Science, technology, engineering and mathematics (STEM) skills

December 2012

SUMMARY	
Overview	➢ Defined as skills held by people with a tertiary level qualification in the corresponding disciplines of science, technology, engineering or mathematics ➢ Progression to higher level STEM skills are achieved through nurturing STEM skills early in general education and through vocational technical education ➢ The supply of STEM skills is critical to the development of knowledge-intensive economies and European competitiveness
Demand	➢ STEM jobs account for 7.4% of employment across the EU-27 (2010) ➢ In the 2000-2008 period, the number of physical, mathematical and engineering science professionals employed grew by 36% in the EU-27; between 2009 and 2011, this has declined by 16% ➢ Demand is anticipated to increase in the short and medium term ➢ Demand consists of STEM-specific technological skills but also increasingly for soft or transversal skills, such as team-working, communication across disciplines, sectors and countries and for commercial awareness.
Supply	➢ The supply of STEM skills is not sufficient due to: ~ Declining numbers of STEM graduates ~ Continuing low achievement in science at schools ~ Ageing of current STEM professionals ~ Some negative perceptions about STEM related careers (such as lower pay) ~ Increasing global competition for STEM graduates
Mismatches	➢ The quality of STEM graduates does not always meet the requirements of the labour market ➢ There is a structural mismatch - some STEM occupations require medium-level vocational qualifications rather than tertiary level qualifications ➢ A number of STEM graduates pursue non-STEM related careers due to the poor image of some STEM jobs and a lack of awareness of the full range of opportunities to use their STEM skills

1. STEM skills: crucial to innovation and growth

Science, technology, engineering and mathematics (STEM) skills are defined here as the skills held by people with a tertiary level qualification in the subjects of science, technology, engineering and mathematics. As such, progression to high-level STEM skills is nurtured through general and technical vocational education.

The understanding and scope of STEM skills varies widely from country to country.[1] This is because while STEM skills supply is relatively clearly identified in terms of qualifications achieved in a number of STEM subjects, the demand for STEM skills is more difficult to define, cross-cutting economic sectors and different occupations. In Europe's knowledge-based economies, the range of occupations that require STEM skills is vast.

The development of STEM skills is a highly-significant policy area. STEM-related industries are considered to be crucial to continuing innovation, the development of knowledge-intensive economies and to European competitiveness in the context of rapidly-paced globalisation and greater geographic fragmentation of production processes.[2] The further development of science and innovation in Europe requires building on the strengths and talent of STEM professionals to raise the quality and impact of STEM-related activities.

2. Current and future demand for STEM skills

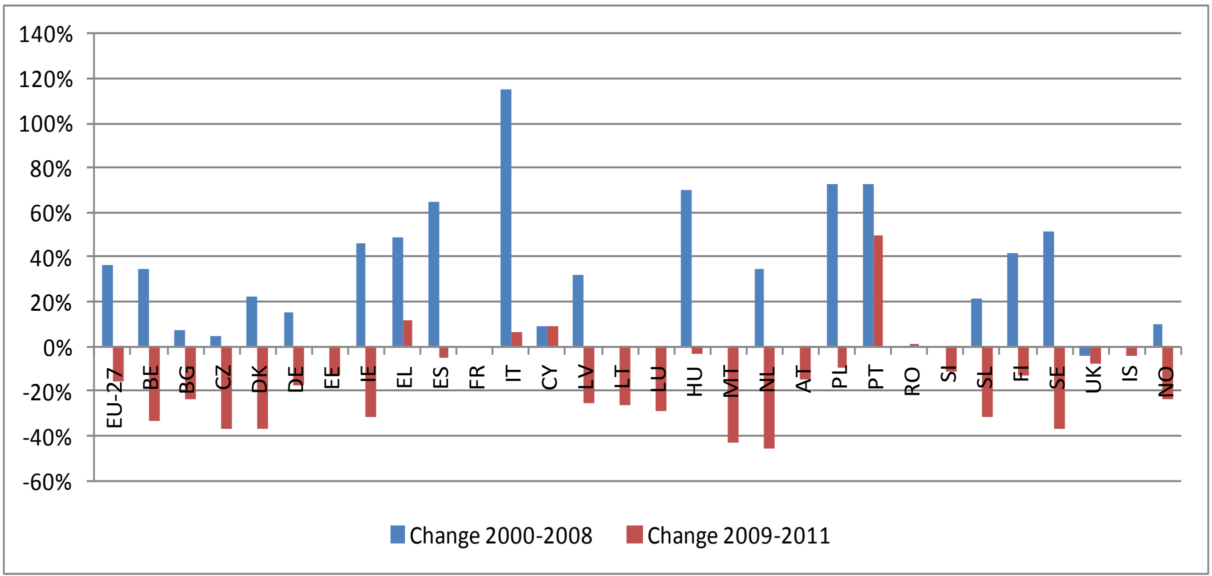
2.1. A mixed picture in the demand for STEM skills

