 2012, p. 77).

Gender patterns are different among vocational graduates, in which men are in the majority in many countries. In Figure 3, the dotted line shows the proportion of women in all fields of study among vocational graduates, with the black and white columns representing the proportion of women among science and engineering graduates, respectively. Only among science graduates in Switzerland is the proportion of women similar to the proportion of women in all fields of study.

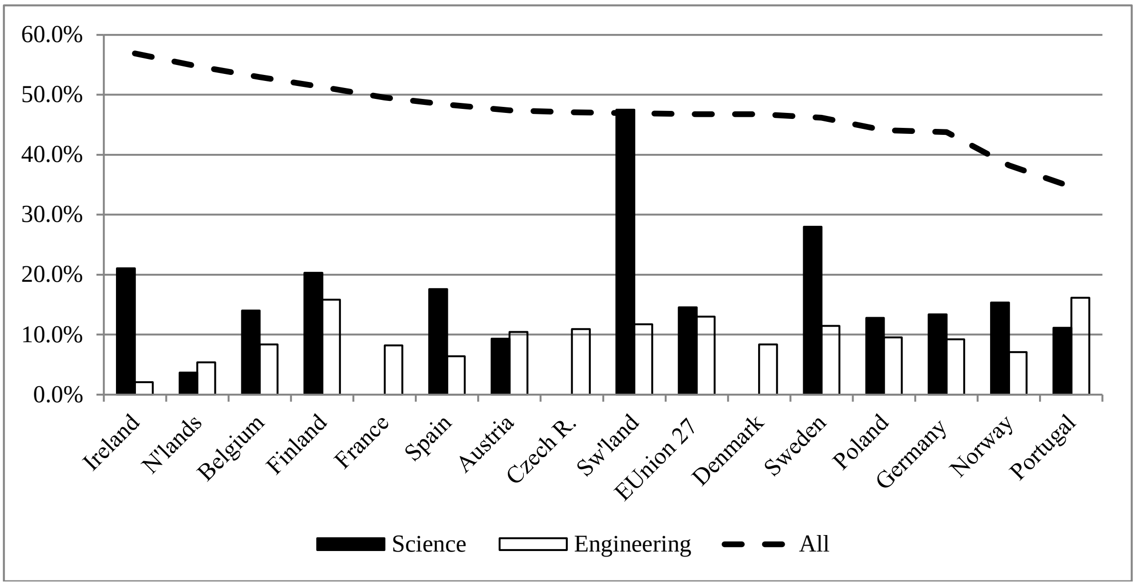
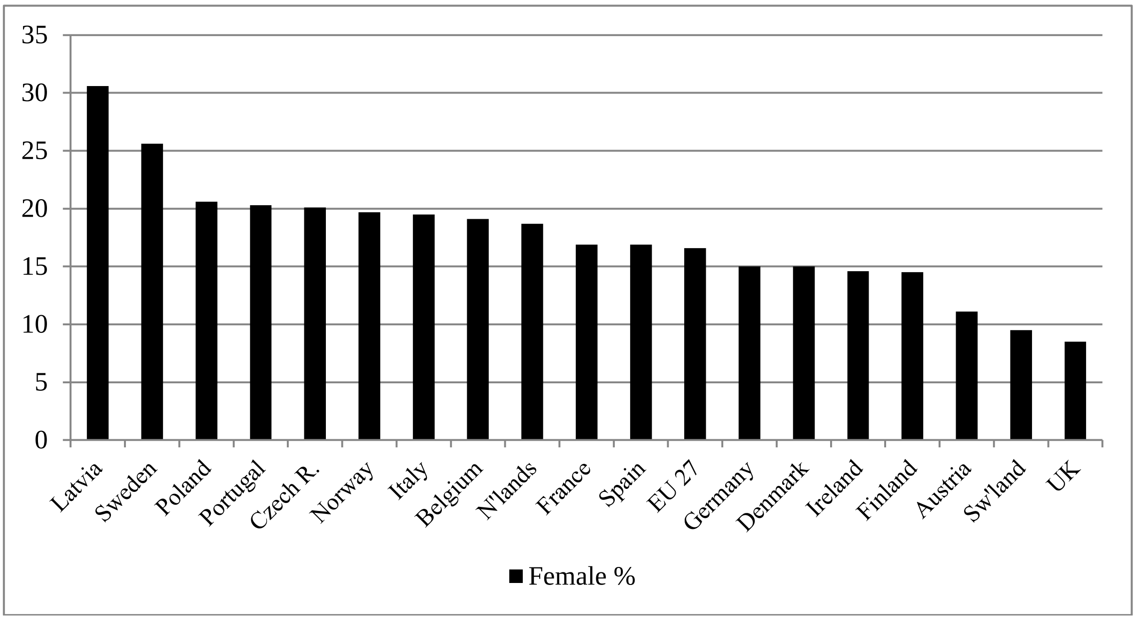


Figure 3: Vocational Graduates – 2010 – Female % of All Fields of Study& Female % of Science and Engineering Graduates

These graduation patterns are repeated in the workforce, at least for engineers. The Association of German Engineers (VDI) produced its *European Engineering Report* in 2010, and among other things, it reported on female participation in Engineering. The overall span of women in



Source: VDI (2010). European Engineering Report (Based on Fig. 3 from that report)
Figure 4: Female Employed Engineering Workers – Proportion of total, 2007

the engineering workforce in 2007 ranged from a low of 8.5 per cent in the United Kingdom, to just over 30 per cent in Latvia.

Getting girls and young women to enter the STEM fields of study and to move on to a career in a STEM occupation is often couched in terms of women as an untapped source of STEM professionals. It has been said that recruiting more women to STEM has both quantity and quality aspects '… because a higher participation from women in [STEM] may expand the scope and way of thinking, prioritising and working within this area and contribute to gender equity' (IRIS, 2008, p. 5).

Stereotypes, negative perceptions and external pressures seem to be responsible for the continued disinclination to go into STEM. As with the recommendations made about stimulating STEM in general, many of them are the same or similar from report to report. These most commonly cover the need for reforms to teacher training and curriculum, role model development, promoting multi-disciplinarity, and mentoring (OECD, 2008).

One Europe-wide initiative to promote women going into science is the EU's 'Women in Research and Innovation' campaign, which is part of a wider EU strategy for gender equality in research and innovation. It was launched in June 2012. According to the website, 'the first phase of the *Science: It's a girl thing*![13] campaign targets girls aged 13-18 – especially those who would not normally be interested in careers in research. Through online and face-to-face activities with inspiring women scientist role models, the campaign will reach out to these teenagers to give real information about the excitement and challenges of being a professional scientist or engineer'. The website provides profiles of women in science, provides 'six reasons why science needs you' and a list of 'dream jobs'. However, the campaign became slightly tarnished because of the adverse reaction to the initial video clip targeted at young girls. (The video clip is no longer available on the EU website, but is elsewhere on the internet[14]). According to the website, the second phase of the campaign will target young women aged 19-25 at university and encourage them to choose research as a career. The visual presentation and activities of this phase will be adapted for this target audience.

Some countries have women-specific guidance programmes in place within existing programmes. These include the (German) Go MINT! as part of the National Pact for Women in MINT (German for STEM). It was established in 2008 to try to raise interest in female pupils in STEM subjects '… by offering assistance in deciding on a course of study and facilitation of contacts with the working environment'[15].

In Finland, the GISEL Project (gender issues, science education and learning) conducted between 2002 and 2005 had similar aims. The GISEL project was informed via usage of the Norway-developed ROSE questionnaire, for 15 year olds, described below.

STEM reports

The best year to pick as the starting point for an analysis of STEM-promoting activity is moot; concerns about assuring a technically-competent workforce have been around for decades. Restricting the focus to this century, in 2001 European education ministers sought to contribute to 'the Lisbon process of fostering a dynamic and innovative knowledge-based economy' by increasing enrolments in scientific and technical fields (Kearney, 2011, p. 3). Subsequently, the European Commission set up the Mathematics, Science and Technology (MST) cluster (of 13 interested countries), which produced reports on science education and mathematics education.

The general argument that is run across Europe (as in the rest of the world) is that technological development is necessary for continued economic development and that future shortages of a labour force skilled in the STEM disciplines will be an obstacle to economic growth (BusinessEurope, 2011). That there will be a STEM workforce shortage (if there is not already one) is posited on two demographic grounds. First,

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13 http://science-girl-thing.eu/en
14 http://www.youtube.com/watch?v=g032MPrSjFA
15 http://www.komm-mach-mint.de/English-Information

changes in demographic patterns within Europe mean that there are relatively fewer young people to move through the education system towards labour markets, and lower proportions of these young people are being attracted to studies in the STEM disciplines. Second, relatively high numbers of current labour market participants are approaching retirement age.

Attitudes to science and technology by young people in much of Europe are such that the STEM professions are not seen as attractive propositions. Kearney (2011, p. 3) emphasises what is in effect said in many reports, that '…two actions are at the heart of the drive to make STEM studies and professions a more popular option for young learners: the development of effective and attractive STEM curricula and teaching methods, and improved teacher education and professional development'. Most European countries have national strategies, and others have established dedicated centres, nationally, regionally or locally. Some countries have both.

These issues lead into considerations of how to increase student interest, including the need to change the nature of science education and the quality and up-to-datedness of teachers' knowledge.

The European Commission produced a report entitled *Europe needs more scientists: increasing human resources for science and technology in Europe*[16] in 2004. Starting from the premise that there is a European crisis in the production of human resources for science, engineering and technology, the authors provide recommendations that overlap with recommendations of authors of similar reports produced before and since. These relate to matters such as the need for a common European policy, the need to attract young people into 'science' study and labour market, the need to increase involvement by women, the need for university teaching to improved, and not aimed exclusively at those contemplating an academic future and the need to popularise and communicate 'science' more broadly.

Among the interesting observations in this report is one about school science: In their 17th recommendation, the authors state:

> It can be argued that school science education policy and practice live in a world of their own. Despite the existence of established and vigorous European research into science teaching and learning, science education remains empirically grounded. Students often perceive science as too abstract because it is trying to teach fundamental ideas without sufficient experimental, observational and interpretational background, without showing sufficient understanding of their implications, and without giving them the opportunity for a cumulative development of understanding and interest. Science curricula are often excessively factual, partly because of the explosion in scientific knowledge and the constant 'adding-on' of topics to an already extensive range of topics. More importantly, the traditionally established content-delivery model of teaching, which sustains factually oriented curricula, tends to distort student understanding of the nature of both science and knowledge by ignoring the methodological, reasoning and cultural aspects of science (European Commission, 2004, p. 184).

The authors also discuss the importance of science teachers.

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16 European Commission. (2004). Europe needs more scientists: increasing human resources for science and technology in Europe. Report by the High Level Group on Increasing Human Resources for Science and Technology in Europe 2004 (215 pp). http://ec.europa.eu/research/conferences/2004/sciprof/pdf/final_en.pdf

The European Commission's 2007 report *Science education now: a renewed pedagogy for the future of Europe* [17] (often referred to as the Rocard Report) focussed on school education. In the executive summary, it is noted that '… many studies have highlighted an alarming decline in young people's interest in key science studies and mathematics. Despite the numerous projects and actions that are being implemented to reverse this trend, the signs of improvement are still modest. Unless more effective action is taken, Europe's longer term capacity to innovate, and the quality of its research will also decline. Furthermore, among the population in general, the acquisition of skills that are becoming essential in all walks of life, in a society increasingly dependent on the use of knowledge, is also under increasing threat' (European Commission, 2007, p. 2).

The report says that the decline in interest among young people for science studies has its origin in the way science is taught in schools. Therefore, it promotes 'a reversal of school science-teaching pedagogy from mainly deductive to inquiry-based methods provides the means to increase interest in science. *Inquiry-based science education* (IBSE) has proved its efficacy at both primary and secondary levels in increasing children's and students' interest and attainments levels while at the same time stimulating teacher motivation (European Commission, 2007, p. 2). The report notes the key role of teachers in renewing science education and science teacher practices. Also recommended was the establishment of a European Science Education Advisory Board.

The OECD's (2008) report *Encouraging student interest in science and technology studies* is as good a source from which to identify the major issues with respect to the attractiveness of STEM:

- even if the number of STEM enrolments has increased, the proportion going into STEM has declined
- women are underrepresented
- students' choices are mostly determined by their image of science and technology professions, curriculum content and teaching quality.

Considering the third of these points further, the key factors that have an impact on student interest, motivation and career choice are the negative perceptions that come from inaccurate stereotypes of STEM: dry fact-based subject matter that students find difficult or boring; science that does not resonate with students' self-perception and negative experiences of STEM at school (European Schoolnet, n.d.[18]).

The UK's Nuffield Foundation typically focusses on domestic matters, but commissioned *Science Education in Europe: Critical Reflexions*.[19] This study covers similar ground to the Rocard report and argues that despite the consensus of the need for compulsory school science,

> … there has been little debate about its nature and structure…. curricula have simply evolved from pre-existing forms… these curricula have been determined by scientists who perceive school science as

17 European Commission. (2007). Science education now: a renewed pedagogy for the future of Europe. http://ec.europa.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf

18 Science, technology, engineering and mathematics education. Overcoming challenges in Europe. http://ingenious-science.eu/c/document_library/get_file?uuid=3252e85a-125c-49c2-a090-eaeb3130737a&groupId=10136

19 Osborn, J. & Dillon, J. (2008). Science Education in Europe: Critical Reflexions. A Report to the Nuffield Foundation http://www.fisica.unina.it/traces/attachments/article/149/Nuffield-Foundation-Osborne-Dillon-Science-Education-in-Europe.pdf

> basic preparation for a science degree … such an education does not meet the needs of the majority of students… [and that] the content and pedagogy associated with such curricula are increasingly failing to engage young people with the further study of science (Osborn & Dillon, 2008, p. 7).

These authors differ from many others in that they suggest that there is insufficient knowledge about the future demand for scientists and engineers, and that 'encouraging or persuading young people to pursue careers in science without the evidence of demand would be morally questionable' (Osborn, & Dillon, 2008, p. 7)[20]. They add that transforming young people's attitudes to science is a long-term project.

Osborne and Doyle recommend that the prime goal of science education should be explanatory and about how science works; that there is a need for innovative curricula and arrangement of teaching to address low student motivation; and a need to invest in improving human and physical resources available to schools for informing about careers *in* science and *from* science. They want teachers 'to be of the highest quality for primary and lower secondary years, with teaching emphasis < 14 on engaging students with science and scientific phenomena [and to] develop and extend the way science is taught; sustained investment in continuous professional development' (Osborn, & Dillon, 2008, p. 7). In addition, there should be investment in R&D in science education assessment and good quality teachers with up-to-date knowledge and skills.

A key participant in policy and practice development in science education is the European Schoolnet (EUN). Its role, history and programme are laid out in *Transforming education in Europe: European Schoolnet at work*.[21] First established in the mid-1990s, it is a network of about 30 ministries of education. Its aim is '… to bring about innovation in teaching and learning to its key stakeholders: Ministries of Education, schools, teachers and researchers' (European Schoolnet, 2011a).

EUN's project work is of two main activity types: school services; and policy, research and innovation. It is a 'knowledge-building network' that enables 'Ministries of Education to share experiences and to learn from each other' (European Schoolnet, 2011a, p. 7). STEM has been one of EUN's main endeavours since 2007, and it reports on four main factors to implement change and to support the STEM agenda at the European level. These are motivated and recognised STEM teachers; more innovative pedagogy and a creative curriculum; a better recognised role for business and the active engagement of the private sector; and work 'on the demand side', to provide better role models and better information (European Schoolnet, 2011).

EUN has been responsible for a number of initiatives and has produced a number of reports. Although EUN had a major role to play in Ingenious, the European coordinating body (see below), it has produced major reports of STEM support activities engaged in by member states. The main study relevant here was *Efforts to increase students' interest in pursuing science, technology, Engineering and mathematics studies and careers* (Kearney, 2011)[22]. This report was based on national

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[20] In fact, a small number of papers can be found in which authors declare that there is no overall shortage of STEM practitioners in the labour markets (STEM shortage deniers??).
See for example McNeely & Hahm (n.d.); Teitelbaum, 2012).

[21] http://www.eun.org/web/guest/about/publications/-/asset_publisher/EbG7/content/112616?redirect=%2Fweb%2Fguest%2Fabout%2Fpublications

[22] Science, technology, engineering and mathematics education. Overcoming challenges in Europe. http://ingenious-science.eu/c/document_library/get_file?uuid=3252e85a-125c-49c2-a090-eaeb3130737a&groupId=10136

responses from 21 European countries to a questionnaire relating to national measures to increase students' interest in pursuing STEM studies and careers. These national responses are considered in a subsequent section.

The EUN has been involved in several European-spanning programmes and schemes, such as Ingenious (a coordinating body in STEM education), Scientix, a web-based platform for science education; SPICE, a project (2009 – 2011) 'to collect, analyse, validate and share innovative pedagogical practice, particularly focussed on inquiry-based learning, whilst enhancing pupils' interest in the sciences' (European Schoolnet, 2011, p. 27); and Xperimania, a partnership with industry. These schemes are outlined below.

The over-riding advice from the EUN is that initiatives imposed on teachers need to have had strong input from teachers, or else those initiatives will not be successful. Seeking to impose new practices on teachers will not work unless there has been teacher involvement.

The European Commission's Eurydice network provides information on and analyses of European education systems and policies. It primarily focuses on the way education in Europe is structured and organised at all levels. It provides a vast source of information, including detailed descriptions and overviews of national education systems, comparative thematic reports, indicators and statistics. Its 2011 report *Science Education in Europe: National Policies, Practices and Research*[23] provides a summary of many aspects of science education in Europe. As observed by the authors and paraphrased here, countries support many individual programmes to promote science, but overall strategies are rare. Few European countries have developed a broad strategic framework to raise the profile of science in education and wider society, and even though a wide range of initiatives has been implemented in many countries, the impact of these various activities is difficult to measure. The report discusses school partnerships with science-related organisations and science centres to contribute to improving science education by providing students with activities that go beyond what schools typically offer. The report also notes that few countries have implemented specific guidance measures for science and that few have initiatives which focus on encouraging girls to choose science careers.

As mentioned earlier, in a different context, integrated science teaching occurs mostly at lower levels of education, and that science education across Europe begins as one general integrated subject and is taught in this way almost everywhere throughout the entire period of primary education, and in many countries the same approach is continued for one or two years into lower secondary education. Science teaching is usually split into the separate subjects after lower secondary. Therefore, not all students are taught science at the same level of difficulty and/or study science subjects throughout all grades in upper secondary years. Science is taught 'in context' in most countries: i.e. in relation to contemporary societal issues…and the application of scientific achievements to daily life are recommended for inclusion in science lessons in most European countries. The report mentions also that there are many national initiatives to help improve teachers' skills, but fewer initiatives that focus on the initial education of science teachers.

Scholarly associations and academies also tend to be participants in discussions about the STEM disciplines. For example, FEANI, the European Federation of National Engineering Associations is a federation of professional engineers that unites national engineering associations from 32 European countries. According to its website, FEANI

[23] http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/133EN.pdf

represents the interests of over 3.5 million professional engineers in Europe, and attempts to provide a single voice for the engineering profession. It produced a position paper on education policy in 2010 in which issues similar to those raised by others are specified: primary and secondary education to be modern, attractive and practical; the need to improve the quality of engineering education; increased funding is required; gender balance issues; lifelong learning; and the need for positive and inspiring communication (FEANI, 2011).[24]

Also with a specific focus on engineering, the Association of German Engineers (VDI) was responsible for the *European Engineering Report* in 2010.[25] It presented a thorough a specific examination of the 'E' part of STEM. Typically reports tend to be more generally focussed on science. However, it also considers the fact that not all engineers work in the engineering profession, and that some in the engineering profession have degrees in other disciplines, such as physics or computer science. The VDI report considers only tertiary graduates, so this report does not consider technician-level workers in the broader STEM workforce. The report also provides useful information about hours of work, age structure and participation by gender across about 30 European countries.

ALLEA (ALL European Academies) is a federation of 52 academies of sciences and humanities from more than 40 European countries. A working group of delegates from 25 academies published a report in 2012 based on analyses of surveys conducted in 2010 and 2011. The report (*A Renewal of science education in Europe: Views and Actions of National Academies*[26]) details the views and actions taken by European National Academies to advance the renewal of science education and maintain the passion for science and technology among the young, typically drawing on the support of leading scientists from the science academies.

Starting from a background of declining interest in science and a shrinking scientific workforce, the report builds on the Rocard and other reports in that it 'pleads for inquiry-based science education (IBSE) extension and for a strong effort in the sphere of science teacher training pre- and in-service …'. The report comments on the common features of responses from academies, including 'the pervasive lack of interest, among pupils, in S&T; followed by a serious decrease of the number of students in sciences, mathematics and engineering; the hazard of society's declining scientific literacy; and of a lack of the necessary scientific skills among the available workforce' (ALLEA, 2012b).

