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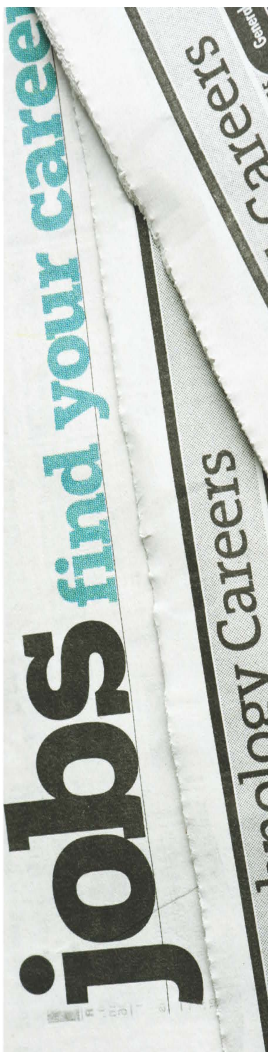

Encouraging STEM Studies for the Labour Market

Encouraging STEM Studies for the Labour Market

Study for the EMPL Committee

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DIRECTORATE GENERAL FOR INTERNAL POLICIES
POLICY DEPARTMENT A: ECONOMIC AND SCIENTIFIC POLICY

Encouraging STEM studies

Labour Market Situation and Comparison of Practices Targeted at Young People in Different Member States

STUDY

Abstract

There is evidence of skills shortages in STEM (Science, Technology, Engineering, Mathematics) fields in spite of high unemployment rates in many Member States. This document, prepared by Policy Department A at the request of the Committee on Employment and Social Affairs, intends to provide an up-to-date overview of the labour market situation in STEM occupations and to analyse European and national approaches to encourage STEM uptake in relation to these labour market needs. The aim is to identify practices which help to increase the supply of STEM skilled labour.

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LIST OF ABBREVIATIONS

CPD Continuing Professional Development

ICT Information Communication Technologies

STEM Science, Technology, Engineering and Mathematics

VET Vocational Education and Training

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EXECUTIVE SUMMARY

Background

A sufficient labour supply equipped with STEM skills is essential to implement the European Agenda for Growth and Jobs.

This document has been prepared at the request of the Committee on Employment and Social Affairs of the European Parliament.

Major areas of concern for the Committee include the evidence of persisting skills shortages in STEM fields in spite of high unemployment levels in many Member States. Against this background, policies and initiatives to improve matching the supply of skills and qualifications with demand for labour are seen as a way to increase the competitiveness of European labour markets and to recover from the crisis.

Aim

This document intends to provide an up-to-date overview of the labour market situation in STEM occupations and to analyse European and national approaches to encourage STEM uptake corresponding to labour market needs. The aim is to identify practices which help to increase the supply of STEM skilled labour.

Labour market situation in STEM-related jobs

In the European Union employment of STEM skilled labour is increasing in spite of the economic crisis and demand is expected to grow. At the same time, high numbers of STEM workers are approaching retirement age. Around 7 million job openings are forecast until 2025.

Employment prospects in STEM-related sectors differ. Demand is expected to rise in professional services and computing, whilst no employment growth is forecast in the pharmaceutical sector.

Demand for STEM skills requires both upper-secondary and university graduates. Medium-level qualifications are required for almost half of STEM occupations and this trend is expected to persist.

The share of STEM university graduates has increased in 15 Member States and at European level since the mid-2000s, whilst a decline in the share of STEM VET graduates is the predominant trend at the national level.

Concerns about the supply of STEM skills rely on two basic facts: the proportion of students going into STEM is not increasing at the European level and the underrepresentation of women persists. So far, these trends have been mitigated by the expansion of higher education, which has seen since the mid-2000s an increase in the absolute numbers of STEM university graduates in the European Union. The number of STEM VET graduates has nevertheless decreased.

The majority of Member States have experienced recruitment difficulties in relation to STEM skilled labour in recent years. Shortages are more pronounced for technological occupations (Engineering and ITC) and for professionals.

The unemployment rate for STEM skilled labour has been very low and well below the total unemployment rate since the beginning of the 2000s, even in countries particularly hit by the crisis, such as Greece, Portugal and Spain. This fact shows the high demand for workers with these skills.