In the pre-crisis period, the number of physical, mathematical and engineering science professionals grew by 36% in the EU-27 (see Figure 1). Since 2008, this has declined by 16% at the EU level, with a few exceptions where the number of STEM professionals grew (e.g. CY, EL, IT and PT).

[1] See UKCES (2010); Undervisningsministeriet (The Ministry of Education) (2012).

[2] OECD (2011).

Figure 1 - Change in the number of employed 'Physical, mathematical and engineering science professionals' (2000-2008 and 2009-2011)



Source: Eurostat, table *(lfsa_egais).*

In 2010, around 16.5 million people were employed as STEM professionals and associate professionals, accounting for 7.4% of the overall employed population (see Table 1). Whereas all occupations are expected to grow by 3% by 2020, STEM professionals and associate professionals are expected to grow by 14% and 7% respectively. Replacement demand will play a key role in the future, with the majority of the future required workers needed to replace retiring /departing current workers.

Table 1 – Current and anticipated future employment demand in key STEM-related occupations, EU-27, 2010-2020, (000s)

	2010	2020	Change 2010-2020	Expansion demand, 2020	Replacement demand, 2020	Total requirement, 2020
Physical, mathematical and engineering science professionals	8,290	9,472	14%	1,183	2,364	3,546
Physical, mathematical and engineering science associate professionals	8,333	8,877	7%	543	2,253	2,797
All occupations	223,219	230,847	3%	7,627	4,617	12,244

Source: Cedefop (2012).

Anticipated future demand in key STEM-related sectors shows a mixed picture (see Table 2). Overall employment growth of 9% is anticipated in key STEM-related sectors between 2010 and 2020, with particularly strong growth anticipated in the computing and professional service sectors, and to a lesser degree in mechanical engineering.

Table 2 – Anticipated future employment demand in key STEM-related sectors, EU-27, 2010-2020

	2010 (000s)	2020 (000s)	Change 2010-2020 (%)
Pharmaceuticals	494	493	0.0
Chemicals not specified elsewhere	1,168	1,169	0.1
Non-Metallic Mineral Products	1,618	1,549	-4.3
Mechanical Engineering	3,453	3,644	5.5
Electronics	967	980	1.3
Electrical Engineering & Instruments	2,750	2,780	1.1
Motor Vehicles	2,208	2,164	-2.0
Manufacturing not specified elsewhere	2,204	2,206	0.1
Communications	3,011	3,156	4.8
Computing Services	3,040	3,270	7.6
Professional Services	7,530	8,578	13.9
All industries	223,219	230,847	3.4

Source: Cedefop (2012).

2.2. Increasing demand for higher level technical skills combined with soft skills amongst STEM professionals

Certain personal and behavioural attributes are increasingly in demand in several sectors where STEM skills are prevalent.[3] Creativity, team working, communication and problem solving are critical in the context of applying STEM skills to develop new and innovative technologies. Employees dealing with new technological developments often work in multi-disciplinary teams and across sectors and countries. The production of scientific knowledge is shifting from single individuals to groups, from single to multiple institutions, and from national to international domains placing greater emphasis on the combination of technical expertise, creativity and communication skills.[4]

As STEM-driven technology and services become more embedded in everyday life, both in business and in society, STEM professionals need to be able to understand and respond to customer challenges, consumer choices and the opportunities they present.[5] Employer surveys have shown that some STEM graduates are considered under-skilled in the requisite personal and behavioural competences expected of

[3] European Commission (2012).
[4] OECD (2011).
[5] E-Skills UK (2011).

them, such as team-working, communication and time management/organisational skills, as well as the more commercially-related skills including product development, customer service and business acumen.[6]

The successful development of these skills requires an education system capable of preparing students through more active and problem-based learning approaches, using assignments from the 'real world' and including support for risk taking and creativity.