'The present report shows a vast diversity of approaches towards renewing science education and at the same time a unanimous agreement among all academies about the need to reform and strengthen it. These different approaches observed cannot be correlated in any direct way to the size, wealth, or constitutional setup of the educational system (centralized or based on federal states or other administrative units)' (ALLEA, 2012a). The report also states agreement on the use of IBSE, the need for continuous professional development, the beneficial role of 'cross-border exchange of ideas and novel practices', and building alliances with industrial, corporate and political bodies.

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24 http://www.feani.org/site/index.php?eID=tx_nawsecuredl&u=0&file=fileadmin/PDF_Documents/Position_papers/Educational_policy_paper_approved_GA_2010.pdf&t=1359607795&hash=24c8d1cb1e3eeaba9665ccbacdd4a9c6d405f8c9

25 VDI (2010). European Engineering Report. http://www.vdi.de/uploads/media/2010-04_IW_European_Engineering_Report_02.pdf

26 http://www.allea.org/Content/ALLEA/WG%20Science%20Education/ALLEA%20Report_A%20renewal%20of%20science%20education%20in%20europe.pdf

Moving into the 'private' realm, the European Round Table of Industrialists (ERT) and BusinessEurope both consider STEM issues, with a greater focus on the labour market issues.

ERT, a forum of leaders of major European companies produced its *Mathematics, Science & Technology Education Report* in 2009.[27] They state that 'ERT has identified increasing young people's interest in mathematics science and technology as essential for sustainable economic growth in Europe' (ERT, 2009, p. 4). The report ultimately calls for the establishment of a European coordinating body, which subsequently occurred in the form of Ingenious (see below). The authors of the report consider Europe's 'enormous demographic challenge', with many countries expecting a decline of more than 3 per cent of the number of 18 year-olds between 2008 and 2020. On the demand side, they point to the large number of people moving towards retirement age. They also consider the disinclination of the young to undertake STEM education and careers, the failure to engage youth interest, the misleading image of STEM careers and the gender disparity. The role of business is considered, as is the need to engage with teachers and the need for new instruments to analyse market requirements for STEM workers in order to train the right number of people.

BusinessEurope produced *Plugging the Skills Gap: The Clock is Ticking*[28] in 2011. It covers much of the same territory as other reports, but also includes comments on the mismatches that occur: where there is unemployment of STEM professionals at the same time as there is a shortage of STEM workers.

STEM: some pan-European projects

The aforementioned OECD reports on science and mathematics education led eventually to the production of a *Compendium of Best Practice in MST*[29]*,* a study of peer learning activities in France, the Netherlands, Norway and Sweden, later updated to include Latvia and Portugal. Major national initiatives are discussed in the Compendium, and various national programmes from pre-school to higher education. The existence of comprehensive reports of 'best practice' such as this one is perhaps a good way to suggest that successful STEM-related programmes need to be disseminated via a highly visible and accessible platform, such as Ingenious, described below.

All countries have their own national, regional and even institutional programmes to boost STEM popularity and uptake, but other schemes are available across Europe. Naturally, such schemes are usually the product of centralised member organisations, such as the OECD and European Schoolnet.

Several reports including the ERT report mentioned above discussed the need for the coordination of STEM activity in Europe. In consideration of this, a coordinating body in STEM education named Ingenious was established as a joint initiative of European Schoolnet and the ERT. European Schoolnet continues to be a major player in Europe-wide school-based projects, including STEM-related ones.

Ingenious[30]*('shaping the future of maths and science education')* had specific goals relating to communicating with children and students about science. It aims to reinforce

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27 ERT. (2009). Mathematics, Science and Technology Education Report. http://www.ert.eu/sites/default/files/MST%20Report%20FINAL.pdf

28 http://www.businesseurope.eu/Content/default.asp?pageid=568&docid=28659

29 http://www.kslll.net/Documents/MST%20Compendium.pdf

30 http://www.ingenious-science.eu/web/guest/about

interest of the young in science education and careers, thereby addressing future EU skills. Ingenious is currently being funded via a grant of €8 million over a 3-year period from the European Commission's 7th Framework Programme. The importance of Ingenious is that it is a consortium that brings together ministries of education, businesses and universities. Ingenious developed a STEM education best practice repository, communicated best practice, had an impact on STEM education policy by addressing all stakeholders and changed opinions about science. The Ingenious virtuous circle is to educate, communicate and inspire (European Schoolnet, 2011a).

Scientix is a portal managed by European Schoolnet (EUN) on behalf of the European Commission. Its objective is to ensure that the results and knowledge gained from the many science education projects funded by the EU are accessible to those that might find them useful. The Scientix project started in December 2009 and the website was launched in May 2010. To quote from its website,

> Scientix is the community for science education in Europe. It was created to facilitate regular dissemination and sharing of know-how and best practices in science education across the European Union. Scientix is open for teachers, researchers, policy makers, parents and anyone interested in science education. Scientix collects teaching materials and research reports from European science education projects financed by the European Union under the *6th and 7th Framework Programmes for Research and Technological Development* (Directorate General Research), *the Lifelong Learning Programme* (Directorate General Education and Culture) and various national initiatives. Through various online and off-line services Scientix wants to create a lively community for its users[31].

Using Scientix, it is possible to find information on European science education projects funded by the European Commission or other public entities. Material is available in six languages: English, French, German, Italian, Polish and Spanish. Currently material on about 200 projects (each divided into basic information, research information and teacher information) can be obtained. In addition, Scientix provides:

- a repository of hundreds of teaching materials from EU funded projects
- research reports and policy-making documents
- a translation on demand service for teaching materials into any of the 23 EU languages
- a forum and chat rooms
- an online news service and calendar of events and professional development opportunities
- a monthly newsletter.

According to the report, Scientix has managed to reach the intended target groups, of which two-thirds are teachers at schools or universities, and researchers, policy makers and education managers. The European Commission's 2011 report can be found on the internet.[32]

Although it is not specifically mentioned as such, Scientix seems to have had an antecedent (at least in part) in *Technopolis*, an earlier European Union study that aimed at disseminating bext practice in science mentoring and science ambassador

[31] http://www.scientix.eu/web/guest/about
[32] Scientix. The community for science education in Europe.

schemes across Europe. The Technopolis report also makes for interesting reading, [33] but there is considerable overlap.

The EUN has been involved in three major studies relating to STEM practices in Europe as part of the framework of the **SPICE** (Science Pedagogy Innovation Centre for Europe) project. One of these had a teacher and teaching focus, and the other two had a student perspective. The SPICE project, which ran from December 2009 until November 2011, was to find and promote good practices in mathematics, science and technology teaching. The project was coordinated by European Schoolnet and a partner each from Portugal and the Czech Republic. A great deal of the focus in teaching is for countries to adopt inquiry-based learning.

'The main objective of the SPICE project was to collect, analyse, validate and share innovative pedagogical practices, especially those based on inquiry-based learning, while enhancing pupil motivation for science studies at primary and secondary level (12 – 15 year old students)' (European Schoolnet, 2011b, p. 3). The final report is entitled *Spice: Spicing up science and maths classes by exchanging practices with teachers from other countries* (Schwarzenbacher et al., 2011).[34]

The other reports relate to the report by Keaney, a researcher with European Schoolnet and referred to above. The second report included information from five additional countries and updates in its *Efforts to increase students' interest in pursuing science, technology, Engineering and mathematics studies and careers.*

Xperimania was devised by EUN (and is coordinated by them) in conjunction with the Association of Petrochemical Producers in Europe. 'It is aimed at pupils in the 10–20 year age group and the project provides teachers with a range of virtual hands-on activities in chemistry and physics. It demonstrates how the petrochemical industry has an impact on the development and manufacture of the most mundane items in our everyday lives. The pedagogical basis of the activities is inquiry-based learning' (European Schoolnet, 2011a, p. 27).

DESIRE is an acronym for Disseminating Educational Science, Innovation and Research in Europe. It is a two-year project that commenced in 2011, carried out between the EUN and partners in Spain and Denmark, and Ecsite (The European Network of Science Centres and Museums). The project is being funded under the European Commission's Lifelong Learning Programme. Its aim is to develop models of diffusion and exploitation to ease the spreading of science education projects results to teachers, and the primary objective is to identify how new project results on methods and practises in science education can reach teachers and schools more efficiently. From the website: '… We invite science teachers, STEM professionals, science project planners, policy-makers, organisers of science events and organisers of activities and expositions in museums to tell about their experience in accessing or disseminating tools and methods that have helped know about project results. The sharing of practical experience will help us identify the best practise dissemination models for project results. DESIRE will ensure that more teachers throughout Europe will have access to inspiring methods and tools they can integrate in their teaching practices' (DESIRE, n.d.).[35]

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33 TECHNOPOLIS Identification and dissemination of best practice in science mentoring and science ambassador schemes across Europe http://ec.europa.eu/research/science-society/document_library/pdf_06/technopolis-mainreport_en.pdf

34 http://spice.eun.org/c/document_library/get_file?p_l_id=16294&folderId=16435&name=DLFE-9322.pdf

35 http://desire.eun.org/about

The fact that many of these programmes and projects overlap in timing and in coverage is probably a reflection of the nature and sources of funding such projects.

The **STENCIL Network**[36] (Science Teaching European Network for Creativity and Innovation in Learning) began in January 2011 with funding from the European Commission and will continue until December, 2013. It comprises 21 members from nine European countries: Bulgaria, Germany, Greece, France, Italy, Malta, Portugal, Slovenia and Turkey. According to its website, the STENCIL Network's main objectives are to

- identify and promote innovative practices in science teaching, by publishing an annual report on the State of Innovation in Science Education;
- bring together science education practitioners to share experiences and learn from each other by organising periodic study visits and workshops, in a peer to peer approach;
- disseminate through the STENCIL web portal materials and outcomes from previous EU funded projects and other science education initiatives, and national communities, as well as through a wide range of dissemination actions;
- provide educational authorities and policy makers with guidelines and a manifesto for innovating science education in their countries, especially focused on the establishment of contacts between research institutes, schools and industries.

It is not easy to discern the ways in which the STENCIL initiative is different from others mentioned.

What do they do in Europe? A summary of some country-specific programmes

All countries agree that having a STEM-trained labour force to improve national economic development depends on having enough students undertaking STEM studies, at all levels. Some reports outline the various countries' responses to this perceived need. Comments below have been summarised from three of these reports, but most reports make similar points. The three reports that have been used to draw this information are Eurydice's *Science Education in Europe* (2011); European Schoolnet's *Efforts to increase students' interest in pursuing science, technology, engineering and mathematics studies and careers* (Kearney, 2011) and ALLEA's *A Renewal of science education in Europe: Views and Actions of National Academies* (2012) each provide country by country information on activities to boost uptake of the STEM disciplines. The European Schoolnet report notes 'It is worth noting that while this report mainly focused on national measures taken by countries in the area of promoting STEM studies and careers, many of the countries who contributed to it are also involved in European and international initiatives in this area' (Kearney, 2011, p. 36).

Eurydice (2011) states the most commonly expressed reasons for new strategies to improve science education are

- declining interest in science studies
- rising demand for qualified personnel and
- concern about a potential decline in innovation and economic development.

[36] http://www.stencil-science.eu/

Both the Eurydice and ALLEA reports note that unimpressive national performance in international surveys such as PISA and TIMSS have also been the instigator of new initiatives in some countries.

STEM: national strategies

Not all countries have STEM-related strategies in place, and not all countries have the same governance arrangements for education. For example, federal countries such as Germany and Switzerland (and the USA, Canada and Australia, no doubt) present interesting cases, because of the differentiation of responsibility for and authority over education. Belgium and Switzerland are interesting because of language-based divisions in different regions of the country. Finland also has two official languages (Finnish and Swedish), but education is still dealt with in a centralised manner. The main differences relate to the use of one's mother tongue in formal testing at the end of senior secondary school.

According to Eurydice (2011), **Austria, Germany, France, Ireland, the Netherlands, Norway, Spain,** and the **United Kingdom** all have national strategies in place. 'The aims expressed in these strategies are, in many cases, linked to broader educational goals for society as a whole. The most common aims are to:

- promote a positive image of science;
- improve public knowledge of science;
- improve school-based science teaching and learning;
- raise pupils' interest in science subjects and consequently increase uptake of science studies at upper secondary and tertiary education levels;
- strive for a better gender balance in MST studies and professions;
- provide employers with the skills they need and so help to maintain competitiveness'.

Areas usually considered important and in need of improvement at the level of school education are curricula, teacher education (both initial and continuing) and teaching methods (Eurydice, 2011, p. 27).

Kearney (2011) used a 21-country survey to provide information about national strategies. Interestingly, her report identifies **Austria, Finland, Slovenia** and the **Slovak Republic** as countries that 'no longer consider STEM-related study and career issues, in a holistic sense, as an educational priority at national level' (p. 6).

Eurydice reports that **Spain** is promoting science as a national priority, something that is evidenced by the creation of a separate Ministry of Science and Innovation in 2009.

Ireland set up its Discover Science and Engineering (DSE) programme to increase interest in STEM[37].

In **Germany**, its High-Tech Strategy from 2006 aims to attract more of the young to STEM subjects (MINT is the equivalent acronym in German). The strategy was reconfirmed in 2010 and extended to 2020. The aim of the Federal Government is to meet the requirements for skilled staff primarily through training and continuing efforts in education.

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37 http://www.discover-science.ie/

German education is complicated by its federal system, with 16 federal states. Relatively poor performance in international tests led to numerous initiatives to rejuvenate German science education, with some measures supported by federal funding. Moves aimed at popularising inquiry-based science education have been set in place, including the German-instigated Europe-wide Pollen project, to help network IBSE experiences in 12 'seed cities' in the European Union. Pollen also considered gender-based differences in science uptake. According to the Pollen website[38]:

> Pollen was launched in January 2006 and took place over a three-and-a-half-year period. With inquiry-based science education as a primary objective, the project focused on the creation of 12 Seed Cities throughout the European Union. A Seed City is an educational territory that supports primary science education through the commitment of the whole community. The major goal of Pollen was to provide an empirical illustration of how science teaching can be reformed on a local level within schools whilst involving the whole community, in order to demonstrate the sustainability and efficiency of the Seed City approach to stakeholders and national education authorities, and to seek leverage leverage effects. In each Seed City, Pollen provided material and methodological and pedagogical support compatible with the framework of the local curriculum. All of the materials produced as part of Pollen, as well as further information about the project, can be accessed free of charge through the Pollen website.

The SINUS Transfer[39] programme started as a federally-supported pilot following German students' poor performance in the 1997 TIMSS tests. It related to improving the learning and teaching of mathematics, and an expert group analysed the deficiencies of traditional classroom teaching and suggested strategies for improvement. The pilot involved 180 schools between 1998 and 2003. Sinus Transfer ended in 2007, and the länder are now responsible for disseminating the strategies underlying it. Bavaria, for example,

> … devised a sophisticated advanced teacher training strategy reaching a large number of schools. SINUS relies on competent and experienced teachers at different levels of schooling. Teachers are expected to make their own decisions about their aims and the means they intend to use for improving their classroom teaching. These are not isolated endeavours but the initiation of a process that will lead to sustainable improvement in classroom teaching…. Another contributory factor to the success of the SINUS programmes is the way they offer teachers a framework for staff cooperation (Bavarian State Ministry of Education and Cultural Affairs, 2010, pp. 6 – 7).

The Bèta Techniek (Science and Technology) Platform has been commissioned in the **Netherlands**, '…by the government, education and business sectors to ensure sufficient availability of people who have a background in scientific or technical education. This approach has been formulated in the *Deltaplan Bèta Techniek*, a memorandum on preventing workforce shortages' (Eurydice, p. 28). Kearney (2011) which adds that 'the Delta Plan is divided into five sub-programmes each targeting different levels and types of education and preparation for working life' (p. 7). A crucial instrument of the *Delta plan* is the *Beta Techniek Platform*, which has the task of increasing enrolment in, progression through and graduation from science and technology subjects' (p. 7).

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38 http://www.pollen-europa.net/?page=CLDGDJVwskY%3D

39 http://sinus-transfer.eu/

In **Belgium**, schooling is in separate streams along linguistic lines, and three different models follow French, Dutch and German lines respectively. The German community is much smaller than the other two. The Flemish Belgian community established a Science Communication Action Plan, inspired in part by the Dutch Delta plan. The Department of Economy, Science and Innovation administers the Action Plan, in consultation with the Science Information Network. The targets are young people, teachers and the general public 'to promote a scientific and innovative culture in all walks of life and ensure a wider participation in the public debate about these issues and their impact on society' (p. 8). According to the ALLEA report, 'A long line of activities has been launched by successive Belgian governments to stimulate the study of science in school and at university, but it is difficult or outright impossible to assess the success of these measures (nor, it is fair to admit, has such an assessment been tried). Yet, a simplistic interpretation of the perhaps surprisingly strong economic performance of Belgian hi-tech industry even in times of crisis at the end of the 2000's seems to suggest that something must have been done right' (p. 34). The observation about assessment of the success of programmes is fairly common.

The **United Kingdom** has a STEM Programme that began in 2004, scheduled to run for ten years. It has 11 'action programmes', and inaugurated a National STEM Centre in 2009, to house the UK's largest collection of STEM teaching resources.

Norway also has a nationally-focussed strategy: *Science for the Future Strategy for Strengthening Mathematics, Science and Technology (MST) 2010–2014* [40]. The aim is '… strengthening STEM competence from kindergarten all the way through to a person's working life' (Kearney, p. 8). The strategy seeks cooperation between education and labour markets to improve recruitment into STEM professions (Kearney, 2011). **Germany**, **the Netherlands** and **Norway** 'share a particular focus on raising the interest level of girls/women' (Eurydice, 2011, p. 27).

The national strategies for **France**, **Switzerland** and **Italy** focus more specifically on school science education rather than being spread out over the lifelong learning spectrum (Kearney, 2011). **France** aimed at stimulating interest in STEM subjects from primary to upper secondary school through a national action plan launched in January 2011. **Switzerland** had a scheme in place for the promotion of science among young scholars between 2008 and 2011. It is built on public-private partnerships, '… and is meant to bundle various existing initiatives, create synergies between projects and boost new initiatives for the promotion of STEM careers. The policy measure is intended to address Switzerland's lack of skilled workers in industry, particularly in the field of ICT (p. 10). **Italy** set up an *Inter-departmental working group for the development of a scientific and technological culture* in 2006.

France is not one of the countries singled out for specific attention in this report, and even if its latest action plan dates from 2011, a couple of earlier programmes dating back to 1996 are worthy of mention. One project (*La main à la pâté*) has been mentioned in both the Rocard report and in the MST Compendium of Best Practice (European Commission, 2007, 2010) According to this long direct quote from the ALLEA report, primarily about French advances into inquiry-based science education….

> ***La main à la pâte*** ('hand in the dough') project was launched in 1996 and has proved to be remarkably effective in terms of transformations of science education all across the country and by triggering policy debates and

40 http://www.regjeringen.no/upload/KD/Vedlegg/UH/Rapporter_og_planer/Science_for_the_future.pdf

initiatives. As the intellectual and pedagogical project developed, it became structured around the 'ten principles', some basic rules initially developed for the specific French educational and institutional context, but applicable and adaptable to other national educational systems. The fundamental point of departure for the IBSE methodology is to:

(1) Encourage children to observe an object or phenomenon in the real world that surrounds them and, if appropriate, experiment with it.
(2) In the course of seeking to understand their observations, they use arguments, share and discuss their ideas and interpretations and build their knowledge; a purely manual activity is therefore insufficient and is not what is meant by 'hands-on' science education.
(3) Teachers propose activities that are organised within a teaching module, preferably related to official school programmes, while, at the same time, affording pupils ample independence for their autonomous pursuit of understanding.
(4) It is considered important that sufficient time is spent on any given thematic, a minimum of two hours per week for several weeks; by the same token, it is considered critical that continuity of activities and pedagogical methods is ensured, ideally throughout the school programme, at least from kindergarten to early secondary schools.
(5) Pupils are required to keep a science notebook or book of experiments, written and updated in their own words, and recording the work they performed in the science classroom, or related activities carried out at home (importance given to language).
(6) An objective is the gradual appropriation by pupils of scientific concepts and techniques, and working methods, including the notion of uncertainty and a proper understanding of discovery, also through a consolidated grasp of oral and written expression.
(7) Families and local communities are expected to be closely associated with the process of structured acquisition of knowledge.
(8) Local scientific partners would be envisaged as accompanying the work as well (for example: universities, engineering schools, etc.) supporting classroom work and offering access to their specialized skills and facilities.
(9) Teacher training colleges are expected to make their pedagogical and didactic experience available to teachers, and to offer in-service professional development.
(10) Teachers can obtain teaching modules, ideas for activities, and answers to questions at the website. They can take part in collaborative work with colleagues, trainers and scientists; the contact to the most advanced scientists as role models is a central element.