Initiatives to encourage STEM studies and careers

Different social, cultural, economic and educational institutional factors explain why STEM studies and careers are unattractive for young people. This combines with gender related issues to explain the persisting under-representation of women.

Three main policy approaches related to encouraging STEM studies and careers in Europe have been pursued. These focus on, curricular and teaching methods, teacher professional development and guiding young people to STEM. EU initiatives have also contributed to developments in Member States.

Most countries use a mix of these three policy approaches albeit to varying degrees in efforts to encourage a better take-up of STEM studies. Increased school-industry partnership is stressed as imperative in advancing all these three policy approaches –but is particularly important in career guidance initiatives.

The majority of policies and initiatives being undertaken to encourage STEM take-up are carried out in the educational sphere. There are surprisingly few initiatives or research which focuses on the labour market and industry settings.

European coordination and EU funded research has provided a collection of good practices currently being developed in Member States. The selected practices were identified by qualitative expert assessment and partly by showing a positive quantitative impact. These show a range of different initiatives that attempt to encourage STEM throughout the life-course, including initiatives developed at the primary school level, secondary school level, VET, higher education and active labour market policies.

Conclusions

In spite of national diversity in the European Union, common policies, initiatives and programmes have been pursued to encourage STEM studies. Most countries have a global approach to dealing with STEM issues at the national level. This has been complemented by a wide-range of European initiatives.

Despite the various policies, initiatives, programmes and projects developed in order to encourage STEM studies –it seemed as though little progress was made until the mid-2000s. Evaluations of recent trends however indicate more positive results. Data about university graduates in STEM also gives an indication of progress made with 15 Member States showing a rise in the share of STEM university graduates since the mid-2000s.

To conclude from the analysis, national strategies should amongst other things aim to promote a positive image of science, raise awareness of science, make improvements in school based science teaching and learning, increase student's interest in science and aim for gender balance. Transforming young people's attitudes to science is a long-term project that will not occur overnight- the effects will be seen in the long-term.

Although there is an increasing recognition of the importance of school-industry partnerships – there is little emphasis on the labour market and industry settings for these types of initiatives.

Furthermore, there seems to be scope for developing active labour market policies in the field, providing further training to those unemployed to tackle STEM shortages. This could be accompanied by an increased emphasis on VET short cycles of higher education in STEM.

Finally, analysis shows that more systematic evaluation is needed of the different types of initiatives and their impact on STEM uptake.

1. INTRODUCTION

This document has been prepared at the request of the Committee on Employment and Social Affairs of the European Parliament.

Major areas of concern for the Committee include the evidence of persisting skills shortages in STEM fields in spite of high unemployment levels in many Member States. Against this background, policies and initiatives to improve matching supply of skills and qualifications with demand for labour are seen as a way to increase the competitiveness of European labour markets and to recover from the crisis.

A sufficient labour supply equipped with STEM skills is an essential precondition to implement the European Agenda for Growth and Jobs:

- According to the European Commission's Work programme 2015[1] the EU aims to promote the agenda, research and innovation in the energy field and to strengthen Europe's industrial base including support for job creation and employability measures. Areas in which STEM skills are of particular relevance are considered as strategic by the "Jobs, Growth and Investment Package"[2] (infrastructure, notably broadband and energy networks, as well as transport infrastructure, particularly in industrial centres; education, research and innovation; and renewable energy and energy efficiency).
- In its resolution on "How can the European Union contribute to creating a hospitable environment for enterprises, businesses and start-ups to create jobs?" of 15 April 2014[3] the European Parliament stresses that Member States should invest more in human capital, be more responsive to labour market needs, create variable transition schemes from education to the labour market and foster a partnership approach with a particular view to STEM subjects, retraining and further training of workers, particularly those with low or obsolete skills.

The note intends to provide an up-to-date overview of the labour market situation in STEM fields and to analyse national approaches to encourage STEM uptake in relation to these labour market needs. The aim is to identify practices or element of practices which help to increase the supply of skilled labour in different STEM fields.

For the purposes of this note, STEM fields include natural sciences (i.e. physics, biology or chemistry), mathematics, engineering, architecture and computing. Other fields such as medicine or social sciences are not included.