2.3. Country-specific demand developments and trends

National examples point to current shortages in the supply of STEM skills and professionals and ongoing demand across the EU in the short and medium term:

- In **Austria**, in 2010, 77% of Austrian companies reported difficulties in recruiting people in the field of technology and production.[7]
- In **Belgium**, the number of unfilled vacancies for engineering professions was 2,500 in 2009, despite 2,000 engineers graduating each year. [8] A survey of human resource managers showed that they expected this position to become worse in the coming years.
- In **Germany**, the shortage of STEM-skilled workers is seen as a structural problem.[9] In 2008, the economic peak year, there were over 114,000 additional skilled people needed by the sector. This number diminished in 2009 and 2010, but subsequently increased, reaching 117,000 in February 2011.
- In **Hungary**, science and engineering professionals were found to be the most in demand occupational group in a recent employment survey, with 37% of employers reporting recruitment difficulties in this area.[10]
- In **Ireland**, existing analysis shows that, after software engineers, electronic engineers are the second highest growth occupation, as well as being the second largest area of skills shortage, in the country.[11] This trend is expected to continue in the medium-term to 2015.
- In **Italy**, an increase in the number of individuals working as specialists in mathematics, physical and natural sciences is anticipated, growing from 153,251 in 2010 to 166,198 in 2015 (an increase of 12,947 jobs, or 8.4%). This compares to the average growth across all occupations of 3.3%.[12]

[6] UK Department for Business, Innovation and Skills (2011).
[7] BusinessEurope (2012).
[8] Ibid.
[9] Ibid.
[10] Hungarian Labour Market Prognosis (2012).
[11] Expert Group on Future Skills Needs (2012).
[12] ISFOL(2012).

- In **Sweden**, the latest annual employer survey showed a shortage of recently qualified construction and industrial engineers, computer programmers and systems analysts.[13]
- In the **UK**, the demand for science and technology professionals is forecast to grow by 18% by 2014, compared to 4% growth for all other occupations.[14] This suggests 775,000 new jobs which will require high-level STEM skills by 2014. When expansion and replacement demand are considered together, a total of 2.4 million positions are forecast to require high-level STEM skills by 2014. However, recent trends in the UK show a more mixed picture. In 2009, in England, STEM employers report similar vacancy levels to all employers[15]. Vacancies due to skills shortages were slightly higher among STEM employers compared to all vacancies (21.1% for STEM employers; 16.3% for all employers). Note that this reflects the difficulty in looking at STEM sectors as a whole - where skill deficits may relate to very specialised technical areas which can be lost in any over-arching analysis.

3. Current and future skill supply of STEM skills

Overall, the current supply of STEM skills is considered to be insufficient and when combined with forecast growth in demand for STEM skills, these shortages present a potentially significant constraint on future economic growth in Europe.[16]

3.1. Numbers of STEM graduates are in slight decline

Figure 2 shows, that the supply of tertiary education graduates with STEM skills varies significantly across the EU, with STEM graduates constituting around 11-12% of all graduates in the UK, Germany, Greece and Ireland compared to around 5% in Latvia, Lithuania, Romania and Bulgaria. Importantly, however, across the EU, the proportion of tertiary education graduates in science, mathematics and computing fields has declined slightly in the 2006-2010 period, from 9.8% in 2006 to 9.1% in 2010. Country-level trends are very different, with significant increases in the number of STEM graduates apparent in Denmark, Germany, Malta, Czech Republic and Slovenia (albeit from a rather low base), but significant decreases in Belgium, Ireland, Cyprus and Austria.