La main à la pâte pays particular attention to the need to retrain teachers, preparing them to develop ownership of the method of inquiry.

Based on these principles, many actions were implemented to counteract the negative dynamics in science education. In 1996, an experimental programme was launched in a small sample of 350 classes. An evaluation conducted by the Ministry of Education acknowledged the merits of the experimental approach and a nationwide roll-out of the programme was initiated by the Ministry for the last three grades of elementary schools (2000–2003).

> A study of teaching practices carried out by *La main à la pâte* has shown that the most successful initiatives for bringing scientific inquiry and active pedagogy into the classroom were those that provided teachers with long-term, continuous, in-class support, familiarising them progressively with IBSE practices.

The ***ASTEP*** programme was also set up in 1996 ('*Accompagnement Scientifique et Technologique à l'Ecole Primaire'* / Scientific and Technological Support for Teachers in Primary Schools). The programme encourages university-based active scientists to offer support to teachers in classroom activities. It now involves 27 French universities and 19 engineering schools.

According to ALLEA, these initiatives have led to a change in the perception of the importance of early science education among decision makers, whether politicians or civil servants. A subsequent programme named EIST, or '*Enseignement Integré de Science et Technologie'* (Integrated Education in Science and Technology), was launched in 2006 to introduce IBSE methodologies into secondary schools, in an effort to sustain the renewed interest of children for science throughout their school careers.

These programmes have been evaluated, and appear to have received wide acceptance. Of course, it is always difficult to assess the longer-term impact on matters such as an expanding STEM labour force.

….STEM support centres

Most countries have centres that focus on providing support for STEM teaching and/or for promoting science, or to popularise science. For example, among the former, **Norway** has the *Centre for Mathematics Education* (set up in 2002) and the *Norwegian Centre for Science Education* (set up in 2003), to support schools and other stakeholders by implementing initiatives focusing on the curriculum, equality and outreach activities, developing teaching materials and training, and producing and maintaining magazines, websites, annual conferences and seminars for teachers.

Finland has LUMA[41], an umbrella organisation coordinated by the University of Helsinki to promote and enhance the learning of STEM disciplines.

Belgium (Flanders) has the RVO-Society[42] acting as a gateway between research and STEM education. It is a not-for-profit organisation. The RVO-Society promotes technology in education.

In **France**, the *Academie des Sciences* set up a Delegation for Education and Teacher Training, whose aim is to guarantee nationally, at all school levels, the quality of scientific and technological teaching, as well as training for science teachers. Various other organisations have input into strengthening primary and secondary education. **Sweden** has four resource centres funded by the education funding agency.

In the **Netherlands**, the Freudenthal Institute for Science and Mathematics Education (FIsme) aims to improve education in the fields of arithmetic, mathematics, and the sciences, with a focus on primary, secondary and vocational education. The Institute contributes towards this aim through research, teaching, curriculum development and other services.

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41 http://www.helsinki.fi/luma/english/generalinformation

42 http://www.rvo-society.be/

In **Switzerland** the MINT (*Mathematik, Informatik, Naturwissenschaften und Technik*) *Learning Centre* at the Swiss Federal Institute of Technology (ETH) was established in 2008 to develop teaching methods, learning objects, programmes and curricula for the teaching of non-life sciences throughout primary and secondary education.

Matters relating to Swiss school education are somewhat complicated by the absence of a federal education ministry. School education is under the purview of 26 cantons, each of which has its own educational system and decides on its own school curricula (ALLEA, 2012). This occurs in a nation of about eight million living in territory 187th the size of Australia.

Denmark set up a *Centre for Science, Technology and Health* in 2009 to target all STEM subjects and age-groups from kindergarten to university. The centre plans to collaborate with private and public companies, universities, museums and other relevant science centres, as well as schools, and to develop a network of relevant partners.

Fact finding

Much of the material above was based on the opinions of experts, practitioners, researchers and bureaucrats. While these are good sources of information, current and potential students can also provide useful information, via questionnaires and other survey methods.

A survey of 'technology' students was conducted in 2005 by BEST- the Board of European Students of Technology[43]. As with any survey, the coverage and response rates can be questioned, and this survey's responses seem over-represented by Mediterranean countries. Nonetheless, the responses are interesting. Over 60 per cent of students said they chose [STEM] studies because of their general interest in the topic. About 55 per cent indicated that the chances of getting a job were important. About 30 per cent of students said they chose STEM because of working conditions, expected salary or prestige of having a STEM degree. At the other end of the scale, the difficulty of the subject, the workload and the male/female ratio were considered to be among the more negative features of studying STEM (OECD, 2008b).

Norway has presented the promotion of STEM in Europe with a series of floral acronyms: ROSE, IRIS and LILY. The ROSE (Relevance of Science Education) project '… is a cooperative research project with wide international participation. … The purpose of ROSE is to gather and analyse information from the learners about several factors that have a bearing on their attitudes to S&T and their motivation to learn S&T' (Sjøberg & Schreiner, 2010, p. 1). ROSE focussed initially on students up to 15 years of age in the compulsory school years. It grew out of an earlier 'pilot' study entitled Science and Scientists (SAS). Forty countries participated in the ROSE project, but results from some countries were considered to be not necessarily representative. According to the ROSE website, '… the purpose of ROSE is not testing of achievement, but rather to address attitudinal and motivational aspects of S&T. Consequently, ROSE will complement the TIMSS and PISA studies by providing different information about the status of science education in the country'.

The ROSE questionnaire was developed in Norway, but in English, and great care was taken in translations into other languages. A paper on the development of the project and the questionnaire can be downloaded from the website[44].

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[43] http://www.best.eu.org/index.jsp

[44] http://www.uv.uio.no/ils/english/research/projects/rose/

The overall results found that attitudes to science and technology are mainly positive; young people in the richer countries are more ambivalent than older people; and there is a growing gender difference, with girls being more negative or sceptical.

Among other findings, girls found science to be less interesting than other subjects at school than boys did; students in richer countries expressed less interest in science than those from less wealthy countries; science curricula and textbooks rated low in interest; girls' and boys' interests are context-driven, with boys favouring technical, mechanical and electrical more when compared with girls.

Few young people agreed with a statement that they would like to become scientists or have jobs in technology, with many fewer girls expressing interest. According to the authors, the data from the ROSE survey indicate that European countries are facing a serious problem. To counter this, the authors say that students' experiences and interest should be attended to when constructing curricula, producing textbooks and classroom activities. Teaching must be motivating, meaningful and engaging: 'Teaching material and teaching practices that do not engage students in meaningful learning is not likely to give lasting positive results … Current science curricula are to a large extent based on the assumption that school science is the first step in the process to educate the future scientist … In particular there [is] a need to 'humanise' school science, to show that science is part of human history and culture …'.

LILY[45] is not an acronym; in Norwegian the project is known as Vilje-con-valg. LILY is a follow-up of the international project ROSE, conducted within Norway. It is related to the international IRIS (Interests & Recruitment In Science) project. Lily focussed on factors influencing recruitment, retention and gender equity in science, technology and mathematics higher education. The overall aim of LILY is to contribute to improving recruitment, retention and gender equity patterns in STEM educations and careers.

A survey of new students was administered in 2008. Over 5,000 of the 7,500 responses from Norwegian universities and university colleges were from students enrolled in the STEM disciplines. STEM and Non-STEM respondents were divided into sub-groups. One set of questions asked respondents about which persons had inspired their choice of study. Parents came out the highest, teachers quite low as sources of inspiration, and publicly-known people provided no influence at all. Institutional websites were rated as important sources of inspiration.

IRIS followed up from LILY and ROSE, the next stage of development has been the IRIS (Interest and Recruitment in Science) programme that looks at the factors influencing recruitment, retention and gender equity in STEM higher education. A Norwegian study provided the pilot for a Europe-wide IRIS study of first-year tertiary students. According to the IRIS website, IRIS is a collaborative research project addressing the challenge that few young people (women in particular) choose education and career in science, technology and mathematics. The focus is on the challenge that too few young people, especially young women, chose STEM education and a STEM career. The research questions devised for IRIS included the basis on which young people base their choice; the success factors for initiatives and efforts aimed at recruiting more people into STEM education; and matters relating to dropping out / opting out.

Evaluation of strategies

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[45] http://www.naturfagsenteret.no/c1515601/prosjekt/vis.html?tid=1519408

It is fair to say that there has been relatively little formal (or external) programme, project or scheme evaluation. In fact, it is extremely difficult to assess the impact of (say) curriculum reform at primary school on subsequent flows to the STEM labour market. However, some formal evaluation has been reported, in the Netherlands, Finland, the United Kingdom and Norway. According to Eurydice (2011), 'Overall, although evaluation reports consider all strategies as fairly, or even very successful, they also showed that streamlining individual initiatives and making them more consistent was of great importance. A more coordinated approach was considered important at national, regional and local level'.

In the case of Finland, the evaluation in reflection was a review of the antecedent to the current national science centre LUMA, housed at the University of Helsinki. The evaluation of the Dutch strategy also showed that the creation of performance agreements with participating institutions was an important issue. The Netherlands chose the platform approach for carrying out its strategy with a certain level of independence from the ministry and a variety of stakeholders.

Some observations: the quest for role models

STEM is a major point of discussion within European countries, and within the organisations that represent countries (such as the OECD, European Union / Commission, European Schoolnet, etc.). Although the countries themselves are often internally diverse as well as being quite different from other countries, the overall reactions to STEM-related matters tend to be similar.

Study after study comes up with similar findings, and many relate to boosting the supply of young people going into STEM studies. As noted by Kearney (2011, p. 36), 'the development of effective and attractive STEM curricula and teaching methods, and improved teacher education and professional development are at the heart of the drive to make STEM studies and careers a more popular option for young learners'. Attracting more young women is particularly seen as beneficial and the relatively low numbers of women in STEM programmes already (in most countries) suggest a ready potential supply of future STEM-trained workers. Attracting more students needs to be done by getting students interested in science at an early age. 'Inquiry-based science education' seems to be perceived as a necessity in the process of engaging young peoples' minds.

In this setting, some countries perhaps have a higher likelihood of providing a role model for Australia, but the underlying differences between Australia and the countries of Europe could mean that some practices might not succeed. Some observations follow.

As a federal nation, perhaps Australia could find models from Germany or Switzerland, both of which are federal states. However, Germany and Switzerland have many more education 'systems' than Australia. Germany has 17 states / länder responsible for education, although federal involvement is common. As for national models for which Australia could take a closer look, the apparent success of federal German bodies and programmes could be examined. Switzerland, a country of only 7.8 million people and 41,000 km^2 is divided into 26 autonomous cantons and four language groups, and on these grounds alone does not seem to have much in common with Australia. It also lacks a federal education ministry. Belgium is also federal in a sense, because its education is divided across language groups.

The Netherlands, Sweden, Norway and Finland are unitary states with centrally-generated overall policies. As such, they have a single system running through school and tertiary education. Although Australian higher education is organised centrally through the federal government, other levels of education are not. Perhaps this limits the possibility to arrange a unified approach to STEM education, and therefore the applicability of programmes established in unitary nations.

Finland stands out in many ways, such as the performance of its students in PISA and TIMSS (the best outside Asia). However, the national approach to the STEM disciplines in Finland is decidedly low key, and there is already a higher representation of STEM professionals in the Finnish workforce than in many countries. Because of its students' performance in PISA tests, the overall workings of Finnish school education have been well publicised. However, their system is different from most. Whereas most countries have gone down the path of making schools and teachers more accountable, there is no evidence that this improves students' performance (Sahlberg, 2009). *Unless Australian education ministries could be convinced to adopt some of the fundamentally different aspects of the Finnish school system and become overtly more trusting of teachers, then merely following Finnish STEM-boosting methods would probably not work. Finnish teachers find themselves in a fundamentally different situation.*

Despite these potential 'distractions' based on organisational differences, many individual programmes and activities could be assessed for fit in an Australian setting. Perhaps the impact of STEM-boosting activities would have greater national impact if there were a national body charged with such responsibilities. Should an Australian *Ingenious* be set up, to coordinate the quest for improved STEM uptake in Australia?

Leaving the last word to Kearney, as an indication of a possible direction for Australia to follow, 'The most comprehensive approach is taken by countries that have implemented national strategies and/or set up dedicated national or regional centres to improve the quality of STEM teaching and enhance its popularity. This holistic approach usually includes all STEM subjects, covers the lifelong learning span, and involves public-private partnerships between the government, educational sector and industry' (Kearney, 2011, p. 36).

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Country reports to: A critical examination of existing solutions to the STEM skills shortage in comparable countries

These sections include additional reportage on Belgium, Denmark, Germany, the Netherlands, Sweden and Switzerland. These reports should be read as appendices to the broader report on Europe. There is a separate report on Finland, which is structured differently because it was written before the Europe-wide report.

Country report: Belgium

Introduction: Demographic background

Belgium's 11 million people live in a country of 30,510 km^2, making Belgium one of the most densely-settled countries in Europe (352 persons per km^2). About 1.4 million of that population are foreign-born (12.9 per cent). The median age is 42.3 years and the life expectancy at birth is 77.2 and 82.4 years for men and women, respectively (2009) (total: 77.7 in 1999, 79.8 in 2009).

Belgium is populated by a Flemish majority of about 6,000,000 people speaking Dutch, a Walloon minority of 3,400,000 people speaking French, and about 73,000 German speaking people in Wallonia, near the German border. However, these groups are described by experts as *communities* rather than as ethnic groups, and individuals can move easily from one community to the other by learning to speak the other language. The rest consists mostly of French-speaking people from Brussels, and others of non-Belgian origin. (Around 23 per cent of Belgium's population is of non-Belgian origin). Of those living in Brussels, it is estimated that 77 per cent use French and 16% use Dutch in their households.

Belgian education

Belgium seems less like one country and more like three countries, particularly where its education is concerned. From Wikipedia (n.d.):

> Education in Belgium is regulated and for the larger part financed by one of the three communities: Flemish, French and German-speaking. All three communities have a unified school system with small differences from one community to another. The national government plays a very small role: it decides directly the age for mandatory schooling and indirectly the financing of the communities.

The schools can be divided in three groups:

1. Schools owned by the communities
2. Subsidised public schools, organised by provinces and municipalities
3. Subsidized free schools, mainly organised by an organisation affiliated to the Catholic Church. This is the largest group, both in number of schools and in number of pupils.

Education in Belgium is compulsory between the ages of 6 and 18.

Primary education consists of six years and the subjects given are generally the same at all schools. Primary schooling is free and age is the only entrance requirement. Education in primary schools is rather traditional: it concentrates on reading, writing and basic mathematics, but also touches already a very broad range of topics (biology, music, religion, history, etc). There are also some private schools set up to serve various international communities in Belgium (e.g. children of seafarers or

European diplomats), mainly around the larger cities. Some schools offer special primary education for children with disabilities or other special needs.

When graduating from primary school around the age of 12, students enter **secondary education**. Here they have to choose a course that they want to follow, depending on their skill level and interests. Some core lessons are compulsory like the first language and sport, etc. Secondary school is divided into four general types. Each type consists of a set of different directions that may vary from school to school. The general types are:

- General Secondary Education (ASO): A very broad, general education, preparing for higher education. Once students have completed all six years, it is expected that they will continue studying (e.g.: university or college).
- Technical Secondary Education (TSO): The TSO is divided into two groups of education again: TTK and STK. The TTK courses focus more on technical aspects and the STK courses focus more on practical matters. Both offer a general education in mathematics, languages, history, science, and geography, but mostly not at the same level as ASO courses. Lessons have a less theoretical, but more technical and practical approach. Once students have completed all six years they are either ready for the job market (STK courses mostly) or continue to study (TTK courses mostly).
- Vocational Secondary Education (BSO): Very practical and very job specific education. BSO is the only type of secondary education that does not qualify students to pursue higher education.
- Art Secondary Education (KSO): These schools link general and broad secondary education development with active art practice, ranging from performance arts to display arts.

Higher education in Belgium is organized by the two main communities, the Flemish Community and the French Community. German speakers typically enrol in institutions in the French Community or in Germany.

An excellent English-language booklet on education in Flanders is available[46].

STEM uptake

Table 1 indicates that Belgium has a lower proportion of its tertiary education graduates in science and engineering than the European Union average, as it does with upper secondary graduates. Belgium has a higher proportion than the European Union 27 average for doctoral students in science and technology fields, and a higher proportion of its human resources in science and technology. These figures are national ones; from these figures it is not possible to see if there are variations between the language communities.

[46] http://www.eui.eu/Documents/MWP/AcademicCareers/Countries/Belgium/BelgiumFlemishHigherEducation.pdf

Table 1: STEM Uptake - Various Measures - Selected Countries

Country	**Tertiary Graduates - Science & Engineering, % of Total - 2010 #**	**Upper Sec. & Voc. Ed. Graduations Science & Engineering, % of Total - 2010 #**	**Human Res. in Sci. & Tech. % of labour force 2011**	**Doctoral students in Sci. & Tech. Fields. % of Population Aged 20-29 2010 +**
Belgium	**16.1%**	**18.6%**	**49.6%**	**0.43%**
Austria	29.1%	27.5%	40.5%	0.69%
Czech Republic	23.4%	33.5%	36.0%	0.84%
Denmark +	19.3%	35.3%	51.5%	0.48%
EU27	21.3%	30.5%	42.3%	0.30%
Finland	31.8%	34.2%	52.6%	1.29%
France	26.2%	34.7%	48.1%	0.44%
Germany	25.6%	34.8%	44.9%	0.55%
Netherlands	14.0%	21.4%	52.2%	0.58%
Norway	16.0%	47.1%	54.8%	0.49%
Portugal	24.9%	3.7%	27.0%	0.49%
Sweden	26.9%	38.7%	52.2%	0.71%
Switzerland	19.8%	40.1%	54.7%	0.81%
UK - England	22.4%	0.0%	51.2%	0.40%

comprises the fields of science, mathematics & computing and engineering, manufacturing & construction
+ EU 27: Figure is for 2007
Source: Eurostats

STEM and gender

In general, women represent only a small proportion of science and engineering in the first and second stages of tertiary study (ISCED 5 and 6, respectively). Table 2 provides a ranking by the proportion of female students in STEM of all female students, and also shows the proportion that male and female STEM enrolments are as a proportion of all enrolments. The table shows that Belgium is one of the least successful countries in attracting women into STEM disciplines, with only the Netherlands trailing. Belgian women represent 55.2 per cent of all tertiary enrolments, but only 8.0 per cent of female students chose to undertake tertiary-level STEM programmes.

The VDI's European Engineering report shows that 19.1 per cent of Belgian engineers were women (2007), comparing favourably with the European average (16.6 per cent), and well ahead of countries such as Switzerland (9.5 per cent) and the United Kingdom (8.5 per cent).

BeWiSe[47] is the name of the organisation *Belgian Women in Science*. It is dedicated to achieving equal and full participation of women in all scientific disciplines and at all levels, by, e.g. creating a network for support and exchange of information, experience and knowledge, organising meetings, seminars and workshops, etc.

There is a mentoring programme, aimed at *women in the beginning of their scientific career* who are at least in their third year doctoral studies. It is for women who would like to *increase their knowledge* of scientific careers, who want to *position themselves better in the scientific community* and who want to *boost their careers* thanks to exchanges with a mentor. It is also aimed at *scientists, women and men, who have at least 10 years of scientific research experience* after their doctoral degree and who would like to share their knowledge and extensive professional experience to help young women in the beginning of their career.

47 http://www.bewise.be/

BeWiSe has a 14 minute promotional video on YouTube that demonstrates what they do[48].

In the main, BeWiSe activities are directed at those already in science, rather than trying to attract women to science in the first place.

Table 2 Uptake of STEM by All and Female Students at ISCED Levels 5 & 6 - 2010

Country	**Women % of All Students (1)**	**All Students in Science & Engineering as % of All Students (2)**	**Female Science & Engineering students as % of All Female Students (3)**
Finland	53.8	35.1	16.1
Germany	51.3	30.7	15.8
Ireland	52.4	27.6	14.7
Sweden	59.4	25.3	14.2
France	55.0	25.6	14.1
Austria	53.1	25.7	13.9
European Union (27 countries)	55.4	25.0	13.6
Czech Republic	56.8	25.3	13.1
United Kingdom	56.6	23.0	12.2
Poland	59.2	21.2	11.8
Denmark	58.1	18.7	11.2
Switzerland	49.2	22.9	10.6
Norway	60.8	16.4	8.5
Belgium	55.2	17.7	8.0
Netherlands	51.8	14.5	5.1

Source: Eurostat

(1) Women among students in ISCED 5-6 - as % of the total students at these levels
(2) Students at ISCED levels 5-6 enrolled in the following fields: science, mathematics, computing, engineering, manufacturing, construction - as % of all students
(3) Female students at ISCED levels 5-6 enrolled in the following fields: science, mathematics and computing; engineering, manufacturing and construction - as % of all female students

STEM promotion in Belgium

As with most aspects of life in Belgium, activities are dividing along language lines. The promotion of STEM is no different. Web-based material from the French and German communities is fairly sparse; so much of what is recorded here is based on the Flemish community.