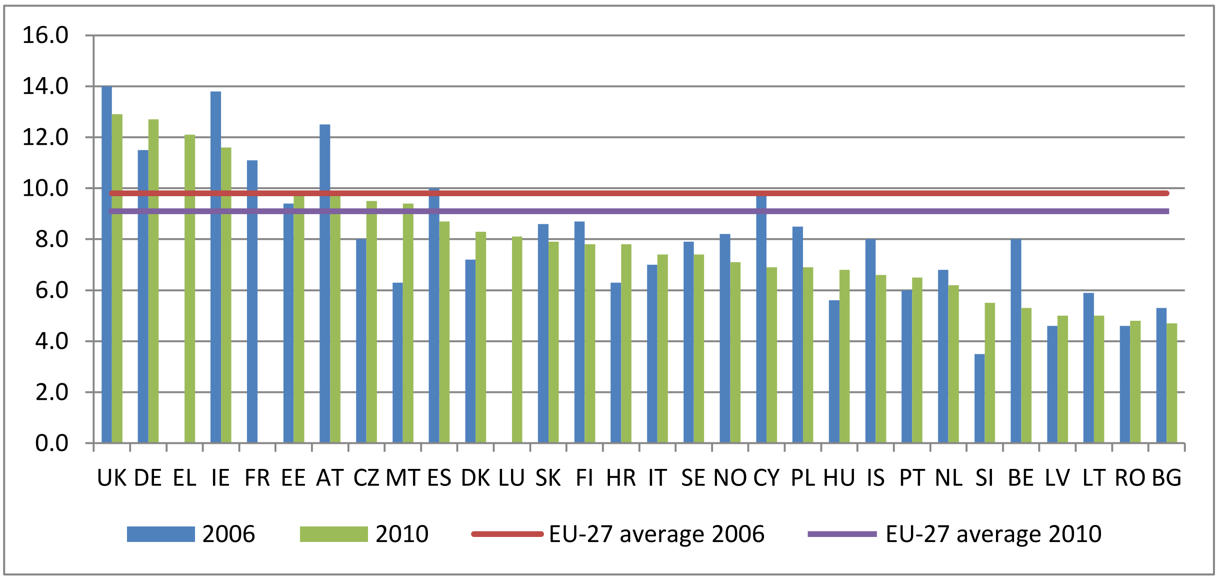
[13] Arbetsformedlingen (2012).

[14] BusinessEurope (2012).

[15] UKCES (2011a).

[16] BusinessEurope (2012).

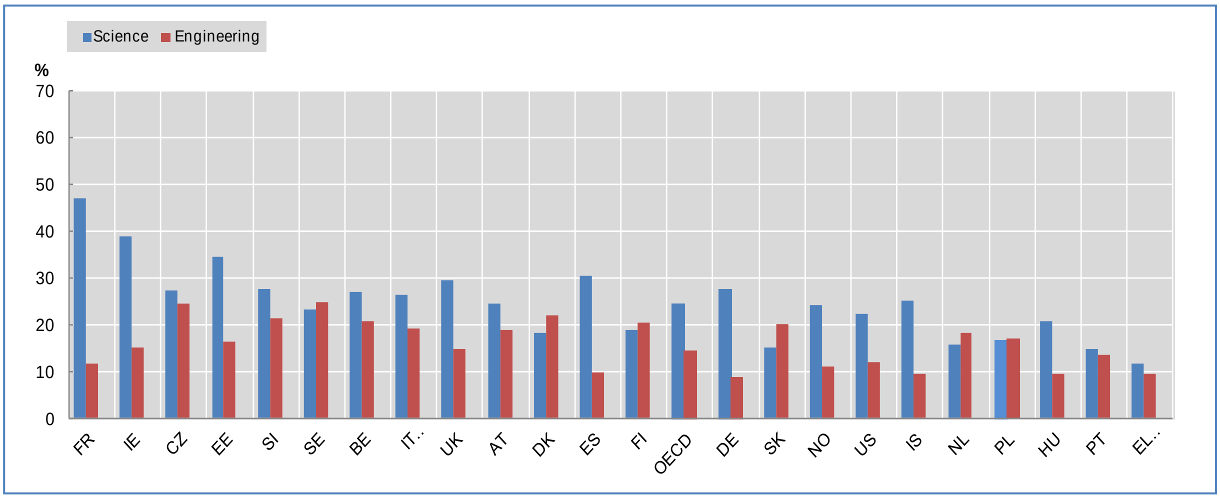
Figure 2 - Graduates (ISCED 5-6) in science, mathematics and computing field - as % of all fields, 2006-2010



Source: Eurostat, table [educ_itertc].

Doctoral level graduates in STEM subjects are particularly important to research and innovation. The United States is the largest single contributor to the supply of Ph.Ds, accounting for over a quarter of the approximately 89,000 new doctorates in science and engineering awarded across the OECD in 2009 (see Figure 3). The United States is followed by Germany, the United Kingdom and France, with the 20 EU countries combined accounting for more than half of the total number of OECD doctoral degrees awarded in science and engineering.

Figure 3 - Science and engineering graduates at doctorate level, 2009 (percentage of all new degrees awarded at doctorate level)

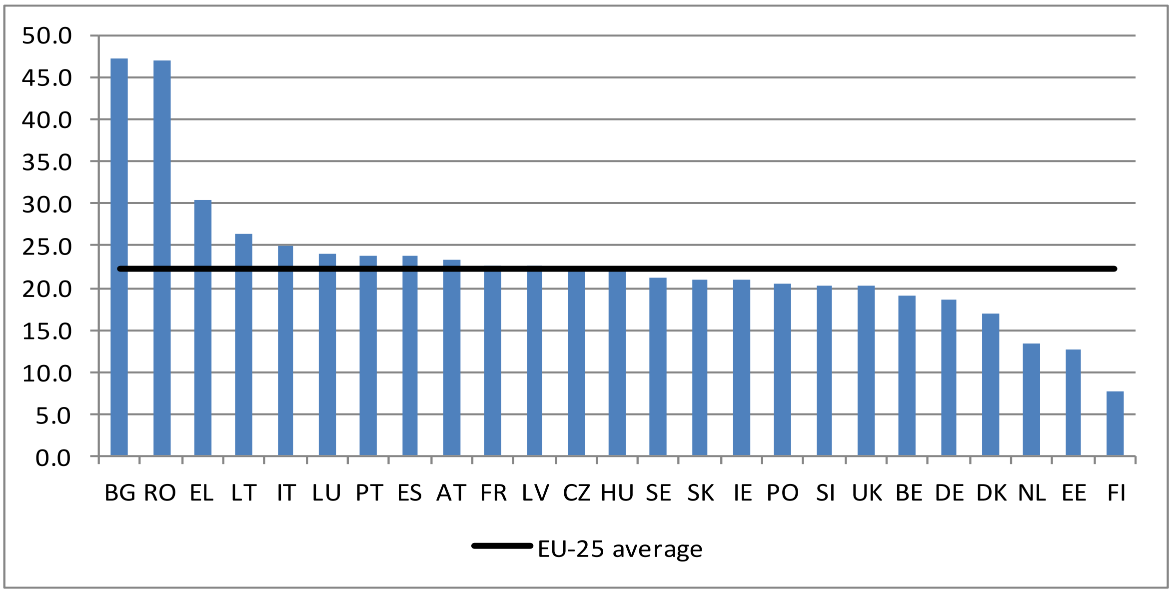


Source: OECD (2011).

3.2. High numbers of low achievers in science amongst 15 year olds

The future supply of STEM skills is ultimately dependent on the development of competences, interest and passion in the sciences through early years of education. Low achievement in science now is a sure precursor to a worsening position in STEM skills supply in the future. The OECD PISA survey, found that nearly 1 in 5 pupils surveyed had low level science skills (below Level 2) across the EU-25 (see Figure 4). This ranged from around 40% of all pupils in Bulgaria and Romania to just 6-8% in Finland and Estonia respectively.

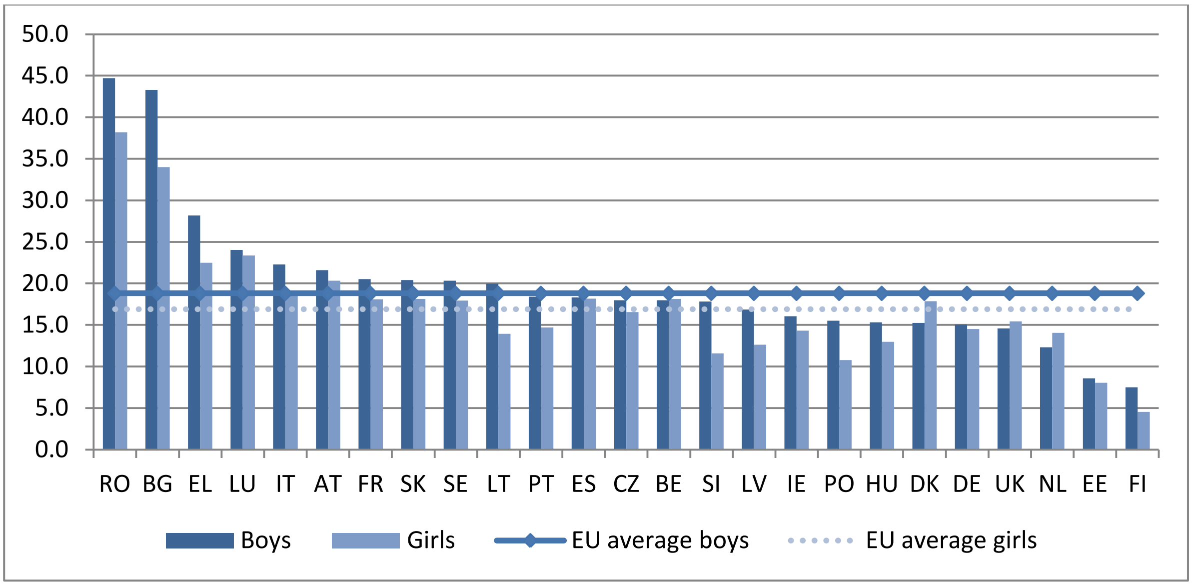
Figure 4 - Low achievers (below Level 2) in science (as % of all surveyed pupils), 2009