The Flemish community has a ‘national’ strategy of a sort. Inspired by the Dutch model, a strategy known as Actieplan Wetenschapscommunicatie[49] (the Science Communication Action Plan) was set up in 2009. Targeted at young people, teachers and the general public, the Action Plan’s main aim is ‘… to promote a scientific and innovative culture in all walks of life and ensure a wider participation in the public debate about these issues and their impact on society’ (Kearney, 2011, p. 8). Those involved in the Action Plan work closely with a wide range of science organisations which form the Science Information Network[50] (WIN). The network aims to exchange information and expertise both within the government and all organisations working in the field of science communication in Flanders. Member organisations can publish their activities and projects on the WIN website, and a monthly newsletter keeps members apprised of each other’s latest news. Uniting all actors on a comprehensive platform

48 https://www.youtube.com/watch?v=_-3fY6re0p4
49 http://www.wetenschapmaaktknap.be/&usg=ALkJrhg8U2VJ44pmqZETCTMCpzzw5wj1HQ
50 http://www.wetenschapsinformatienetwerk.be/

allows the expertise in Flanders to be mapped. The Technopolis[51] platform for science and technology is central to the Science Communication Plan, by bringing science and technology to the people. The platform mainly targets 8-14 year-olds and their teachers, and involves a large number of partners, including businesses and the media.

As a programme to help young people decide on a life in STEM, the **Belgian (Flemish)** *De wererld aan je voeten*[52] (The world at your feet) project is aimed at stimulating 16-18 year old students to choose scientific or technical studies at university level, with a particular focus on encouraging students (especially young women) to pursue careers as civil engineers. Flanders has a shortage of engineers, due to students' lack of awareness of the job's content. This project engages students in web-quests and puts them in direct contact with professional engineers. A variety of partners, including both the Ministry of Science and Economics and the Ministry of Education, private companies, KVIV - the Royal Flemish Society of Engineers, and Flanders' educational portal for teachers – KlasCement[53], are involved in the project. The project was extended until 2012.

The Flemish Science and Innovation Council recently published a report aimed at having young people consider STEM. Entitled *Choosing STEM : the choice of youngsters for S&T studies*[54]*,* the report notes that the shortage of human capital in STEM is an urgent challenge in Flanders for the transition towards a knowledge economy and society. For this reason, the Flemish Council for Science and Innovation (VRWI) commissioned a study to further strengthen understanding in this area. The report suggests that

- Persistent, integral and large-scale initiatives are needed to obtain sustainable results
- Education is central. The VRWI calls for mobilising inspiring teachers through teacher training, and to ensure new, fascinating, motivating and relevant STEM-education based on 'inquiry-based learning'
- There should be a focus on girls and underprivileged youngsters
- The availability of interesting STEM-jobs should be ensured
- More media attention on STEM is needed
- A focus on retraining towards STEM jobs is needed
- Attracting and retaining foreign STEM graduates and students is needed
- An independent STEM platform that puts things in motion and that can raise enthusiasm is important
- A realistic budget is needed to obtain sustainable results, and
- Further and permanent (oriented) research is desirable. (Flemish Science and Innovation Council, 2012)

Currently moves are afoot to satisfy the requests of the Flemish Parliament. Acknowledging that engineering and technical professions are subject to shortages of qualified labour, a new STEM action plan is being written. The writing is difficult, because three ministries are involved. A new platform will be installed, and the project will involve a high-level group from industry.

[51] http://technopolis.be/eng
[52] http://www.dewereldaanjevoeten.be/keuze.html
[53] http://www.klascement.eu/
[54] http://www.vrwi.be/en/publications/advisory-report-175

Belgium (Flanders) has the RVO-Society[55] acting as a gateway between research and STEM education. It is a not-for-profit organisation. The RVO-Society promotes technology in education.

End word

As a source of policy and practice information, Belgium is fragmented. The two main sections, comprising the Dutch-speaking majority and the French-speaking minority almost never work in concert. The Dutch-speaking Flanders community have a range of initiatives on the go, many of which parallel contemporary activity in the Netherlands. All in all, there are better and less complicated 'models' available from other parts of Europe.

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55 http://www.rvo-society.be/

Country report: Denmark

Introduction: Demographic background[56]

The Kingdom of Denmark has about 5.5 million people in a country that covers 43,098 sq. km. and consists of the peninsula of Jutland (29,778 sq. km.) and 407 islands (13,320 sq. km.) of which 82 are inhabited. The population density is 128.4 inhabitants per sq. km. Denmark also comprises the two self-governing territories: the Faroe Islands (1,399 km^2. with 48,433 inhabitants) and Greenland (2,166,086 km^2. with 56,462 inhabitants).

The average age of the Danish population was 40 on 1 January 2008, three years older than in 1980. The rise is partly a result of the increasing number of persons over the age of 80. Life expectancy for men is 76 years and 80.5 for women. In 2008, for every 100 persons in the active labour force there were 89 persons to be provided for, i.e. persons outside the labour force. If this trend continues, there will be 110 persons to be provided for in 2030.

Immigrants and their descendants comprise approximately 9.1 per cent of the Danish population.

In 2008, approximately 35 per cent of the Danish population resided in cities with 10,000 or more inhabitants, whereas approximately 14 per cent resided in country districts. Copenhagen, the capital, had in the same year 672,218 inhabitants.

Education in Denmark[57]

The Danish Agency for Universities and Internationalisation within the Ministry of Science, Innovation, and Higher Education provides an official source of information on Danish education. Much of what follows has been paraphrased from their website.

In common with education in several European nations, Danish education has nine years of compulsory education up to age 15 or 16, which includes primary and lower secondary education, which then bifurcates into upper secondary general or vocational streams. It is not mandatory to attend school in Denmark, but few children are home taught. In 2010, nearly 675,000 students were enrolled in compulsory education, 34 per cent of the population aged 0-29 (Eurydice, 2011). Since 2009, one year of pre-primary education is also compulsory.

Curriculum control comes from the Ministry of Children and Education. The curriculum comprises three blocks, of which one is ‘science’: mathematics in all years; science/ technology in years 1 to 6; geography, biology and physics/chemistry respectively in years 7 to 9. Teachers must meet the needs of all students in mixed ability groups (Eurydice, 2011). There are no prescribed text books in compulsory schooling.

Upper secondary education programmes (ISCED 3), also referred to as youth education programmes, can be divided into:

- General upper secondary education programmes, which primarily prepare for higher education.

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56 http://eacea.ec.europa.eu/education/eurydice/documents/eurybase/eurybase_full_reports/DK_EN.pdf

57 Refer to: http://en.iu.dk/education-in-denmark/the-danish-education-system/higher-education-1

- Vocational upper secondary education and training programmes, which primarily prepare trainees for a career in a specific trade or industry.

In 2008, 241,000 pupils were enrolled in upper secondary education programmes, 49 per cent were enrolled in a general programme.

There are four academically oriented general upper secondary programmes, all of which prepare pupils for further study. One of those programmes also has enrolments of older students.

Vocational education and training (VET) includes a vast range of programmes. VET programmes are sandwich-type programmes in which theoretical and practical education at a vocational college alternates with practical training in an approved company or organisation (33:67). The dual training principle ensures that the trainees acquire theoretical, practical, general and personal skills, which are in demand on the labour market. VET programmes are normally completed with a journeyman's test or a similar examination testing vocational skills and knowledge. There are 12 vocational clusters from which to pick. Admission to VET requires completion of compulsory education. All programmes qualify trainees for labour market entry as skilled workers. In addition, some programmes can qualify trainees for admission to certain types of higher education programmes. Nearly all VET students go down this path, but there can also be other specific arrangements for some students.

Higher education in Denmark is taught at universities, university colleges, academies of professional higher education, and ‘university level institutions’. The programmes prepare the students for performing practical, vocational tasks on an analytical basis and may lead to employment in middle-management positions. They combine theoretical studies with a practically oriented approach in the form of work placement.

All Danish universities are research-intensive institutions offering research-based study programmes in all three cycles up to PhD level. The bachelor degree (BSc/BA) qualifies graduates for a professional career and further studies at second cycle level. Most students choose to continue in a second cycle master’s degree. They usually include one or two of the major fields of study of the bachelor programme, and require independent research activities and the writing of a master's thesis. Graduates are qualified for a professional career and for scientific work.

The PhD degree consists of research, participation in research courses, teaching and public defence of a thesis.

University Colleges (professionshøjskoler) and specialised colleges offer professional bachelor programmes in fields such as business, education, engineering and nursing. The programmes have a strong focus on professional practice and provide students with knowledge of theory and the application of theory to professions and industries.

Academies of professional higher education (erhvervsakademier) offer academy profession programmes in fields such as business, technology and IT. The programmes prepare students for performing practical, vocational tasks on an analytical basis and may lead to employment in middle-management positions. They combine theoretical studies with a practically oriented approach in the form of work placement.

‘University level institutions’ are regulated by the Ministry and offer first, second and third cycle degrees in fields such as fine arts, architecture, music and performing arts.

General access requirements to higher education are one of the general upper secondary school leaving examinations, or comparable qualifications. Access may also depend on specific requirements such as a particular subject combination in upper secondary school or a certain level of grades. Admission to some particular programmes requires completion of an entrance examination or submission of a portfolio of artistic work.

The education system is financed by the state or the municipalities (schools, primarily). Some institutions are self-governing, while others are owned by the state or the municipalities. In addition to public financing, tuition fees are charged at private schools and there is a user payment for a number of adult education programmes.

Teachers in different levels of education require different levels of qualification. Pre-primary teachers require a three-year bachelor's degree; compulsory school teachers require a four-year professional bachelor's degree. Both degrees are provided via university colleges. Upper secondary teachers need to be specialised in one or more subject areas, and need a master's degree. Vocational college teachers require the same or equivalent vocational subjects.

STEM uptake

Table 1 presents statistics that provide a reflection of STEM uptake in selected European countries. In the case of Denmark, according to the data available through Eurstat[58], Denmark produces a lower proportion of tertiary STEM graduates than the EU27 average, but a higher proportion of vocational graduates. It has a higher proportion of its labour force in science and technology areas. The proportion of all doctoral students enrolled in science and technology programmes in Denmark is higher than the EU27 average, but lower than is the case in several other countries.

[58] http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/

Table 1: STEM Uptake - Various Measures - Selected Countries

Country	**Tertiary Graduates - Science & Engineering, % of Total - 2010 #**	**Upper Sec. & Voc. Ed. Graduations Science & Engineering, % of Total - 2010 #**	**Human Res. in Sci. & Tech. % of labour force 2011**	**Doctoral students in Sci. & Tech. Fields. % of Population Aged 20-29 - 2010 +**
Denmark +	**19.3%**	**35.3%**	**51.5%**	**0.48%**
Austria	29.1%	27.5%	40.5%	0.69%
Belgium	16.1%	18.6%	49.6%	0.43%
Czech Republic	23.4%	33.5%	36.0%	0.84%
EU27	21.3%	30.5%	42.3%	0.30%
Finland	31.8%	34.2%	52.6%	1.29%
France	26.2%	34.7%	48.1%	0.44%
Germany	25.6%	34.8%	44.9%	0.55%
Netherlands	14.0%	21.4%	52.2%	0.58%
Norway	16.0%	47.1%	54.8%	0.49%
Portugal	24.9%	3.7%	27.0%	0.49%
Sweden	26.9%	38.7%	52.2%	0.71%
Switzerland	19.8%	40.1%	54.7%	0.81%
UK - England	22.4%	0.0%	51.2%	0.40%

comprises the fields of science, mathematics & computing and engineering, manufacturing & construction
+ EU 27: Figure is for 2007
Source: Eurostats

STEM uptake and gender

Although women represent 58.1 per cent of tertiary enrolments, only 11.2 per cent of women undertake studies in STEM disciplines. The overall percentage of all students undertaking STEM is also quite low, at 18.7 per cent. In countries such as Germany and Finland, the study of STEM disciplines is at a much higher rate, even if the uptake by women is relatively low.

Table 2 Uptake of STEM by All and Female Students at ISCED Levels 5 & 6 - 2010

	Women % of All Students (1)	All Students in Science & Engineering as % of All Students (2)	Female Science & Engineering students as % of All Female Students (3)
Finland	53.8	35.1	16.1
Germany	51.3	30.7	15.8
Ireland	52.4	27.6	14.7
Sweden	59.4	25.3	14.2
France	55.0	25.6	14.1
Austria	53.1	25.7	13.9
European Union (27 countries)	55.4	25.0	13.6
Czech Republic	56.8	25.3	13.1
United Kingdom	56.6	23.0	12.2
Poland	59.2	21.2	11.8
Denmark	**58.1**	**18.7**	**11.2**
Switzerland	49.2	22.9	10.6
Norway	60.8	16.4	8.5
Belgium	55.2	17.7	8.0
Netherlands	51.8	14.5	5.1

Source: Eurostat
(1) Women among students in ISCED 5-6 - as % of the total students at these levels
(2) Students at ISCED levels 5-6 enrolled in the following fields: science, mathematics, computing, engineering, manufacturing, construction - as % of all students
(3) Female students at ISCED levels 5-6 enrolled in the following fields: science, mathematics and computing; engineering, manufacturing and construction - as % of all female students

Denmark has strong ‘promotion of science’ programmes in place, and a specific agency with a focus on communication, but there appears to be relatively little in place in the form of a national programme. Gender equality has its own ministry and minister, so is taken seriously: ‘Gender Equality Work in Denmark is integrated into all public authorities and is organized by the Department of Gender Equality set up under the Minister of Gender Equality’ (EMBO[59]).

Danish science promotion

Denmark has a national-level body for the promotion of science named *Dansk Naturvidenskabs-formidling* - Danish Science Communication (DNF)[60]. The direct quotations below come from the DNF website. The mission of this organisation is to create enthusiasm for science among children and adolescents: ‘We believe that science should be a natural part of children and young people's education and that they should be able to experience the joy of dealing with science’.

Danish Science Communication was founded in 2001 by the people and the organisations behind the Danish Science Week as an autonomous and independent non-profit organisation working with the support of the Ministries of Education, and Science, Technology and Innovation as well as private foundations, companies and other organisations. The board includes representatives from universities, industry, schools and other educational institutions. Danish Science Communication’s current brief now continues to 2015 (as was mooted in 2010).

Danish Science Communication has 16 full-time employees, with degrees in science and communication. The Danish Government meets 15 per cent of operating expenses. The remaining operational funds are obtained by developing projects for

59 http://www.embo.org/science-policy/women-in-science/embo-policy/50.html#denmark
60 http://www.formidling.dk/

ministries with sponsorships and donations coming from a range of private enterprises and organisations. The organisational strategy includes an invitation to other organisations and institutions to establish partnerships in order to create new projects and disseminate new knowledge.

Danish Science Communication works with development projects and large long-term initiatives and sees itself as innovative and creative. The objective of projects is '… to inspire teachers and facilitators in their work with children and young people, to create synergies between the many good initiatives and to find new ways to create enthusiasm for science'.

Danish Science Communication arranges both elite and popular activities and aspires to create change. Danish Science Communication coordinates recurring activities, such as the annual Danish Science Festival - a nationwide campaign with activities for primary and secondary schools throughout the country and the annual Young Scientists competition. Danish Science Communication also coordinates one-off projects, such as Science municipalities (to develop science and cooperation within regional councils) and ISI 2015 (an integration project).

Science municipalities

A Science Municipality is a municipality with a strategy for the development of science area that interact with local strategy for business. This was a development plan '… to create synergy between Denmark's many initiatives in science… [it is] based on the idea that children and young people's interest in science and engineering can be enhanced if all good forces within the municipal boundary interact. It ran between 2008 and 2011 with the DNF and financial support from the Ministry of Education. Although the project has now been completed, it will continue at several levels both within and outside the Science Municipalities. Inspiration from the project will continue to be utilised in the future building on the perceived successes. The project was evaluated each year. Some of the key points from the conclusion of the final evaluation[61] follow.

> …It is difficult to draw any clear conclusions from the 25 different municipalities with such diverse conditions and processes during the Science Municipality project. Therefore, it is … important to emphasise that the following conclusions should be viewed as overall patterns in a very motley collection of data. That said, there are important insights to be gained from project, which has left lasting traces in several municipalities….

The key lessons from the project

- Efforts must be worn by cooperation between many different actors in the municipality. Developments need to have cooperation between many actors, including obtaining the requisite funding. Involving multiple partners with similar interests together across existing organisational and cultural boundaries can be fruitful. There were several examples of how these collaborations could lead to a better use of existing resources in the area.
- There must be a dedicated municipal coordination of efforts on science area in the municipality. The science coordinator has a central role, and was interpreted differently in different municipalities; science coordinators had very different backgrounds, employment, working conditions, responsibilities and functions. Most municipalities installed a coordinating body in the layer between the political /

61 http://science-kommuner.wikispaces.com/2010-2011

administrative level within the municipality and practice level (schools, businesses, informal learning environments, etc.). Science coordinators helped to establish the first contact between the players. It was also found to be a great advantage when the science coordinator function was shared between several people with complementary skills and personal networks. This meant that science coordinators could bring other perspectives, practices and networking in games than if science coordinators came exclusively from management.

- Political engagement is needed to ensure a long-term effort and a good framework for development.
- Fundamental change takes time. One important experience from the project has been that 'things take time'. Establishing good cooperation, coordination of efforts on science area and political anchor has proved to be cumbersome and time-consuming. In this perspective, three years is only a short time, and the results of science municipal project should be seen in this light.

ISI 2015: a project with ethnic minorities
(ISI = innovation, science, inclusion (earlier: integration)

ISI 2015 is a six year project, being carried out in five multicultural schools in Odense from 2009 to 2015. The main elements of the project are training teachers, fostering school cooperation with society, arranging annual exhibitions and organising networking activities. It is a programme to tap into what is perceived as an under-utilised source of future STEM professionals, as well as fostering inclusion of ethnic minorities in secondary and post-secondary education. 'The aim of the project is to improve skills in science subjects among young people from multicultural schools and thereby encourage more people to choose a natural academic, secondary school'. The focus is on multicultural schools because it is known that ethnic minority students are more likely choose courses in specific technical subjects such as engineering than are ethnic Danes.

The primary target group is students who started in sixth class in August 2010. Secondary target groups are teachers and leaders in schools to implement the project activities and ensure the sustainability of the project by anchoring the development of the school's strategy and culture. The Industry Foundation, Odense Municipality and the DNF are collaborating in running ISI 2015.

School-related projects

DNF is involved in school projects, which aim to inspire students towards science education. Cooperation with teachers and the development of new educational initiatives in the science area are seen as an important part of DNF's work. Some projects:

- *Danish Science Festival*[62] is held once a year - always in September. It involves hundreds of activities, and engages about a third of the country's primary schools and half of the general and technical secondary schools. The theme for 2012 was 'All that we do not know'.
- *Novo Science Ambassadors*[63] - A team of graduate students at Novo is trained to give lectures and visit upper secondary schools and the upper classes in elementary school. Students meet an enthusiastic young person who is not much older than themselves, and get an idea of their experience as 'budding scientists'

[62] www.formidling.dk/sw7730.asp
[63] http://www.formidling.dk/sw1811.asp

and the opportunities for personal development and fulfilment that can be attached to a career in biotechnology, medicine and health research.

- *Test-o-teket.dk*[64] - A website full of light science kitchen experiments for all grade levels to engage with.
- *Young Scientists* is a science competition, held annually, and offering a prize. The theme for the 2012 Young Scientists competition was My Wildest Idea. This is a competition that provides inspiration and working methods for science teachers to inspire their students to find investigative science education exciting, different, fun and inspiring. Young Scientists can submit a science projects and win up to DK25,000. Projects can be theoretical, experiments, discoveries and inventions or a combination. Students from all year levels can work individually or in groups.

The National Centre for Science, Technology and Health Education

The decision to establish a national centre for education in science, technology and health was taken in 2009 on the basis of recommendations from a working group appointed by the Minister of Education and Minister of Science, Technology and Innovation. The Working Group had since 2007 worked to prepare a national strategy for science, technology and health in the Danish education. Its purpose is to increase the interest in, the recruitment of, and the quality of the education in science, technology and health in the Danish education system. From its website[65] [66] it can be learned that its responsibilities are to:

- increase the quality of the education in science, technology and health through IT-based teaching resources and contribute to creating a better linkage in the education system
- contribute to the development of further education of teachers and educators in order to generate a continuous quality development of the education as well as to increase the interest among pupils and students
- create a better interaction between various sectors, both between the formal educational system and informal learning environment (private and public companies, museums, activity centres etc.) and between different parts of the educational system
- contribute to creating Danish networks for teachers/educators, local authorities, informal learning environments etc. with a view to knowledge sharing and structured gathering of experience
- be part of international networks with corresponding foreign centres with a view to knowledge sharing
- to gather and communicate experience from practice and research in professional didactics with a view to communication of knowledge for e-knowledge based development of teaching resources etc.