Source: OECD (2009). EU-25 average refers to data from 25 Member States (excludes Cyprus and Malta for which data is not available). Low achieving is defined as below Level 2 and capable of carrying out only the least complex tasks.

Low achievement in science also has a gender dimension, with girls outperforming boys in terms of science skill achievement (see Figure 5). Across the EU-25, the proportion of low achieving girls in science was lower (16.9%) compared to the proportion of low achieving boys (18.8%). This gender pattern was consistent across the Member States participating in the PISA survey, with the exceptions of Belgium, Denmark, Netherlands and the United Kingdom.

Figure 5 - Low achieving boys and girls (below Level 2) in science (as % of all surveyed pupils), PISA 2009 survey



Source: OECD (2009). EU-25 average refers to data from 25 Member States (excludes Cyprus and Malta for which data is not available). Low achieving is defined as below Level 2 and capable of carrying out only the least complex tasks.

3.3. Ageing of the workforce is significant

The demographic changes and the ageing of societies across Europe will also affect the requirement for STEM professionals. A relatively high outflow from the labour market can be anticipated due to large-scale retirements.[17] In the UK for instance, up to 70% of current high-skilled employees in the nuclear industry will retire by 2025.[18] Table 1 above showed significant forecast replacement demand for STEM skills – all of which further supports the conclusion of a worsening position in STEM skills supply.

3.4. Lack of influx of foreign talent

In addition to the problems of nurturing home-grown STEM talent, Europe is also facing competition for highly-skilled STEM professionals from other industrialised countries like the United States, Canada or Australia.[19] It appears that Europe is not necessarily the preferred destination for highly-skilled third-country nationals, and Europe is not doing as well as other destinations in attracting foreign-born talent, including STEM professionals.[20] This is due to a combination of factors, including 'hard' migration policy (such as the regulation of work permits, access to citizenship,

[17] European Commission (2009b).

[18] BusinessEurope (2012).

[19] European Commission (2011).

[20] OECD (2012).

economic and social rights and social services and taxation exemptions/ reductions for immigrants), but also softer aspects such as language issues, quality of life, quality of employment, the real and perceived extent of ethnic diversity and tolerance and the national image.

3.5. Country-specific developments and trends in the supply of STEM skills

Country examples point to a variety of trends in relation to the supply of STEM skills:

- In the region of Flanders (**Belgium**) the number of tertiary education graduates in maths, sciences and technology increased from 8,201 in 2000-2001 to 11,096 in 2008-2009 (an increase of 35.3%)[21]. However, the proportion of STEM qualifications relative to all higher education qualifications decreased from 20.5% in 2001-2002 to 19% in 2008-2009.
- In **Denmark**, since 2009, national tests in selected subjects carried out in primary schools point to an improvement in attainment in mathematics, physics and chemistry between 2009 and 2011. Data from the tests shows a slight improvement between the latest academic years of 2009/2010 to 2010/2011 within mathematics, physics and chemistry.[22]
- Traditionally, in **Malta**, the emphasis of education has been on the liberal arts and science. Education in technical subjects was confined to the technical schools which had a lower status than the grammar schools. During the past decade, the government has invested heavily in the development of STEM skills at the University of Malta, through the establishment and constant expansion of the Malta College of Arts, Science and Technology (MCAST) and the provision of scholarships for further study in educational institutions in Malta and abroad.
- In **Slovenia**, the awareness among the relevant institutions and general public about the importance of basic STEM competences is high. Unfortunately, PISA data shows this is not always matched by achievement. In comparison with other EU countries and the European education benchmark (15% of pupils or less not achieving Level 2 standard), Slovenia had slightly over 20% of low-achievers in mathematics, but was above the European average in science, with only 14% of low-achievers.[23]
- Almost one in five **Swedish** students (19.3%) did not achieve the expected standards in mathematics in 2011, and just over one in ten (11.1%) were classified as high-achievers in the Swedish national school tests. In comparison, in science in 2011, national tests show that 12.7% of

[21] Flemish Parliament (2012).