Denmark in Europe

Through DNF, Denmark is active in several European and wider science-related networks. Denmark is a member of EUSCEA the European Science Events Association which is the European network of science festivals. This organisation was established in 2001 and now has more than 80 member organisations from 34 countries. Its purpose is to create a festivals network; exchange ideas and activities and helping to start new festivals.

[64] http://www.formidling.dk/sw41090.asp
[65] http://www.ecsite.eu/members/directory/national-centre-science-technology-and-health-education-denmark
[66] http://nts-centeret.dk/baggrund/menu-id-76

Denmark is a participant in activities through **Ingenious** (an EU project on school / business cooperation, with 26 partners from 16 European countries which joined forces to create enthusiasm for science through school / business cooperation.

Denmark is also involved in **DESIRE** (Disseminating Educational Science, Innovation and Research in Europe), an EU project to make research information more readily available to teachers. The target group for dissemination are teachers. The project started in December 2011, will run for two years and is a collaboration between European Schoolnet, Universitat Autonoma de Barcelona, the Association of European Science Centres and Museums (ECSITE), the Italian National Agency for the Development of Education INDIRE and Danish Science Communication.

Still on the 'science communication' theme, perhaps a precursor to DESIRE, was a project entitled **SciCo** (an abbreviation of science communication, which is the English term for this concept). SciCo ran from January 2009 to December 2010 and was financed by the Danish Agency for Science, Technology and Innovation, the Danish research funding body and the University of Southern Denmark. The project's aim was to systematise and professionalise research dissemination in Denmark, typically left up to each researcher to decide.

Etcetera: One million viewers can't be mistaken

One interesting (now annual and international) project to help with the popularisation of science has been a film competition arranged by the science faculty at the University of Copenhagen[67], after one of its student films (The power to create)[68] became a hit on Youtube and other popular web channels. It has been seen by over one million viewers. Among other things, it led to twice the number of international students choosing to study science at the University of Copenhagen than before. This perhaps demonstrates the potential power of social and visual media in promoting science. Winning and other entries can be found on the faculty website[69].

End word

In addition to its involvement in generic pan-Europe projects and schemes, Denmark presents a couple of internal projects that might work in an Australian context. First, the concept of science promotion through municipalities is one that could be examined for appropriateness in Australia. Perhaps this happens already, but it might also be that regional universities and their local government councils could boost science in such regions. The model might not work quite so well within metropolitan centres with multiple municipalities / cities and multiple universities.

The other project that could have transportability to Australia is the ISI 2015 project, targeted at migrant-rich schools. Many sections of Australian major cities will have situations that parallel the Danish experience. However, other matters must be considered in the Australian context, such as the costs of fees involved in undertaking STEM studies in Australian universities. Some groups of students *are* debt-averse.

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Country report: Germany

Introduction: Demographic background

Germany is the most populous country in the European Union, with a population of just under 82 million in 2011. This represents 16.3 per cent of the total European Union population. About 30 per cent of the population were aged 29 or less. The area of Germany is 643,548 km^2, 8.1 per cent of the total EU landmass. Population density is about 230 persons per km^2.

About 9.8 million people in German were not born there, meaning that immigrants represent about 12 per cent of the total population. Around 3.4 million of the immigrants are from another European Union state.

Life expectancy at birth for German men and women is 77.2 years and 82.4 years, respectively (Wikipedia, n.d).

Education in Germany

In 2009, there were 7.8 million young people in full-time compulsory education, of whom 92.1 per cent were in general education attending public sector schools, with the remaining 7.9 per cent attended privately-maintained schools. In vocational education, 91.3 per cent of pupils attending public sector schools, 8.7 per cent attended privately-maintained schools (Eurydice, 2011a).

Germany is a federal nation, and according to the Basic Law, education legislation and administration are primarily the responsibility of the states (*Länder*). The Länder cooperate with each other via the Standing Conference of the Ministers of Education and Cultural Affairs (KMK). The Federal Government's responsibilities are also defined in the Basic Law: Among these responsibilities is the legislation concerning the admission to higher education institutions and the degrees they confer, as well as the financial assistance for individual training, including promotion of younger academic staff. The Basic Law also provides for particular forms of cooperation between the Federation and the *Länder*, such as that which occurs in the sector of the promotion of research' (Eurydice, 2011a).

Compulsory education differs between Länder, but covers ages 6 – 15 or 16, and comprises primary school (6-10 years in most Länder) and lower secondary school (10/12 – 15/16). Länder also define the length of the school year and the length of the school day, as they do the curriculum, recommended teaching methods and textbooks.

Once pupils have completed compulsory schooling, they move into upper secondary education. The type of school entered depends on the qualifications and entitlements obtained at the end of lower secondary education. The range of courses on offer includes full-time general education and vocational schools, as well as vocational training within the *duales System* (dual system). Post-compulsory education includes upper secondary education for age groups 15/16 – 18/19.

The tertiary sector encompasses institutions of higher education and other establishments that offer study courses qualifying for entry into a profession to students who have completed the upper secondary level and obtained a higher education entrance qualification. Germany's binary higher education system comprises universities and university-equivalent institutions, and universities of applied sciences (fachhoclschlen). There are also other higher education options in some Länder, including tertiary education qualifications that are not higher education degrees that provide qualification for a profession (Berufsakademie).

STEM uptake[70]

Table 1 presents statistics that provide a reflection of STEM uptake in selected European countries. According to the data available through Eurostat[71], there are relatively high proportions of tertiary and vocational STEM graduates, STEM Doctoral students and STEM human resources in Germany, certainly higher than the EU27 average and many neighbouring countries.

Table 1: STEM Uptake - Various Measures - Selected Countries

Country	Tertiary Graduates - Science & Engineering, % of Total - 2010 #	Upper Sec. & Voc. Ed. Graduations Science & Engineering, % of Total - 2010 #	Human Res. in Sci. & Tech. % of labour force 2011	Doctoral students in Sci. & Tech. Fields. % of Population Aged 20-29 2010 +
Germany	**25.6%**	**34.8%**	**44.9%**	**0.55**
Austria	29.1%	27.5%	40.5%	0.69
Belgium	16.1%	18.6%	49.6%	0.43
Czech Republic	23.4%	33.5%	36.0%	0.84
Denmark +	19.3%	35.3%	51.5%	0.48
EU27	21.3%	30.5%	42.3%	0.30
Finland	31.8%	34.2%	52.6%	1.29
France	26.2%	34.7%	48.1%	0.44
Netherlands	14.0%	21.4%	52.2%	0.58
Norway	16.0%	47.1%	54.8%	0.49
Portugal	24.9%	3.7%	27.0%	0.49
Sweden	26.9%	38.7%	52.2%	0.71
Switzerland	19.8%	40.1%	54.7%	0.81
UK - England	22.4%	0.0%	51.2%	0.40

comprises the fields of science, mathematics & computing and engineering, manufacturing & construction

+ EU 27: Figure is for 2007

Source: Eurostats

If the graduation rates reflect a country's capacity to meet its technical labour force needs, then the German situation would seem to be relatively more attractive than is the case in some other countries.

STEM and gender

In general, women represent only a small proportion of science and engineering in the first and second stages of tertiary study (ISCED 5 and 6, respectively). Table 2 provides a ranking by the proportion of women of all students, STEM enrolments as a proportion of all enrolments, and women in STEM programmes as a proportion of all female students. The table shows that Germany is one of the more successful countries in attracting women into STEM disciplines, but that the proportion is still low. Women represent 51.3 per cent of all tertiary enrolments, but only 15.8 per cent of female students chose to undertake STEM programmes. STEM enrolments by men and women are considerably higher than the EU average, as is the proportion of German women undertaking STEM studies at the tertiary level.

Table 2 Uptake of STEM by All and Female Students at ISCED Levels 5 & 6 - 2010

70 In German, the equivalent acronym is MINT (Mathematik, Informatik, Naturwissenschaften, Technik)

71 http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/

	Women % of All Students (1)	All Students in Science & Engineering as % of All Students (2)	Female Science & Engineering students as % of All Female Students (3)
Finland	53.8	35.1	16.1
Germany	51.3	30.7	15.8
Ireland	52.4	27.6	14.7
Sweden	59.4	25.3	14.2
France	55.0	25.6	14.1
Austria	53.1	25.7	13.9
European Union (27 countries)	55.4	25.0	13.6
Czech Republic	56.8	25.3	13.1
United Kingdom	56.6	23.0	12.2
Poland	59.2	21.2	11.8
Denmark	58.1	18.7	11.2
Switzerland	49.2	22.9	10.6
Norway	60.8	16.4	8.5
Belgium	55.2	17.7	8.0
Netherlands	51.8	14.5	5.1

Source: Eurostat
(1) Women among students in ISCED 5-6 - as % of the total students at these levels
(2) Students at ISCED levels 5-6 enrolled in the following fields: science, mathematics, computing, engineering, manufacturing, construction - as % of all students
(3) Female students at ISCED levels 5-6 enrolled in the following fields: science, mathematics and computing; engineering, manufacturing and construction - as % of all female students

Germany has a National Pact for Women in MINT Careers – 'Go MINT!' The programme seeks to get female pupils interested in MINT (STEM) subjects, offers decision assistance on a course of study and establishes contacts to the working environment. It also opens up opportunities for women's careers in business and science, with specific measures at the stage of transition from university to the work force.

The National Pact for Women in MINT Careers was launched by the Federal Government in June 2008 as part of the Federal Government's *Get Ahead Through Education* qualifications initiative. The aim has been to build on earlier successes and, to utilise the wealth of diverse experience accumulated in encouraging young women's interest in STEM disciplines.

Along with Pact partners, the Federal Ministry of Education and Research has supported several projects:

MINT Role Models[72]

Verein Deutscher Ingenieure e. V. (the Association of German Engineers, a body active in the promotion of engineering uptake by women) is working with other Pact participants on developing a concept for presenting positive examples of female careers. Attractive MINT career paths are presented at regional and national events and publicised via school newspapers, TV spots and Internet forums.

CyberMentor[73]

72 http://www.mint-role-models.de/
73 https://www.cybermentor.de/

First-hand knowledge: female mentors working in STEM careers are available to schoolgirls via e-mail to answer questions on STEM topics. Schoolgirls can also obtain relevant information from a variety of online and offline sources.

Fraunhofer Talent School and Junior Engineer Academy

Deutsche Telekom Stiftung and Fraunhofer-Gesellschaft offer a joint and continuous promotional programme from high school to university/college entrance. By the end of 2010, at least ten Junior Engineer Academies had been set up and 20 Talent Schools run throughout Germany.

tasteMINT[74]

tasteMINT gives female high school graduates a chance to assess their potential for STEM study areas.

mäta[75] **– Federal girls' technology talent forums in STEM**

This project centres on 'round tables' at which regional activities in STEM subjects are pooled to produce seven national Girls' Technology Conferences. The project aims to establish nationwide networks, building on regional centres, between the mst|femNet network[76] and other girls' and women's networks in MINT fields.

Light up your life

The 'Light up your life – for girls with brains' project aims to expand the choice of careers available to girls in the fields of natural sciences and technology, using the cross-cutting technology of photonics as an example.

A website provides a repository for all the information about 'Go MINT![77]' It is structured for different target groups, and provides the latest news along with dates and event information for schoolgirls, female students, parents / teachers, and businesses / organisations.

German science promotion

Germany is one of the countries identified by Eurydice (2011b) as having a national strategy in place. Part of that strategy is an association known as MINT (STEM) Future, a registered non-profit association that networks and brings together all MINT initiatives. All activities of the organisation go by the name 'Create a MINT future'. The German President is the patron of the organisation.

The objectives of the Association are to be proactive and to network and pool industry and regional business initiatives towards promoting MINT under the name 'creating a MINT future'.

The association's purpose is to:

- promote the interest of students in STEM;

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74 http://www.tastemint.de/
75 http://www.mst-femnet.de/projekt-maeta-ii.html
76 http://www.mst-femnet.de/startseite.html
77 www.komm-mach-mint.de

- increase the number of students in STEM degree programmes at universities in Germany and in particular to increase the proportion of women;
- increase the number of students in STEM courses, i.e., reduce dropout rates in these courses;
- safeguard and improve the quality of STEM graduates.

The philosophy behind the association is that German business is threatened by the lack of new blood in STEM skills and that the bottleneck in the scientifically and technically skilled professionals is a structural problem that has already affected the German economy.

The website holds immense amounts of information, for students, youth, parents, teachers and businesses.

According to ALLEA, the federation of *All European Academies* (founded 1994), which currently brings together 52 Academies in more than 40 countries, numerous initiatives aimed at rejuvenating science education have sprung up to promote STEM uptake in Germany as a reaction to the 'surprisingly poor performance of German schools in international benchmarking exercises…. often supported by scientific institutions and foundations. A number of initiatives also received support from the Federal Ministry of Education and Research (BMBF)' (ALLEA, p 48).

ALLEA published its report *A renewal of science education in Europe* in 2012, a document in which they summarised the input of Europe's learned academies into STEM promotion. Based on an analysis of responses to questionnaires in 2010 and 2011, ALLEA was able to report on activities in various countries. Some of this is presented as direct paraphrased or uncited quotes below.

In the field of *inquiry-based science education*, BBAW, one of the German academies has been cooperating with Freie Universität (FU) Berlin and the French Académie des sciences since 2005. This cooperation was articulated through a series of distinct projects, the first being *Sonnentaler – Naturwissenschaften in Kita und Grundschule*[78] (science in pre- and primary schools), which can be described as the German version of '*La main à la pâte*' ('hand in the paste': see Europe report).

As part of the *SciencEduc*[79] project (2004 – 2006), BBAW was among the co-organisers of the national conference 'Science is primary' in 2005, which allowed for experiences from France, Sweden, and the USA to be featured and compared, and which also involved representatives from other federal states. Teachers' workshops soon became part of the activity, usually centring on a range of conceptual themes.

Germany was also involved in another significant Europe-wide project: *Pollen – Seed Cities for Science: A Community Approach for Sustainable Growth of Science in Europe*' (2006-2009)[80] (www.pollen-europa.net). The project helped IBSE-related experiences in 12 'seed cities' to be networked throughout the European Union, notably among educational districts that sought support for sustainable reforms and innovative science teaching in primary schools by mobilising the commitment of the whole community. Outcomes of the pilots and recommendations for regional action plans were presented and explained to national education authorities with the intention of leveraging wider ranging change across the school systems. One focus of the Berlin-based project component was the differences in attitudes towards science that

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78 http://www.sonnentaler.net/
79 http://scienceduc.cienciaviva.pt/home/
80 www.pollen-europa.net

had been observed between boys and girls – a crucial concern being the decreasing number of science students, and in particular of girls who choose a career in science.

Pollen was also praised in the Rocard report as one of the crucial components of the renewal of science teaching practices in Europe, and the report also mentioned the *Sinus Transfer* programme as one that could increase children's interest and attainments in science. According to Rocard, 'With some adaptation these initiatives could be implemented effectively on a scale that would have the desired impact' (European Commission, 2007, p. 14).

Sinus Transfer started in 1998 as a pilot study 'Increasing efficiency in mathematics and science education' which was abbreviated to 'Sinus'. The aim was to improve German students' showing in international testing programmes: 'SINUS relies on competent and experienced teachers at different levels of schooling. Teachers are expected to make their own decisions about their aims and the means they intend to use for improving their classroom teaching. These are not isolated endeavours but the initiation of a process that will lead to sustainable improvement in classroom teaching' (Bavarian State Ministry of Education and Cultural Affairs, 2010). As noted by Rocard, 'Sinus-Transfer provides secondary school teachers with tools to change their pedagogical approach on science teaching. It includes and emphasizes the importance of using scientific inquiry and experimental approaches. The focus is put on teachers' professional development:

> Sinus-Transfer is characterized by a long-term, school-based and collaborative approach that is focused on students' learning. It relates to didactical problems in science classrooms and stimulates teachers to evaluate and reflect their teaching in a process of continuous quality development. During the process a strong cooperation is established between teachers within and between schools as well as between researchers and practitioners (European Commission, 2007, p. 15).

The German equivalent and partner project had been launched by FU Berlin and BBAW: *TuWaS! (Technik und Naturwissenschaften an Schulen*[81]). The project was conceived as continuing in Germany beyond the funding cycle foreseen for the EU-funded pilots.

At the conceptual and pedagogically operational level, the programme relies on the four stages of the inquiry process, with children sharing their knowledge, following guided experiments, analysing the collected data and their observations, and applying their new insights to new settings. At the institutional level, the programme rests on five main pillars of continuous professional development of teachers' provision of tested and validated new teaching materials, coordination and integration of IBSE teaching elements into the regular school curriculum, involvement of regional and municipal educational administrations, business and civil society, and opening up the laboratories of research institutions for students, and regular evaluation.

A further expansion of these FP6 supported IBSE-oriented projects is the FP7 co-sponsored, *Fibonacci Project*[82] which aims at the wider dissemination of inquiry-based science (and also mathematics) education in Europe.

Most science organisations in Germany, including Acatech, the German national academy of science and engineering, and the Berlin-Brandenburg Academy of Sciences and Humanities (BBAW) are members of *Wissenschaft im Dialog* (WiD -

81 www.tuwas-deutschland.de
82 http://www.fibonacci-project.eu/

Science in Dialogue)[83], Germany's centre of expertise for science communication. WiD encourages dialogue between the general public and scientists through exhibitions, science festivals, symposia, etc. For example, the *exhibition ship MS Wissenschaft* (‘MS Science’) tours 30 cities every year as a floating science centre for primary school children that focuses thematically on the subject of the respective ‘Science Year’. A similar WiD-sponsored programme exists at railway stations in cooperation with Deutsche Bahn. The annual *Wissenschaftssommer* (‘Science summer festival’) is the major science fair in Germany.

WiD’s European engagement is focused on participating in the Euroscience Open Forum ESOF science festival which has the ambition to grow into the European counterpart of the annual science meeting of the American Association for the Advancement of Science (AAAS). WiD is also a member of EUSCEA (European Science Events Association), a platform of 70 organisations in 32 countries specialising in science events and science communication (the WiD director is current president of EUSEA). In this context WiD participates in the FP-funded *2WAYS-project – Communicating Life Science Research*[84] which seeks to bring recent advances of current European life science research to a wider public.

Through local science parliaments of 60-100 students (16-20 years old), who meet for three days and debate controversial questions, delegates are dispatched to the Young Europeans Science Parliament. This gathering was convened in the European Parliament at the end of 2010 with 58 students from 29 cities in 17 countries. Supported by resident experts, four committees discussed a set of predefined questions related to topical issues in the life sciences.

Many activities are also conducted in the various German Länder.

Acatech, the German academy of science and engineering, examined the causes of the current shortage of young scientists and engineers. It also sought to identify measures to promote these fields better. An expert group investigated five key areas: (1) Promotion of skills in children and adolescents; (2) Vocational training and studies; (3) job market: appeal and image of technical and scientific occupations in Germany; (4) Doing Gender in science and engineering, and (5) Technology and society. The findings of the expert group were published and the Academy issued a number of recommendations in its strategy paper ‘for promoting interest in science and engineering: recommendations for the present / research needs for the future’. They were presented and discussed at what was called the *Nachwuchsgipfel* (the national summit for the next generation) in 2009. Those recommendations that relate to science and technology education at pre-university level can be tentatively grouped into several clusters: (1) developing an interest and skills in science and technology is a life-long task that should not be left to schools and the period of school education alone; engagement should be continuous and main-streamed; (2) IBSE-based approaches in pre-school and classroom should be accompanied by activities in informal settings and through the media in which parents can also involved; (3) more attention should be given to appropriate teacher training, including continuous professional development; and (4) industry will need to exert some creative effort to improve the presentation of opportunities and interesting aspects of careers in science and engineering, especially in order to attract women and minorities into science and engineering professions. As a result of this and related projects the ‘*Marilyn’* concept (another acronym) emerged.

End word

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83 www.wissenschaft-im-dialog.de/
84 http://www.twoways.eu/Web/Home/

The promotion of STEM in Germany is vigorous. There is a national not-for-profit association known as MINT Future promoting STEM uptake that makes it possible to see what STEM activities are current. In addition, the German learned academies play an active role in promoting STEM across Germany. The academies have been particularly active in promoting inquiry-based science (and mathematics) education. The promotion of STEM overall is strong, as is the promotion of 'STEM for girls'. The German pattern as a federal nation with strong states (länder) would seem to be a good fit with the Australian situation.