[22] Undervisningsministeriet (The Ministry of Education) (2012).

[23] IMAD (2012).

students did not achieve the goals in science, while 8.3% were classified as high achievers.[24]

- In the **UK**, the decline in numbers of students taking STEM-related A-levels[25] seen between 1996 and 2003 has been reversed in the period to 2009/10. While there has been notable growth in mathematics / further mathematics and chemistry, the numbers taking computer studies and ICT A-levels has declined. Overall STEM subjects represented 28.7% of A-levels in 2009/10 compared to 29.3% in 2003/04. At the tertiary education level, there has been a higher (27%) increase in STEM subject higher education enrolments between 2002/03 and 2009/10. Over this period there were:
  - 61,000 additional enrolments in biological sciences,
  - 30,000 additional enrolments in engineering and technology,
  - 23,000 additional enrolments in physical sciences.[26]
- National results in **Norway** show that the level of mathematics achievement among students in the fifth grade is low compared to achievement in other subjects (such as English and reading skills), although mathematics achievement has improved over the past two years. The national results in science show a higher average score compared to mathematics.[27]

4. A combination of factors contribute to STEM skills mismatches

Besides the quantitative aspects, about whether there are sufficient numbers of workers with STEM qualifications to meet demand as outlined above, there are also qualitative aspects such as whether the competences graduates have are sufficiently geared towards the demands of the labour market.

A key concern is that the quality of the STEM graduates does not appear to meet the requirements of industry. This is due to a combination of factors:

- The lack of good science foundation skills before young people enter higher education STEM courses lead to deficiencies in learning during the higher education course. In the UK, for example, around 70% of biology undergraduates, 38% of chemistry undergraduates and 10% of engineering students did not have A-level maths.[28]

[24] Skolverket (The Swedish National Agency for Education) (2012).

[25] The equivalent of the general education certificate. Subjects include chemistry, physics, other sciences, mathematics/further mathematics, and computer studies.

[26] UKCES (2011a)

[27] Utdanningsdirektoratet (The Norwegian Directorate for Education and Training), 2011.

[28] UKCES (2011b). A levels are equivalent to the general education certificate.

- The quality and content of STEM subjects is not always developed with the involvement of industry and key employers, which can help ensure that subject content is up-to-date and relevant to rapidly changing industry requirements.
- The over-qualification of some employees with STEM skills, where some STEM shortage occupations require medium-level rather than high-level qualifications. For example, in Belgium, the competences of STEM graduates do not always match the needs of the labour market.[29] This is because shortage vacancies often have a technical character not requiring a higher education qualification.

Another type of mismatch in relation to STEM skills is the outflow of STEM graduates to jobs outside core STEM related careers. STEM graduates are found working for employers across all sectors of the economy and in a wide variety of job roles that do not necessarily require STEM skills. The main reasons for the outflow of STEM graduates 'away' from specialised STEM jobs/careers are the perceived greater attractiveness of careers outside STEM (not least the perception of higher salaries in other professions), and graduates' lack of real knowledge about working in STEM core functions.[30]

Overall the evidence would suggest that there is likely to be increasing demand for STEM skills; that there are already significant skills mismatch issues within industry and that these are likely to exacerbate over time. If the supply of STEM skills is not to be a constraint on the economic growth of Europe, greater advances are necessary in: the early nurturing and attainment of STEM skills in schools; developing a passion and interest in science in young minds; enhancing the wrap-around skills needed for the effective application of STEM skills in a multi-disciplinary, creative and collaborative work environment; and informing graduates about the realities of a rewarding career in STEM related occupations.

Useful resources

This section lists European and national sources of information used in the paper (as well as general information sources)

European level sources

BusinessEurope (2012) Plugging the Skills Gap – The clock is ticking (science, technology and maths), http://www.businesseurope.eu/Content/default.asp?pageid=568&docid=28659

Cedefop (2012) Skills Forecasts Online Tool, http://www.cedefop.europa.eu/EN/about-cedefop/projects/forecasting-skill-demand-and-supply/skills-forecasts.aspx

[29] Flemish Parliament (2012).

[30] UK Department for Business, Innovation and Skills (2011).

European Commission (2009a) Investing in the Future of Jobs and Skills Scenarios, implications and options in anticipation of future skills and knowledge needs Sector Report Chemicals, Pharmaceuticals, Rubber & Plastic Products, http://ec.europa.eu/social/main.jsp?langId=en&catId=782&newsId=555&furtherNews=yes

European Commission (2009b) Comprehensive sectoral analysis of emerging competences and economic activities in the European Union, Lot 6: Electromechanical engineering, http://ec.europa.eu/social/main.jsp?langId=en&catId=782&newsId=529&furtherNews=yes

European Commission, European Migration Network (2011) Satisfying Labour Demand through Migration, http://ec.europa.eu/home-affairs/policies/immigration/docs/Satisfying_Labour_Demand_Through_Migration_FINAL_20110708.PDF

European Commission (2012) Assessment of impacts of NMP technologies and changing industrial patterns on skills and human resources, http://ec.europa.eu/research/industrial_technologies/pdf/nmp-skills-report_en.pdf

OECD (2009) PISA Results: What students know and can do. Student performance in reading, mathematics and science. http://www.oecd.org/pisa/pisaproducts/48852548.pdf

OECD (2011) OECD Science, Technology and Industry Scoreboard 2011, http://www.oecd-ilibrary.org/science-and-technology/oecd-science-technology-and-industry-scoreboard-2011_sti_scoreboard-2011-en

OECD (2012) Connecting with Emigrants, A Global Profile of Diasporas, http://www.oecd-ilibrary.org/content/book/9789264177949-en

National level sources

Belgium

Flemish Parliament (2012), Note of the Flemish Government. Action Plan for stimulating careers in mathematics, exact sciences and technology, 8 February 2012.

Denmark

Undervisningsministeriet (The Ministry of Education) (2012), National Science Test Results, http://uvm.dk/Uddannelser-og-dagtilbud/Folkeskolen/De-nationale-test-og-evaluering/Fakta-om-de-nationale-test/Testresultater/National-praestationsprofil

Hungary

Hungarian Labour Market Prognosis (2012), Employer Survey, http://www.mmpp.hu

Ireland

Expert Group on future Skills Needs (2012) Addressing High-Level ICT Skills Recruitment Needs; Research Findings

Italy

ISFOL (2012) Professioni, occupazione e fabbisogni http://professionioccupazione.isfol.it/

Slovenia

IMAD (2012) Development Report 2012, http://www.umar.gov.si/fileadmin/user_upload/publikacije/pr/2012/PoR_2012.pdf

Sweden

Arbetsformedlingen (2012) ""Var finns jobben? Bedömning för 2012 och en långsiktig utblick" ("Where are the jobs? Assessment for 2012 and a long term view") http://www.arbetsformedlingen.se/download/18.6a167f531341a047838800012318/Ura+2012_1+VFJ+h%C3%B6sten+2011ny.pdf

Skolverket (The Swedish National Agency for Education), 2012). Provresultat i grundskolan vårterminen 2011 (Test results in primary and lower secondary schools, spring 2011). Available at http://www.skolverket.se/statistik-och-analys/statistik/2.4290/2.1512

UK

E-skills UK (2011) Technology Insights 2011
http://www.e-skills.com/research/research-themes/future-trends/

UKCES (2011a) The Supply and Demand for High-Level STEM Skills, Briefing Paper, December 2011, analysis of the NESS/UK Employer Skills Survey predecessor

UKCES (2011b) The Supply and Demand for High-Level STEM Skills, Briefing Paper, December 2011,

UK Department for Innovation, Universities and Skills (2009) The Demand for Science, Technology, Engineering and Mathematics (STEM) Skills, January 2009

UK Department for Business, Innovation and Skills (2011), STEM Graduates in Non STEM Jobs", Report, March 2011

Norway

Utdanningsdirektoratet (The Norwegian Directorate for Education and Training) (2011) "Resultater - Nasjonale prøver 5. Trinn" (Results of national school tests, Grade 5)
http://skoleporten.udir.no/rapportvisning.aspx?enhetsid=00&vurderingsomrade=88e13531-a5b6-4c33-ad87-b0ceb59b26b1&skoletype=0
http://skoleporten.udir.no/rapportvisning.aspx?enhetsid=00&vurderingsomrade=88e13531-a5b6-4c33-ad87-b0ceb59b26b1&skoletype=1

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