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Country report: The Netherlands

Introduction: Demographic background

The Netherlands is a monarchy with a population of about 16.5 million, living in a country with an area of 41,526 km². The population density is 397 per km², or 487 per km² if only the land area of 33,883 km² is considered. Life expectancy at birth is 76.9 for men and 82.3 for women. The median age is almost 40. The population includes 1.8 million foreign born people, or 11.1 per cent of the population.

Even though the Netherlands is so densely populated; there are no cities with a population over 1 million in the Netherlands. Instead 'four big cities' as they are called (Amsterdam, Rotterdam, The Hague and Utrecht) can in many ways be regarded as a single metropolitan area, the Randstad ('rim or edge city') with about seven million inhabitants around an agricultural 'green heart' (het Groene Hart) (Wikipedia, n.d.).

Education in the Netherlands[85]

Primary and secondary education

Dutch education matches the broad organisational pattern of several other countries. Pre-primary education is followed by primary, junior secondary and senior secondary education. Some students then progress to higher education in the Netherlands' binary system of universities and universities of applied sciences (see also Eurydice, 2011).

Children are allowed to begin school at the age of four, but are not legally required to do so until the age of five. Primary education lasts eight years (of which seven are compulsory), in the last year of which pupils are advised as to the type of secondary education they should pursue.

Secondary education, which begins at the age of 12 and is compulsory until the age of 16, is offered at several levels. On the vocational side, VMBO programmes (four years) combine *general and vocational education*, after which pupils can continue in *senior secondary vocational education and training* (MBO) lasting one to four years. Two programmes of general education lead towards admission to higher education. These are HAVO (five years) and VWO (six years). Pupils are enrolled according to their ability, and although VWO is more rigorous, both programmes can be characterised as selective types of secondary education. The VWO curriculum prepares pupils for university, and only the VWO diploma grants access to research oriented research programmes. The HAVO diploma is the minimum requirement for access to a university of applied sciences, the Netherland's non-university higher education institutions (HBO). The last two years of HAVO and the last three years of VWO are upper secondary education. During these years, pupils focus on one of four subject clusters (profielen), each of which emphasises a certain field of study in addition to satisfying general education requirements. Each cluster is designed to prepare pupils for programmes of study at the tertiary level. A pupil enrolled in VWO or HAVO can choose from the following subject clusters: Science and Technology; Science and Health; Economics and Society; and Culture and Society.

Senior secondary vocational education and training (MBO) is offered in the areas of economics, technology, health, personal care, social welfare and agriculture. MBO programmes vary in length from one to four years as well as in level (1 to 4).

[85] http://www.kempel.nl/DeKempel/Documents/EducationSystemInTheNetherlands.pdf

Graduates of VMBO programmes are eligible for admission to MBO, and completion of MBO programmes at level 4 qualifies pupils for access to HBO.

Higher education in the Netherlands is offered at two types of institutions: research universities (universiteiten) and universities of applied sciences (hogescholen). Research universities include general universities, universities specialising in engineering and agriculture, and the Open University. Research universities are primarily responsible for offering research-oriented programmes (wetenschappelijk onderwijs, WO). Dutch research universities provide education and conduct research in a wide range of disciplines: language and culture, behaviour and society, economics, law, medical and health sciences, natural sciences, engineering, and agriculture. Universities offer third cycle (doctoral) programmes.

Universities of applied sciences include general institutions as well as institutions specialising in one of the seven HBO sectors: agriculture, engineering and technology, economics and business administration, health care, fine and performing arts, education (teacher training), and social welfare. Universities of applied sciences are primarily responsible for offering programmes of higher professional education, which prepare students for particular professions. These tend to be more practically oriented than programmes offered by research universities. In addition to lectures, seminars, projects and independent study, students are required to complete an internship or work placement (stage) which normally takes up part of the third year of study, as well as a final project or a major paper in the fourth year. Universities of applied sciences do not offer third cycle (doctoral) programmes.

STEM uptake

Table 1 presents statistics that provide a reflection of STEM uptake in selected European countries. In the case of the Netherlands, according to the data available through Eurstat[86], there is a considerable gap in the proportions of various cohorts being involved in STEM. For example, only 14.0 per cent of all tertiary graduates in 2010 were in science and technology compared with the European Union 27 average. However, the Netherlands exceeded the European Union 27 average in terms of the proportions of human resources in science and technology as a proportion of the labour force, and the proportion of all doctoral students enrolled in science and technology programmes.

If the graduation rates reflect a country’s capacity to meet its technical labour force needs, then the Netherlands’ situation would be less attractive than some other countries. Neighbouring Belgium seems to be in a comparable situation, but countries such as Finland, France, Germany and Sweden seem to be producing higher proportions of science and engineering graduates.

[86] http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/

Table 1: STEM Uptake - Various Measures - Selected Countries

Country	**Tertiary Graduates - Science & Engineering, % of Total - 2010 #**	**Upper Sec. & Voc. Ed. Graduations Science & Engineering, % of Total - 2010 #**	**Human Res. in Sci. & Tech. % of labour force 2011**	**Doctoral students in Sci. & Tech. Fields. % of Population Aged 20-29 - 2010 +**
Netherlands	**14.0%**	**21.4%**	**52.2%**	**0.58**
Austria	29.1%	27.5%	40.5%	0.69
Belgium	16.1%	18.6%	49.6%	0.43
Czech Republic	23.4%	33.5%	36.0%	0.84
Denmark +	19.3%	35.3%	51.5%	0.48
EU27	21.3%	30.5%	42.3%	0.30
Finland	31.8%	34.2%	52.6%	1.29
France	26.2%	34.7%	48.1%	0.44
Germany	25.6%	34.8%	44.9%	0.55
Norway	16.0%	47.1%	54.8%	0.49
Portugal	24.9%	3.7%	27.0%	0.49
Sweden	26.9%	38.7%	52.2%	0.71
Switzerland	19.8%	40.1%	54.7%	0.81
UK - England	22.4%	0.0%	51.2%	0.40

comprises the fields of science, mathematics & computing and engineering, manufacturing & construction

+ EU 27: Figure is for 2007

Source: Eurostats

STEM and gender

A brief examination of Table 2 indicates both that only a low proportion of students in general undertake higher education-level STEM studies, and an even lower proportion of women. The situation in the Netherlands is such that STEM uptake at the tertiary level is much less than half that of the better-performing countries such as Finland and Germany, and among women, the uptake is less than one-third those two countries.

As is demonstrated amply in the next section, the Netherlands have a thorough and integrated package of programmes to induce people into the STEM disciplines. They also have a national expert organisation on girls/women and science/technology (VHTO)[87], which is attempting to remedy the situation. Its role is to increase the involvement of women and girls in science and technology in the Netherlands. The objectives of the Network are to gain more insight into the various, closely connected aspects of career choices and professional careers of girls/women (and boys/men) in the direction of STEM; and to detect new approaches to actually improve the underrepresentation of girls/women in STEM. VHTO is a partner in a number of European projects and uses knowledge gained from working with partners abroad to bring best practice into the Netherlands and European partners. Efforts are made to develop special projects to get girls interested in STEM, including a role model approach, whereby female STEM teachers are matched to female students to inspire them to take up STEM careers (Kearney, 2011).

Table 2 Uptake of STEM by All and Female Students at ISCED Levels 5 & 6 - 2010

[87] http://www.vhto.nl/over-vhto/engelse-pagina.html

	Women % of All Students (1)	All Students in Science & Engineering as % of All Students (2)	Female Science & Engineering students as % of All Female Students (3)
Finland	53.8	35.1	16.1
Germany	51.3	30.7	15.8
Ireland	52.4	27.6	14.7
Sweden	59.4	25.3	14.2
France	55.0	25.6	14.1
Austria	53.1	25.7	13.9
European Union (27 countries)	55.4	25.0	13.6
Czech Republic	56.8	25.3	13.1
United Kingdom	56.6	23.0	12.2
Poland	59.2	21.2	11.8
Denmark	58.1	18.7	11.2
Switzerland	49.2	22.9	10.6
Norway	60.8	16.4	8.5
Belgium	55.2	17.7	8.0
Netherlands	51.8	14.5	5.1

Source: Eurostat

(1) Women among students in ISCED 5-6 - as % of the total students at these levels

(2) Students at ISCED levels 5-6 enrolled in the following fields: science, mathematics, computing, engineering, manufacturing, construction - as % of all students

(3) Female students at ISCED levels 5-6 enrolled in the following fields: science, mathematics and computing; engineering, manufacturing and construction - as % of all female students

Among the various women-specific projects are:

- **GetMobile: Guidance and European Training in Mobility Opportunities for Business (2011 – 2013).** VHTO is a partner in this programme, with partners from the UK, Netherlands, Italy, Turkey, Iceland and Greece. The project is to encourage greater numbers of female graduates from business, science and technology to consider going abroad on placement to help their career development.

- **Set4Change: Social Entrepreneurship for Women in Business & SET.** VHTO is partner in this European partnership.

- **WITE: women in technical education.** In order to increase the numbers of girls attending technical institutes in Europe, VHTO is working closely with European partners from Italy, Germany, Austria, Hungary, Poland and the Netherlands about stimulating the dissemination of good practice on guidance about the choice of school.

- **TYNET50+.** The TYNET50+ project promotes intergenerational learning through sharing European expertise on methodologies to support young women living abroad and 50+ women who have family abroad, to develop mentoring relationships primarily for supporting ICT development.

- **FE:MALE: Female Entrepreneurs Mentoring and Lifelong Learning across Europe.** FE:MALE aims to support female potential entrepreneurs across Europe, particularly those facing extra challenges such as being from an ethnic background, over 50, a lone parent or long-term unemployed.

Science promotion in the Netherlands

In the Netherlands, there is an active approach to STEM at all educational levels. Funding is available for awareness campaigns and for funding initiatives and experiments in schools and other places. Activities are relatively centralised in the Netherlands. The principal coordinating body is the **National Platform Science & Technology** (*Platform Bèta Techniek*). It was commissioned by the Dutch government, the education and the business sectors to ensure the availability of a sufficient number of people with a background in scientific or technical education. Persons with a background in scientific or technical education are seen as being essential to society, both for developing new products and services as well as for scientific and social change and innovation. An adequate supply of these knowledge workers is required for the Dutch economy to maintain a good international competitive position.

This approach has been formulated in the Delta Plan Science & Technology, a policy concerning the prevention of shortages in the technology sector. The aims are to achieve a structure in the number of pupils and students in scientific and technical education, and to use existing talent more effectively in businesses and research institutes. The goal is not only making careers in science more appealing, but also to introduce educational innovations that will inspire and challenge young people. The Delta Plan is divided into five sub-programmes each targeting different levels and types of education and preparation for working life' (Kearney, 2011 p. 7).

Therefore, the National Platform facilitates mutual contact between schools, universities, businesses, ministries, municipalities, regions and sectors. The objective is to ensure that the future supply of knowledge workers will meet the expected demand. Some of the programmes carried out by the National Platform focus on education from primary school to higher education. Investing in youth at an earlier age will broaden the potential reach of future science and technology talents. These programmes are implemented in close collaboration with the labour market.

The Delta Plan Science / Engineering is seen as fundamental to the establishment of the Science and Technology Platform. This Delta Plan represents the Ministries of Education and Social Affairs and is an integrated approach to have more young people become interested in studies and careers in the science and technology sector. One of the objectives of the Delta Plan was for a 15 per cent increase in the numbers of students in science and technology education (compared to 2000), and this aim was achieved. Another objective was for better use of existing talent in companies and research.

The government/cabinet ambition (February 2012) is that 40 per cent of all students that completed education at levels beyond primary school have done so in a science/engineering programme. This is the 'four out of 10' policy.

The increased attention on the composition and formation of our human capital stock is very much part of a recently revised technology/science policy known as the 'top sector' policy[88]: (Topsectorenbeleid). This led to selecting nine high priority areas for the Netherlands[89] – where focus and mass in research and dedicated human capital policies are needed. According to this policy, higher education institutions are urged to collaborate with business and industry in public-private partnerships. Considerable funding is involved. This policy is a next step in trying to make the Dutch economy more innovation-oriented.

88 http://www.top-sectoren.nl/

89 Agriculture and food; chemicals, creative industries; energy: life sciences and health; high technology; logistics and water.

The public-private partnerships for building human capital in the top sectors are in place now in two different education sectors: the vocational education sector and the higher vocational education sector. The partnerships translate into Centres of Expertise and Centres of Innovative Craftsmanship.

Programmes offered under the National Platform Science & Technology[90]

The website provides a bewildering range of programmes, pitched at students from primary to tertiary levels, and to teachers and others. Some of the programmes overlap.

Primary and secondary school

Orion Program: Science Nodes

Children are naturally curious and the Orion programme encourages them to investigate the world around them. The Orion program encourages the establishment of regional Science Nodes in which children can be 'curious'. The core of a Science Node is a university, several schools and an intermediary, such as a teacher training centre or science centre. The goal is to improve the match between the demand for and supply of scientific knowledge for primary schools. Sustainable cooperation within the Science Nodes results in substantive activities and educational arrangements for primary students. These activities / arrangements allow children to receive an inspiring introduction to science.

Talented students are challenged and have the opportunity to develop their talents and excellent performance. The benefits are seen as being that universities have a unique opportunity for their staff to reflect on the social aspects of their research; primary schools benefit from an improved connection: educational activities are better to fit into the curriculum and there is a learning environment where children are more challenged to learn; and intermediaries can improve their expertise and experience through participation in the partnership.

The Orion Programme provided set-up funds of €200,000 for academic years 2009/2010 to 2011/2012. A group of experts supported the Orion team support in the evaluating proposals, but the Orion team mainly had a supporting and facilitating role.

School aan zet ('School Set On')

School aan zet has a website with tabs for primary, secondary and special secondary education through which teachers (and others) can access information, good practices, tools and knowledge for each level of education. All the information is linked to six themes, including science and technology, and it is possible to search for material etc. according to user selections.

[90] http://www.platformbetatechniek.nl/programmas.html

Talent Force[91]

Talent force is research being conducted through several research universities. The focus in this programme is research into the development of talent in young children (3-14 years) within the domain of science and technology. The starting point for this research was that there should be collaboration between scientists from different scholarly backgrounds.

Beta Excellent

This programme is for secondary schools. In 2011-2012, about 250 schools worked on applying national policies to applications for school. Two of the five themes are science and technology, and mathematics. Participating schools developed two ‘building blocks’, each being an approach developed by a school on a specific theme. The *Expert Committee on Science* provides expertise and best practices to enable schools to improve their own approach. In addition, the Expert Committee holds discussions with schools on school policy and objectives. The members of the Expert Committee come from the educational field and at the interface between education / industry.

Activities are also arranged through Beta Excellent partners. These activities include

- **Jet-Net**[92]: Youth Netherlands Technology Network, a partnership between industry and secondary schools, is an on-going programme for secondary education. It makes an important contribution in encouraging students to choose scientific careers. *Jet-Net* companies help schools enhance the appeal of their science curriculum by using a great variety of activities as well as allowing pupils to gain a better understanding of their future career prospects in industry and technology. Major national events organised within the programme are: the *Jet-Net* Career Day, the National *Jet-Net* Teachers’ Day and Girls’ Day (25 companies involved). In addition, a range of smaller programmes and activities has been developed, e.g. mentoring activities, company-assisted research, guest lectures, expert meetings and teacher workshops.

In particular, the aim is for HAVO / VWO pupils to gain a real picture of science and technology and to interest them in continuing.

The Jet-Net partnership comprises 85 companies, 170 schools and 23 associated partners and is seeking to add more companies to the network.

- **Tech-Net**[93]**:** VMBO schools cooperate with TechniekTalent.nu: a partnership of business, training funds, umbrella organisations and schools. The goal here relates more to attracting and retaining technical talent. Cooperation in TechNet focuses on materials development, setting up a business network for secondary schools, and the use of technology ‘coaches' in primary education. These are (former) employees from the technical sector that teachers support in giving lessons. TechNet promotes regional cooperation among VMBO, vocational and technical companies. In more than a hundred Technet circles, schools and companies make technology education more attractive for young people. Ultimate goal: more students who choose a career in engineering. Schools and businesses can join an existing Circle or create a new loop. A TechNet circuit consists of a minimum of eight companies and a school. The Technet Circles receive a financial

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91 http://www.talentenkracht.nl/?pid=2&page=Home
92 http://www.betaexcellent.nl/?pid=156
93 http://www.betaexcellent.nl/?pid=156 and http://www.technet.nu/

contribution from TechniekTalent.nu to enable sustainable cooperation between schools and businesses.

- **Attractive careers beta course**[94]: A course for science teachers to provide current knowledge about professions in science and technology. The University of Utrecht also offered training for school year 2012-2013 on 'Science Occupations in Class' for science teachers. This training is specifically aimed at the introduction to the many and varied science occupations that match the different sciences.

- **YoungWorks / Masterclass Beta Excellent**[95]: Following the popular Beta Mentality model. Master classes on encouraging young people into science.

The Excellence Model[96]

Top students are extremely important to the Dutch economy and the private sector, and the Dutch government is seeking to make improvements in this area in the coming years. On behalf of the Dutch Ministry of Education, Culture and Science, Platform Bèta Techniek implemented a number of programmes to promote excellence aimed at the top 20 per cent of pupils. The Dutch government, the private sector and the education system all play a key role in this development. However, crucial to this debate are the opinions of young people themselves. A similar survey had been conducted in the past, focusing on young people and their ideas about science and technology, which resulted in the BètaMentality-model ('Science-Mentality Model'). The Excellence Model provides a tool to consider as carefully as possible which group of youngsters is already receiving enough encouragement and which group might be further motivated to excel. In addition, the model also offers guidelines on how to actively encourage children and teenagers who have not yet (or not yet fully) been reached.

Higher education

The Sirius Programme[97]

The objective of the Sirius Programme is to promote excellence in Dutch higher education by identifying talented students and challenging and encouraging them to do their best. The Netherlands has a culture of egalitarianism in education, because all Dutch educational institutions offer a good basic level of education, accessible to all students. Nonetheless, it is believed that a relatively large number of students do not feel sufficiently inspired or challenged. A culture of inclusion prevails: while attempts are made to help less talented students keep pace with the basic curriculum, the facilities to encourage high-potential students to achieve excellence are insufficient. Shifts in Dutch policy in recent years has emphasised the importance of fostering and promoting talent taken place, for the knowledge economy.

The Ministry of Education, Culture and Science established the Sirius Program in and invited all higher education institutions to submit a plan for the promotion of excellence, either independently or in collaboration with other institutions. The largest portion of the Sirius budget has been earmarked for the bachelor's programme that was launched in 2008 (€48.8 million). The master's programme, with a budget of €12.2 million, started

94 http://www.betaexcellent.nl/?pid=159
95 http://www.betaexcellent.nl/?pid=225
96 http://www.excellentiemodel.nl/docs/Documentatie/120509_ym_excelleren_eng_lores.pdf
97 http://www.siriusprogramma.nl/?pid=85&page=In%20English

in 2010. These funds provide the first incentive aiming at inspiring the top five per cent of the students to achieve excellence.

First in the class[98] is a trainee programme for young academics.

The Consortium and the Talent Map

The Talent Power Consortium is a group of seven Dutch and Belgian universities that conduct research to provide an empirically grounded picture of talented technical and scientific thinking in children. Educational resources add to the environment of children, so that children have more opportunities to participate in the upward spiral of talent and encouragement in the field of science and technology. The study includes 14 different research projects, all based on the central concept: for scientific and technical talent in children. The Talent Map is a meaningful and practical description of the ways in which children of different ages and backgrounds can excel under optimal educational conditions in science and technology.

Science - strong together

The Talent Force programme is run by a broad group of scientists with different backgrounds and expertise. What is also special is that these researchers work from a scientific perspective. They exchange knowledge and experiences and cooperate in (sub) projects.

Other

Sector Plan Physics and Chemistry (SNS)

On 12 April 2010, the Commission Implementation Sector Plan for Physics and Chemistry recommended the distribution of the €20M annual funding for physics and chemistry faculties of the universities.

3TU Sector Technology

From 2012 to 2015 €33M has been made available for the implementation of the 3TU Sector Technology. The Sector Technology forms the basis of cooperation between the three universities: Technical University of Delft, the University of Twente and Eindhoven University of Technology. More information can be found on the 3TU website.[99]

The **Freudenthal Institute for Science and Mathematics Education (FIsme)** aims to improve education in the fields of arithmetic, mathematics, and the sciences, with a focus on primary, secondary and vocational education. The Institute contributes towards this aim through research, teaching, curriculum development and other services. (Kearney, 2011)

End word

The Dutch approach seems to be among the more thorough in Europe, and could be used to provide many ideas about promoting STEM in Australia. The *Platform Bèta Techniek* is full of useful information about myriad programmes and replete with links

98 http://www.eerstdeklas.nl/
99 http://www.3tu.nl/

to other websites and other programmes. Although it is simple enough to navigate, the website's architecture and structure are not easy for anyone unfamiliar with the inter-relationships between each of the policies, programmes and projects. Being Dutch speaking would also help. The idea of having such a centralised approach means that tracking what was happening nation-wide is possible. It is uncertain how this 'centralness' would translate to a federal nation such as Australia. The Netherlands' policy makers have demonstrated a strong sense of purpose, and are working towards meeting the goals they have set themselves.

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Country report: Norway

Preamble

Norway is not a member of the European Union, and therefore it does not feature as much in European Union projects as member countries do.

Introduction: Demographic background

Norway's population is approaching five million, of whom over 500,000 were born outside Norway. About 660,000 residents of Norway are migrants or their descendants. Norway covers about 385,000km^2, giving a population density of about 15.5 persons per km^2. The median age is just under 40, and the life expectancy at birth is 78.85 years and 83.15 years for men and women, respectively.

Education in Norway

According to the Ministry of Education website[100], universal schooling for children was introduced in Norway 250 years ago. From 1889, seven years of compulsory education were provided. In 1969 this was increased to nine years and in 1997 to 10 years. As a result of Norway's scattered population, forty per cent of primary and lower secondary schools are so small that children of different ages are taught in the same classroom. Primary and lower secondary levels are often combined in the same school.

The collective objectives and principles for teaching in primary and lower secondary schools are laid down in the national curriculum. The curriculum for primary and lower secondary education includes:

- Core curriculum for primary and lower secondary, upper secondary and adult education
- Principles and guidelines for primary and lower secondary education
- Curricula for individual subjects.

The subject curricula lay down a common learning content for all pupils, which increases in scope throughout the school and is greatest at the lower secondary stage. This common learning content is enlarged on and supplemented to adapt it to local conditions and to the needs of individual pupils.

Primary and lower secondary education is based on the principle of an equal and adapted education for all in an inclusive unified school.

The introduction of the 'Knowledge Promotion' reform has provided all grades with new curricula with clearly stated competence objectives. The curriculum has emphasised basic skills in being able to express oneself orally and in writing, in reading, in numeracy and in the use of digital tools.

Municipalities fund primary and lower secondary education and have a great deal of freedom when it comes to organising the education. Compulsory schooling in Norway lasts for ten years, and the children start school the year they are six years old.

All young people between the ages of 16 and 19 have a right to **upper secondary education** and training. Pupils can choose between vocational education programmes

[100] http://www.regjeringen.no/en/dep/kd/Selected-topics/compulsory-education/the-norwegian-education-system.html?id=445118

or programmes for general studies. As with primary and lower secondary, upper secondary education and training are also adopting new curricula with clearly stated competence objectives.

The county authorities fund upper secondary education and training and have a great deal of freedom when it comes to organising the education. The vocational education programmes include training in training establishments or education in school.

Tertiary vocational education is an alternative to higher education and is based on upper secondary education and training or equivalent informal and non-formal competence. Higher Education Entrance Qualification is not required. The education consists of vocational courses lasting from half a year to two years. Apart from the traditional schools of technical management and maritime subjects which are publicly financed (by the county authorities), most of the schools offering this kind of education are private ones. All courses must be accredited by the Norwegian Agency for Quality Assurance in Education (NOKUT).

Higher education is anything beyond upper secondary school, and normally lasts three years or more. To be accepted to most higher education schools students must have attained a general university admissions certificate (*generell studiekompetanse*). This can be achieved by taking general studies while in upper secondary school or through the 23/5 law where a person must be above 23 years of age, have five years of combined schooling and work experience and have passed examinations in Norwegian, mathematics, natural sciences, English and social studies.

Higher education is broadly divided into:

- Universities, which concentrate on theoretical subjects and provide bachelor's, master's and PhD degrees lasting 3+2+3 years. Universities also run a number of professional studies, including law, medicine, dentistry, pharmacy and psychology, but these are generally separate departments that have little to do with the rest of the university institution.
- University colleges (*høyskole*), which supply a wide range of educational choices, including university degrees at bachelor, master and PhD levels, engineering degrees and professional vocations like teaching and nursing. The grade system is the same as it is for universities.
- Private schools, which tend to specialise in popular subjects with limited capacity in public schools, such as business management, marketing or fine arts. Private schools have about 10 per cent of higher education enrolments.

STEM uptake

Table 1 summarises data taken from Eurostat. It shows that Norway's proportion of tertiary graduations in science and engineering (16 per cent) is below the average of the European Union 27 countries (21.3 per cent), but well above the EU27 average in upper secondary and vocational education graduations in science and engineering. Norway also has a much higher proportion of human resources in science and technology as a percentage of the whole labour force, and a higher than EU27 average presence of doctoral students in science and technology fields.

Table 1: STEM Uptake - Various Measures - Selected Countries

Country	Tertiary Graduates - Science & Engineering, % of Total - 2010 #	Upper Sec. & Voc. Ed. Graduations Science & Engineering, % of Total - 2010 #	Human Res. in Sci. & Tech. % of labour force 2011	Doctoral students in Sci. & Tech. Fields. % of Population Aged 20-29 2010 +
Norway	**16.0%**	**47.1%**	**54.8%**	**0.49**
Austria	29.1%	27.5%	40.5%	0.69
Belgium	16.1%	18.6%	49.6%	0.43
Czech Republic	23.4%	33.5%	36.0%	0.84
Denmark +	19.3%	35.3%	51.5%	0.48
EU27	21.3%	30.5%	42.3%	0.30
Finland	31.8%	34.2%	52.6%	1.29
France	26.2%	34.7%	48.1%	0.44
Germany	25.6%	34.8%	44.9%	0.55
Netherlands	14.0%	21.4%	52.2%	0.58
Portugal	24.9%	3.7%	27.0%	0.49
Sweden	26.9%	38.7%	52.2%	0.71
Switzerland	19.8%	40.1%	54.7%	0.81
UK - England	22.4%	0.0%	51.2%	0.40

comprises the fields of science, mathematics & computing and engineering, manufacturing & construction
+ EU 27: Figure is for 2007
Source: Eurostats

Countries can differ as to the level of qualification considered adequate to undertake certain work, and the proportion of Norwegian higher education graduates going in to STEM areas is towards the lower end of the scale. Norway seems to be excelling at the upper secondary / vocational levels. The extent to which there could be a shortfall in the number of STEM graduates at the tertiary level, and that this could have a negative impact on the Norwegian economy will depend on the detailed structure of the STEM labour market in Norway.

Another factor is that about one-third of those who earned a doctorate in technology and science in 2008 were foreign citizens. In other words, there is a challenge to increase the number of domestic PhD graduates, to reduce the potential 'brain drain' of Norwegian-trained STEM professionals at the top level. It is an additional challenge to retain excellent foreign candidates after they have completed their doctoral degree (Norwegian Ministry of Education and Research, 2012).

STEM and gender

In general, women represent only a small proportion of science and engineering in the first and second stages of tertiary study across Europe (ISCED 5 and 6, respectively). Table 2 provides a ranking by the proportion of women of all students, STEM enrolments as a proportion of all enrolments, and women in STEM programmes as a proportion of all female students. The table shows that Norway is one of the least successful countries in attracting women into STEM disciplines, with only 8.5 per cent of women going into tertiary STEM studies. Of the countries shown, only Belgium and the Netherlands are lower. Women represent 60.8 per cent of all tertiary enrolments, but only 8.5 per cent of those students chose to undertake STEM programmes.

When compared with what is happening in some European countries, there have been relatively few programmes designed to attract young women into science and engineering. However, research in to STEM uptake in Norway (see below) has led to considerations of the gender-based dimension. As shown in Table 2, Norway does present a lower female uptake of STEM than many other European countries.

Norway has an Action Plan for Gender Equality[101], and according to Kearney (2011), part of the plan has a focus on increasing female participation in STEM. The gender aspects of STEM in Norway are further considered below in the section on research into STEM uptake. Part of the problem is that girls are under-represented in STEM-related studies and to ensure a more even gender balance is not only about recruiting more female applicants, it is also about preventing girls from having a higher dropout rate than boys; this being the case in many STEM studies today.

Table 2 Uptake of STEM by All and Female Students at ISCED Levels 5 & 6 - 2010

	Women % of All Students (1)	**All Students in Science & Engineering as % of All Students (2)**	**Female Science & Engineering students as % of All Female Students (3)**
Finland	53.8	35.1	16.1
Germany	51.3	30.7	15.8
Ireland	52.4	27.6	14.7
Sweden	59.4	25.3	14.2
France	55.0	25.6	14.1
Austria	53.1	25.7	13.9
European Union (27 countries)	55.4	25.0	13.6
Czech Republic	56.8	25.3	13.1
United Kingdom	56.6	23.0	12.2
Poland	59.2	21.2	11.8
Denmark	58.1	18.7	11.2
Switzerland	49.2	22.9	10.6
Norway	60.8	16.4	8.5
Belgium	55.2	17.7	8.0
Netherlands	51.8	14.5	5.1

Source: Eurostat

(1) Women among students in ISCED 5-6 - as % of the total students at these levels

(2) Students at ISCED levels 5-6 enrolled in the following fields: science, mathematics, computing, engineering, manufacturing, construction - as % of all students

(3) Female students at ISCED levels 5-6 enrolled in the following fields: science, mathematics and computing; engineering, manufacturing and construction - as % of all female students

STEM promotion in Norway

Norway has a National Forum for Mathematics, Science and Technology which has responsibility for gathering together the central organisations and participants in education from labour markets in Norway. The Forum has been established as an advisory body for the Ministry of Education and Research on matters relating to the status and development of mathematics and technology.

Norway's nationally-focussed strategy: *Science for the Future - Strategy for Strengthening Mathematics, Science and Technology (MST) 2010–2014* [102] is at the centre of its current plans for expanding STEM in Norway. The aim is '… strengthening STEM competence from kindergarten all the way through to a person's working life' (Kearney, p. 8). The strategy seeks cooperation between education and labour markets to improve recruitment into the STEM professions (Kearney, 2011). The standard of English in *Science for the Future* is poor, but it is nonetheless a definitive statement of the contemporary policy on STEM in Norway.

Norway has used a couple of national centres as part of the Norwegian approach to dealing with STEM matters. The Centre for Mathematics Education[103] and the

101 http://www.regjeringen.no/upload/UD/Vedlegg/Utvikling/ActionPlanwomensRights.pdf
102 http://www.regjeringen.no/upload/KD/Vedlegg/UH/Rapporter_og_planer/Science_for_the_future.pdf
103 http://www.matematikksenteret.no/english/

Norwegian Centre for Science Education[104] were established in 2002 and 2003, respectively. These bodies have a focus on curriculum and the development of teaching materials, and support schools by implementing initiatives in these areas. The Mathematics centre says of itself that 'its primary task is to lead and coordinate the development of new and improved working methods and learning strategies in the mathematics education, from kindergartens through teacher education in Norway'. On its website, the science education centre describes its mandate as '… [making] contributions towards the implementation and execution of national educational policy so that children, youths and adults are provided with equal and adapted education of a high quality and as part of an inclusive community'.

Norway also has regional science centres, established in seven regions across the country. These provide regional support for the Norwegian Centre for Science Education.

A programme that translates to 'Natural school bag[105]' provides schools with funding to support teachers to teach outside the classroom (Kearney, 2011). This programme is built on teaching and working methods which means that students and teachers contact groups outside the school and use these communities as part of their learning experience. A trial took place in 2009 in which 11 schools participated. Subsequently in 2009, 78 schools received funds in to participate, and another 109 schools in 2010/2011. This programme involves collaboration between the Ministry of the Environment Directorate for Nature Management and the Ministry of Education. The programme 'aims to develop curiosity and knowledge about nature, awareness of sustainable development and an increased environmental awareness among all students and teachers in basic education. The natural school bag should be rooted in the curriculum for basic education' (Google Translate rendering).

Research into STEM uptake

The major way in which Norway is adding value to matters relating to STEM uptake is its survey-based research into STEM uptake. Through their ROSE, IRIS and LILY studies, Norwegian scholars have sought out the opinions of many young people about their attitudes to STEM disciplines. ROSE ('Relevance of Science Education') has become an international project (involving 40 countries) following the initial design of a survey instrument in Norway: 'ROSE is a cooperative research project with international participation, addressing mainly the affective dimensions of how young learners relate to science and technology' (Sjøberg & Schreiner, 2010, p. 5). ROSE[106] was targeted at 15 year old students, and its broad findings are that there is an overall positive attitude to science but that school science is less interesting than other subjects (Sjøberg & Schreiner, 2010). Results show that the more developed a country is, the less is the overall interest in school science. Results show that relatively few students agree that they would like to become a scientist or have a job in technology.

This project has been followed up by IRIS[107] ('Interest and Recruitment in Science'), aimed at first year tertiary students. In considering the expansion of the STEM workforce, on way to do so is to attract more young women, because they are under-represented in the first place. This study sought to establish the basis for educational choices, including who was influential in students' selection of study in the STEM disciplines. Young people responded to specific questions about who was a source of

[104] http://www.naturfagsenteret.no/c1442967/artikkel/vis.html?tid=1442390
[105] http://www.natursekken.no/c1187995/om/index.html?tid=1188266
[106] http://roseproject.no/network/countries/norway/eng/nor-Sjoberg-Schreiner-overview-2010.pdf
[107] http://iris.fp-7.org/about-iris/

inspiration in their choice of STEM, and the overall response that parents were a source of inspiration to 22 per cent of students *to a very great extent.* Other sources of inspiration were siblings (10 per cent), friends (13 per cent), other acquaintances (10 per cent), and teachers (nine per cent). This suggests that the immediate family is a quite important as a point of influence. Publically known persons were a strong source of inspiration to only one per cent of first year tertiary STEM students.

Maintaining the floral theme, the LILY[108] project (not an acronym, apparently) sought to develop further what had already been learnt by seeking an understanding of the priorities and experiences underlying young people's educational choices. Built around a questionnaire, young people were asked about their educational background, sources of inspiration for the choice of education, expectations for that education, and future jobs: 'Project LILY (Norwegian: Vilje-con-valg) aims to develop new knowledge and theoretical perspectives, and to stimulate informed discussion, of how to recruit and retain more young people in science, technology, engineering and mathematics (STEM) career'.

End word

Many countries (in Europe) have launched many policies, programmes, and projects relating to STEM, and Norway is no exception. However, the main benefit that can be drawn from the Norwegian case is the fact of its research into STEM uptake and retention. The research (particularly via the ROSE and IRIS studies) has provided valuable data on what school students took into account in their decision to study STEM disciplines (or not), and what influences tertiary students to move into STEM studies (or not). Given the research into STEM uptake in Norway, there is a wealth of published material, including at least one recently-accepted doctoral dissertation.

Of course research is all very well, but just knowing what people of various ages have said turned them off or on to STEM will not necessarily lead to either appropriate policy or practice. However, it is a start!

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[108] http://www.naturfagsenteret.no/c1515601/prosjekt/vis.html?tid=1519408

Country report: Sweden

Introduction: Demographic background

Sweden is a monarchy and in 2010 had a population of 9.4 million people of whom 3.4 million were between 0 - 29 years old (Eurydice, 2011). About 1.4 million people are foreign-born, about 14 per cent of the total. Of those 477,000 are from other European Union countries. Sweden covers 450,000 km^2, giving an average population density of about 20.6 persons per km^2. The median age of Swedes is 42 years.

Swedish education

Much information on Swedish education can be found in English[109]. Almost half the Swedish population is involved in some form of organised education and around 886,000 are pupils in compulsory school. The main language of instruction is Swedish, but there are state schools for the Sami population in the north of Sweden, with teaching in Swedish and Sami. The educational system is based on government-funded education for all, supported by publicly subsidised programmes for further education, retraining, adult schools and study groups.

Education is compulsory for all children aged seven to 16, although nearly all start at age six. Junior high school students who pass exams in at least Swedish, English and mathematics — the vast majority — go on to do three years at high school, while the others study educational programmes tailored to their needs. Most of the responsibility for education rests with local municipalities. The majority of the education budget is financed by local taxes, and approximately half of the municipal budget is spent on education. Sweden and Finland are the only two countries that still provide pupils with a free lunch.

Compared with many countries, there is not a great variation between schools when it comes to the socio-economic standing of the pupils and their results. All students have the right to attend an independent, privately-run school for which they do not pay a fee. These schools, which often have a specific focus such as art, music or sport, are spreading rapidly. Today about one in five Swedish high school students attends an independent school.

All young people in Sweden who have completed compulsory school are entitled to three years of upper secondary school education. Upper secondary education provides a good foundation for vocational activities and further studies. Upper secondary education covers upper secondary school, and the upper secondary school for learning disabilities.

There are a total of 18 national **upper secondary programmes**. Each program last three years and includes upper secondary school foundation subjects and other subjects and work.

Each national upper secondary programme covers:

- Nine upper secondary foundation subjects - English, history, physical education and health, mathematics, science studies, social studies, English or English as a second language and religion. In the natural science program, science studies are replaced by the programme specified subjects, i.e. biology, physics, and

[109] http://www.skolverket.se/om-skolverket/in_english

chemistry. In the technology program, science studies are replaced by the programme specified subjects i.e. physics and chemistry.

- A number of subjects specific to a given programme are chosen.
- Diploma Project.
- Workplace-based learning (APL), in vocational Programmes.

The different upper secondary programmes may be either vocational programmes, or preparatory programmes for higher education. A vocational programme can be in the form of an upper secondary apprenticeship education.

Higher vocational educational colleges provide post-secondary school education. The courses are designed in consultation with employees and are tailored to meet the manpower needs of the labour market and lead to jobs. The content and direction of the courses may vary overtime depending on the needs of the labour market. There are both higher vocational education courses (HVECs) and qualified vocational courses (KY courses). About one-third of the training is workplace experience known as *Learning in Work*.

Sweden has a binary system of **universities** and **university colleges** that offer many study programmes and single-subject courses.

The education is divided into three levels based on each other:

- Basic level (three years)
- Advanced level (one to two years)
- Research level (two to four years)

All Swedish university students are entitled to financial assistance, partly in the form of a grant and partly as a loan. The rate at which ex-students repay depends on their income when they start working. Tuition fees are fully subsidised for students from Sweden, the EU/EEA area, and Switzerland. Students from outside the EU/EEA and Switzerland pay tuition fees but scholarship programmes that cover tuition and living costs are available for a number of non-EU countries.

STEM uptake

Table 1 summarises data taken from Eurostat. It shows that Sweden's proportion of tertiary graduations in science and engineering (27.9 per cent) is well above the average of the European Union 27 countries (21.3 per cent). Sweden is also producing more than the European Union average of upper secondary and vocational graduates, the proportion of human resources in science and technology as a percentage of the whole labour force, and in the proportion of doctoral students in science and technology fields.

All countries are seeking to increase the proportion of their work force-ready graduates that have studied in STEM fields, and on the basis of these comparative figures, Sweden would seem to be reasonably well placed.

Table 1: STEM Uptake - Various Measures - Selected Countries

Country	**Tertiary Graduates - Science & Engineering, % of Total - 2010 #**	**Upper Sec. & Voc. Ed. Graduations Science & Engineering, % of Total - 2010 #**	**Human Res. in Sci. & Tech. % of labour force 2011**	**Doctoral students in Sci. & Tech. Fields. % of Population Aged 20-29 2010 +**
Sweden	26.9%	38.7%	52.2%	0.71
Austria	29.1%	27.5%	40.5%	0.69
Belgium	16.1%	18.6%	49.6%	0.43
Czech Republic	23.4%	33.5%	36.0%	0.84
Denmark +	19.3%	35.3%	51.5%	0.48
EU27	21.3%	30.5%	42.3%	0.30
Finland	31.8%	34.2%	52.6%	1.29
France	26.2%	34.7%	48.1%	0.44
Germany	25.6%	34.8%	44.9%	0.55
Netherlands	14.0%	21.4%	52.2%	0.58
Norway	16.0%	47.1%	54.8%	0.49
Portugal	24.9%	3.7%	27.0%	0.49
Switzerland	19.8%	40.1%	54.7%	0.81
UK - England	22.4%	0.0%	51.2%	0.40

comprises the fields of science, mathematics & computing and engineering, manufacturing & construction
+ EU 27: Figure is for 2007
Source: Eurostats

STEM and gender

In general, women represent only a small proportion of science and engineering in the first and second stages of tertiary study (ISCED 5 and 6, respectively). Table 2 provides a ranking by the proportion of women of all students, STEM enrolments as a proportion of all enrolments, and women in STEM programmes as a proportion of all female students, ranked according to the proportion of female students in higher education STEM programmes as a proportion of all female students. The table shows that Sweden is one of the more successful countries in attracting women into STEM disciplines, but that the proportion is still low. Women represent 59.4 per cent of all tertiary enrolments, but only 14.2 per cent of female students chose to undertake STEM programmes.

Sweden also had a better-than-average presence of women employed as engineering workers, with 25.5 per cent of all engineering workers being women in 2007 (VDI, 2010). Gender equality has been mainstreamed into many activities, but Sweden has a Ministry of Integration and Gender Equality[110] from where useful information on the gender equality policy.

Looking at programmes in support of women in STEM, special funding available for women in science is provided by the Swedish Governmental Agency for Innovation Systems. Vinnmer[111], a large programme launched in 2007 aims at promoting postdoctoral women researchers. The programme will run until 2014 with a total budget of about SEK 500 million (€60 million). Also, from 1985 until 2010, Swedish school boards have been funded under the *Teknik för Flickor* summer schools (Technology for Girls). These summer schools were to encourage girls to look at study and careers in science and technology.

Table 2 Uptake of STEM by All and Female Students at ISCED Levels 5 & 6 - 2010

110 http://www.government.se/sb/d/8210/a/98785
111 http://www.vinnova.se/en/Our-activities/The-Knowledge-Triangle/VINNMER/

	Women % of All Students (1)	All Students in Science & Engineering as % of All Students (2)	Female Science & Engineering students as % of All Female Students (3)
Finland	53.8	35.1	16.1
Germany	51.3	30.7	15.8
Ireland	52.4	27.6	14.7
Sweden	**59.4**	**25.3**	**14.2**
France	55.0	25.6	14.1
Austria	53.1	25.7	13.9
European Union (27 countries)	55.4	25.0	13.6
Czech Republic	56.8	25.3	13.1
United Kingdom	56.6	23.0	12.2
Poland	59.2	21.2	11.8
Denmark	58.1	18.7	11.2
Switzerland	49.2	22.9	10.6
Norway	60.8	16.4	8.5
Belgium	55.2	17.7	8.0
Netherlands	51.8	14.5	5.1

Source: Eurostat
(1) Women among students in ISCED 5-6 - as % of the total students at these levels
(2) Students at ISCED levels 5-6 enrolled in the following fields: science, mathematics, computing, engineering, manufacturing, construction - as % of all students
(3) Female students at ISCED levels 5-6 enrolled in the following fields: science, mathematics and computing; engineering, manufacturing and construction - as % of all female students

STEM promotion in Sweden

Sweden has been quite vigorous in its promotion of science and its Royal Swedish Academy of Sciences has been involved in supporting and improving science education back to the 1980s. The Academy has been '… awarding annual prizes to up to four teachers in mathematics, biology, chemistry and physics who through their enthusiasm, their new ideas and their inspiring work have awakened their pupils' interest in these fields' ALLEA, 2012, p 77). The Academy has also organised annual teachers' days in different locations across the country for several years, primarily targeting high school and upper secondary school teachers.

There is also collaboration with Sweden's engineering academy, and in 2006 co-promoted the 2nd European Conference on Primary Science and Technology Education ('*Science is Primary II: Engaging the new generation*') which focused on inquiry-based primary science education, robust methods for evaluation and research, and sought to provide an overview over European perspectives. The conference gathered teachers, principals, policy makers, program coordinators, researchers, scientists, teacher trainers, representatives from school administration and mass media.

The most important, largest and most visible effort of the two academies has been the NTA[112] programme (*Naturvetenskap och Teknik för Alla*: Science and Technology for all), first floated in 1997: 'This programme supports teachers in their efforts to stimulate pupils´ curiosity, knowledge and possible interest in a career in science and technology. It currently targets primarily classes from kindergarten through to 7th grade (students of 13 years of age). It is owned, run and funded through the municipalities, often with funds from the Ministry of Education and Science or from private sponsors, and offers methods, tools and services for improving learning and teaching in science and technology' ALLEA, 2012, p. 79). The programme was launched when it became

[112] http://www.nta.kva.se/

obvious that the municipalities that run most schools, were poorly prepared for the new national syllabus introduced in 1994.

In the participating municipalities, the NTA programme helps create long-term plans for school development that involve local industry and institutions for higher education and research. In each participating municipality a local coordinator for the programme is appointed.

According to ALLEA (2012, p.79), '…an inquiry-based pedagogy fits well the Swedish National Curriculum which seeks to inject democratic principles into education, enabling students to critically observe and examine facts, communicate and discuss, notice and evaluate consequences and work independently and with others to solve problems. [However], a number of not insignificant obstacles still need to be overcome: evaluations have revealed different outcomes for boys (who benefit more from NTA-based teaching notably in the first area, "Nature and Man") and girls'.

The lack of science and technology training that the majority of primary teachers have received prior to entering their service at schools remains a problem.

The Academy - and through it the NTA Programme – has participated in a number of FP-co-sponsored projects, such as *ScienceEduc, Pollen, Helena* and *Fibonacci*[113], where the Swedish expertise and experiences are often taken as models for the development of adapted national programmes.

An important piece of research Young people's attitudes towards science, technology and researchers were presented in a series of studies conducted in 2007 and summarised in English in the 2008 report 'Knowledge Rocks! - Summary of a youth study by VA[114] (VA is a group that promotes dialogue and transparency between the public and researchers). 'The studies found that Sweden is battling with some of the same problems known also from other countries: while young people are generally interested in new knowledge, in their eyes "science" may often have a negative connotation; "usefulness," context and relevance are important, and these categories are defined in the context of their own experiences. All initiatives to stimulate interest in science have to reckon with the researcher stereotypes that are rife notably in the popular media; one way of dismantling the stereotypes is, of course, to create arenas for researchers to meet children and young people' (ALLEA, 2012, p. 81).

The European Commission's (2010) *Compendium best practices in MST* identifies a number of Sweden's initiatives in STEM recruitment, including *Attracting more students in mathematics education in higher education:* 'Enhancing the interest for maths education especially in higher education has to do with working on the transition from the upper secondary school to higher education. A project focusing on transition from the upper secondary school to higher education originated from the fact that attention was raised on this issue through several reports. These reports showed that students failed in maths for a variety of reasons, there was a content gap, a culture gap, there was weak knowledge of algebra and arithmetic, the admission requirements had been lowered and there was limited cooperation between secondary schools and higher education to prepare the transition between the two….[the aim was] to develop an internet-based transition course (www.math.se), to organise national meetings to bring together key people concerned by transition issues and to stimulate local meetings between all those concerned by the transition problems. This concerned mainly teachers from upper secondary schools, students in their final year of upper secondary

113 http://fibonacci.uni-bayreuth.de/?id=129
114 http://v-a.se/2008/02/knowledge-rocks-summary-of-a-youth-study-by-va/

school and lecturers from universities or university colleges. The internet-based course (www.mattebron.se) has been successful so far as 4000 to 5000 students have already taken this course' (European Commission, 2010, p. 22).

The European Commission also recognises the Swedish action plan for the promotion of mathematics education as an example of best practice. The action plan developed subsequently contains four proposals to enhance the quality of mathematics education in Sweden. The action plan took on board successful initiatives that existed before. There was to be more support, such as a focus on mathematics by the science; more qualified teachers in maths at all levels for all children, young people and adults; more support for teachers; and clarification of the aims, goals, content and assessment.

On the matter of resource centres, four centres (physics, chemistry, biology and technology) have been funded by the Swedish National Agency for Education to provide in-service teacher training. (Kearney, 2011). Sweden also had 14 regional centres in 2009.

Teacher training and continuing professional development are always mentioned in STEM studies of things that need attention, and Sweden has the Boost for Teachers initiative. This initiative is broader than just STEM teaching (Kearney, 2011).

Another initiative has been the *matematiksatsningen* [115], '…which consists of a government grant available to … school principals to invest in development projects and training to enhance the quality of mathematics at compulsory school level during the period 2009 – 2011' (Kearney, 2011, p. 25).

End word

Sweden presents an interesting case to be considered when looking for models. The *Naturvetenskap och Teknik för Alla* (NTA): Science and Technology for all programme, effectively collaboration between the learned academies and the national education agency is impressive. However, the context is a unitary state, so some elements might not be so easily transportable to a federal context. Sweden has a relatively high uptake of STEM, and the proportion of women in STEM and in the engineering work force is also quite high when compared with many other countries.

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Country report: Switzerland

Preamble

Switzerland is not a member of the European Union, and therefore does not appear in as many analyses as member states.

Introduction: Demographic background

Switzerland has a population of about 9.4 million people, in a land-locked country of 41,000km^2. The average population density therefore, is about 229 persons per km^2. About 1.4 million of its population are foreign-born, about 14.3 per cent of the total. About one-third of the immigrant population is from European Union countries.

Switzerland is linguistically diverse, with four official languages. German is the predominant language (64 per cent), with French, Italian and Romansh speakers representing 20 per cent, seven per cent and 0.5 per cent, respectively.

The Swiss education system

The Swiss Conference of Cantonal Ministers of Education website[116] provides a convenient summary of many aspect of Swiss education:

> The education system of the multilingual and federally structured Switzerland is unique because it is firmly rooted in the local municipalities, cantons and language regions. The primary responsibility lies with the 26 cantons. The federal authorities and the cantons share responsibility for post-compulsory education.
>
> In Switzerland, the main responsibility for education and culture lies with the cantons. They coordinate their work at the national level. The 26 cantonal ministers of education together form a political body to carry out this work: the Swiss Conference of Cantonal Ministers of Education (EDK). Legally binding, inter-cantonal agreements (known as concordats) form the foundation for the work of the EDK.
>
> The EDK has a secondary function and fulfils tasks that cannot be performed by the regions or cantons. ….
>
> *Education in a multilingual and federalist country*
> In Switzerland, education is the responsibility of the government from the pre-school (kindergarten) to the tertiary level (universities and higher vocational education and training). The main responsibility for education lies with the 26 cantons. The federal government and cantons share responsibility for public post-compulsory education (matura schools, vocational education and training and universities). The cantons and their local municipalities finance about 87 per cent (2005) of public educational expenditures.
>
> *Pre-school and compulsory schooling*
> Most students in Switzerland (95 per cent) complete pre-school and compulsory schooling at the state school in the municipality in which they live. 5% attend a private school.

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116 http://www.edk.ch/dyn/11586.php

State schools play an important role in integration: children who have different social, linguistic and cultural backgrounds all attend the same school.

The schools are the responsibility of the cantons. The local municipalities organize the way in which schools are run. Because education is locally rooted, individual solutions can be implemented at each location.

All cantons provide 1-2 years of free pre-school education ("kindergarten", "école enfantine"); the canton of Ticino offers three years. Compulsory schooling today begins at age 6 and continues for nine school years. Most primary schools today span grades 1-6. This is followed by the lower secondary level (grades 7-9) where pupils receive instruction in performance-based groups, either in all subjects or in some subjects.

The language of instruction is German, French, Italian or Romansh, depending on the language region, though Romansh-language communities are a special case (more). Traditionally, language learning has an important role in Switzerland. All students learn at least two other languages during their compulsory schooling. This is generally one of the other languages spoken in Switzerland and English.

The federal and decentralised structure of pre-school education and compulsory education makes it possible to deal appropriately with the cultural differences in a multilingual country and its regional-specific school traditions. National requirements apply to key parameters (school entry age, length of compulsory schooling). These requirements will be broadened over the next few years on the basis of a new inter-cantonal agreement of the EDK on harmonisation of compulsory education (HarmoS). Two years of pre-school will become compulsory through this harmonisation process.

Post-compulsory education
Swiss legislation (intercantonal or national) forms the basis for the type of education in the area of post-compulsory education (upper secondary level and tertiary level). The cantons are responsible for enforcing this legislation and are responsible for the organisation of the schools. The only exceptions are the Swiss Federal Institutes of Technology, which are in charge of the federal authorities.

Ninety per cent of young people in Switzerland complete upper secondary education at the age of 18 or 19 which allows them to start working, to switch to a college of higher vocational training or – with a matura/baccalaureate – to continue their education at a university or a university of applied sciences.

The mainly positive spin placed on the multi-sided governance in Switzerland by governments and related agencies is not shared throughout. In a report on education and IT, Barras had the following to say:

The main thrust of educational reform in Switzerland currently concerns the question of harmonisation. Differences in education systems from one canton to another can be a considerable barrier to mobility within the country. One approach to the issue is to improve the coordination between the many actors involved in the education system. In May 2006, the Swiss population voted massively in favour of modifying the Constitution so as to oblige the Confederation and the cantons to coordinate their actions and collaborate more closely in the field of education from primary school to university. One key aspect was the will to fix the duration of each level of education and the specific objectives to be attained by pupils at the end of each level. The latter is the subject of the HarmoS project led by the Swiss Conference of Cantonal Directors of Education (CDIP)….By September 2009, 11 (out of 26) cantons had joined the agreement.

It is staggering to think that there could be so many education systems inside one small country.

STEM uptake

Switzerland has a lower proportion of tertiary graduates from STEM disciplines than the European Union 27 countries average, but a higher proportion of STEM graduates from upper secondary and vocational and doctoral students. It also has a higher proportion of human resources in science and technology as a percentage of the total workforce than the European average.

Table 1: STEM Uptake - Various Measures - Selected Countries

Country	**Tertiary Graduates - Science & Engineering, % of Total - 2010 #**	**Upper Sec. & Voc. Ed. Graduations Science & Engineering, % of Total - 2010 #**	**Human Res. in Sci. & Tech. % of labour force 2011**	**Doctoral students in Sci. & Tech. Fields. % of Population Aged 20-29 2010 +**
Switzerland	**19.8%**	**40.1%**	**54.7%**	**0.81**
Austria	29.1%	27.5%	40.5%	0.69
Belgium	16.1%	18.6%	49.6%	0.43
Czech Republic	23.4%	33.5%	36.0%	0.84
Denmark +	19.3%	35.3%	51.5%	0.48
EU27	21.3%	30.5%	42.3%	0.30
Finland	31.8%	34.2%	52.6%	1.29
France	26.2%	34.7%	48.1%	0.44
Germany	25.6%	34.8%	44.9%	0.55
Netherlands	14.0%	21.4%	52.2%	0.58
Norway	16.0%	47.1%	54.8%	0.49
Portugal	24.9%	3.7%	27.0%	0.49
Sweden	26.9%	38.7%	52.2%	0.71
UK - England	22.4%	0.0%	51.2%	0.40

comprises the fields of science, mathematics & computing and engineering, manufacturing & construction

+ EU 27: Figure is for 2007

Source: Eurostats

One imagines that most countries would prefer to be able to say that the proportion of their STEM-skilled labour force was higher, but Switzerland might be looking to boost its STEM proportion among tertiary graduates.

STEM and gender

In general, women represent only a small proportion of science and engineering in the first and second stages of tertiary study (ISCED 5 and 6, respectively). Table 2 provides a ranking by the proportion of women of all students, STEM enrolments as a proportion of all enrolments, and women in STEM programmes as a proportion of all female students. The table shows that Switzerland is not one of the more successful countries in attracting women into STEM disciplines. Swiss women represent 49.2 per cent of all tertiary enrolments, a figure which is relatively low. In Norway, for example, women make up over 60 per cent of tertiary enrolments. Swiss women enrolled in

STEM programmes make up 10.6 per cent of all female tertiary enrolments, which is lower than the European Union 27 countries proportion, and higher only than in Norway, Belgium and the Netherlands.

In common with other countries, Switzerland has programmes and initiatives to increase the uptake of STEM by women. For example, a foundation called Swiss Science and Youth offered a workshop on various STEM topics for girls aged 10 to 13 in 2009, with the aspiration of raising awareness of gender roles (Kearney, 2011).

Table 2 Uptake of STEM by All and Female Students at ISCED Levels 5 & 6 - 2010

	Women % of All Students (1)	All Students in Science & Engineering as % of All Students (2)	Female Science & Engineering students as % of All Female Students (3)
Finland	53.8	35.1	16.1
Germany	51.3	30.7	15.8
Ireland	52.4	27.6	14.7
Sweden	59.4	25.3	14.2
France	55.0	25.6	14.1
Austria	53.1	25.7	13.9
European Union (27 countries)	55.4	25.0	13.6
Czech Republic	56.8	25.3	13.1
United Kingdom	56.6	23.0	12.2
Poland	59.2	21.2	11.8
Denmark	58.1	18.7	11.2
Switzerland	49.2	22.9	10.6
Norway	60.8	16.4	8.5
Belgium	55.2	17.7	8.0
Netherlands	51.8	14.5	5.1

Source: Eurostat

(1) Women among students in ISCED 5-6 - as % of the total students at these levels

(2) Students at ISCED levels 5-6 enrolled in the following fields: science, mathematics, computing, engineering, manufacturing, construction - as % of all students

(3) Female students at ISCED levels 5-6 enrolled in the following fields: science, mathematics and computing; engineering, manufacturing and construction - as % of all female students

STEM promotion in Switzerland

According to ALLEA (2012) (and obviously, perhaps), intervention in education by academies or other organisations in Switzerland is complicated by the absence of a federal ministry of education with responsibility for science education. Rather, this responsibility is divided 26 ways. Each canton has a different educational system and decides on its own school curricula. Nonetheless, reports ALLEA, the Academies and others have been successful in promoting innovative interactions between science and society that also reach the classroom. In recent years, the country has come to witness a public debate about science literacy; the Swiss Academies play an active role in these debates. Another round of debates has been triggered by the observation of a critical lack of specialised staff.

At a more general level, the promotion of science literacy as part of the mission of the Swiss Academies has led to a number of new projects in collaboration with the Swiss National Science Foundation and with the "*Science et Cité*" foundation. Museums, in conjunction with universities, play a role in promoting and reinforcing science literacy, as do, evidently, science centres, such as Technorama[117] the Swiss science centre – to whom a link is provided through the Academy supported project "Science et Cité".

[117] http://www.technorama.ch/en/

In 2012, the Swiss Academies set up a new web-platform (called educamint[118]) in order to offer school teachers assistance and guidance with the vast number of materials and events on that are available for children of any age in the STEM fields (MINT = STEM in German). While the Academies are active in such activities in informal environments, they are not directly involved in improving formal natural science education through inquiry-based methods in primary and secondary school classrooms.

Educamint was established for the general promotion of science. Its website states '… social development and prosperity in Switzerland depend to a large part on achievements in science and technology. Inventiveness and intelligent implementation of basic knowledge have a long tradition. Hence current students [need to] get an exciting approach to the fascinating world of mathematics, computer science, natural sciences and engineering (STEM. Several partners [the academies and other science-related bodies] have been involved in the launch of the educa.Agenda platform'.

A policy statement by the academies in 2009 (Future – Education – Switzerland) triggered harsh reactions from the public, when statements about the soon-to-be-felt shortfall of highly qualified staff in engineering and health professions were in fact denied: 'Some of the arguments, which were given little attention in the public debate, were precisely those that are of relevance for the reform of S&T education. They include the request to better network S&T domains in higher education and the relevant corporate sectors, but also the suggestion to create stronger linkages between science education at school and the real life experiences and requirements. The report also emphasised the need of the school system to improve in terms of promoting inclusiveness and equal opportunities, and demanded better support for the professional development and recognition of teachers' (ALLEA, 2012, p. 82).

There are several other relatively small initiatives in place. The *Swiss Mathematical Society*[119], a member organisation of the Swiss Academy of Sciences offers activities specifically dedicated to the teaching of mathematics such as in-house training for teachers, summer school for the pupils.

In 2008, the Life Science Learning Centre[120] was named by the EU-funded Action Support Programme form-it: Take part in Research as a Swiss example of good practice for successful cooperation between research institutions and the educational sector.

In the field of technology (and with a certain emphasis on energy and transport issues) the explore-it project[121] provides materials and task kits that would enable young people to be technically innovative at school.

The do-it-werkstatt[122] (do-it-lab) (http://shop.do-it-werkstatt.ch/index.php) has its focus on technologies and textile design; the project targets teachers and students, offering advice and tools for S&T literacy, and support for classroom activities.

Real-tec[123] is a project that aims to bring children, through hands-on experiments and tasks, to a more genuine appreciation of science, technology and related professions.

118 http://mint.educa.ch/de/%C3%BCber-uns-5
119 http://www.math.ch/mathematics-at-school/
120 http://www.form-it.eu/examples.htm
121 http://www.explore-it.org/en.html
122 http://shop.do-it-werkstatt.ch/index.php
123 http://www.real-tec.ch/

The project is cognizant of the different degrees of exposure of children to the realities (opportunities and risks) of research and development in the modern world – and of the fact that prevalent teaching methods at school do little to make up for these differences - and has deliberately sought to design its activities in a way that promotes inclusion and integration. The lab targets teenagers of 12 to 16 years of age.

There is also a website that includes a career guidance platform targeting 12 to 16 year-olds. It covers all STEM areas. SimplySscience[124] is to be extended to have wider coverage.

End word

Although evidence can be found for a great number of initiatives, programmes and projects, there is something vaguely chaotic about a country with 26 systems of education in a geographic space about two-thirds the size of Tasmania. It is likely that other countries are more likely to provide better role models in STEM (and other matters) than Switzerland is. That said, differences between some Australian states, such as the timing of terms and the content of curricula, are a reality. On the former point, however, it has to be acknowledged that it is a long way from north to south and from west to east.

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124 http://www.simplyscience.ch