Desk research focusing on relevant data and studies was carried out in the field of the labour market and national policy initiatives to encourage the take-up of STEM studies. This desk research was accompanied by interviews carried out with representatives from CEDEFOP, European Schoolnet and Eurydice[4].

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1 http://ec.europa.eu/atwork/pdf/cwp_2015_en.pdf.

2 COM(2014) 903.

3 http://www.europarl.europa.eu/sides/getDoc.do?pubRef=//EP//TEXT+REPORT+A7-2014_0101+0+DOC+XML+V0//EN.

4 Marc Durando, EUN Executive Director, European Schoolnet, inGenious (03.03.2015); Teodora Parveva, Co-ordinator Education Policy Analysis, European Commission, Education, Audiovisual and Culture Executive Agency, Eurydice (05.03.2015); Steve Bainbridge, Expert, Area Research and Policy Analysis, CEDEFOP (05.03.2015).

2. LABOUR MARKET SITUATION IN STEM-RELATED JOBS

KEY FINDINGS

- Employment of STEM skilled labour in the European Union is increasing in spite of the economic crisis and demand is expected to grow. In parallel, high numbers of STEM workers are approaching retirement age. Around 7 million job openings are forecast until 2025 - two-thirds for replacing retiring workers.
- Employment prospects in STEM-related sectors differ. Demand is expected to rise in professional services and computing, whilst no employment growth is forecast in the pharmaceutical sector.
- Demand for STEM skills concerns both upper-secondary and university graduates. Currently almost half of the STEM occupations require medium-level qualifications and this trend is expected to persist.
- The share of STEM university graduates has increased in 15 Member States since the mid-2000s and at European level, whilst a decline in the share of STEM VET graduates is the predominant trend at the national level.
- Concerns about the supply of STEM skills rely on two basic facts: the proportion of students going into STEM is not increasing at the European level and the underrepresentation of women persists. So far, these trends have been mitigated by the expansion of higher education, which has led to an increase in the absolute numbers of STEM university graduates in the European Union since the mid-2000s. The number of STEM VET graduates has nevertheless decreased.
- A large majority of Member States have experienced recent recruitment difficulties in relation to STEM skilled labour. Shortages appear to be more pronounced for technological occupations (engineering and ICT) and professionals. Challenges arise from insufficient number of graduates and a lack of experienced staff.
- The unemployment rate for STEM skilled labour has been very low and well below the total unemployment rate since the beginning of the 2000s, even in countries particularly hit by the crisis, such as Greece, Portugal and Spain. This fact shows the high demand for workers with these skills.

2.1. Demand for STEM skills

Analysis by CEDEFOP[5] shows that employment of STEM professionals[6] and associate professionals[7] in the European Union (EU) has increased since 2000 in spite of the economic crisis and **demand is expected to grow until 2025**:

- Employment of STEM professionals and associate professionals in the EU was approximately 12 % higher in 2013 than it was in 2000.

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5 http://www.cedefop.europa.eu/en/publications-and-resources/statistics-and-indicators/statistics-and-graphs/rising- stems4.

6 STEM professionals are defined as ISCO-08 21 'Science and engineering professionals'.

7 STEM associate professionals are defined as ISCO-08 31 'Science and engineering associate professionals' and ISCO-08 35 'Information and communication technicians'.

- Demand for STEM professionals and associate professionals is expected to grow by 8 % between 2013 and 2025, whilst the average growth forecast for all occupations is 3 %.
- Employment forecast in STEM-related sectors shows a similar trend: it is estimated to rise by 6.5 % between 2013 and 2025, although with huge differences across sectors. Whilst zero employment growth is expected in the pharmaceuticals sector, employment is expected to rise by 8 % in computing and by 15 % in professional services.
- According to CEDEFOP's forecasting around two-thirds of the estimated job opportunities for STEM-related professions will replace retiring workers.

Employment in STEM is **male-dominated**. Women account for just 24 % of science and engineering professionals and 15 % of science and engineering associate professionals[8].

Current demand of STEM skills concerns both upper-secondary and tertiary graduates and this trend is expected to persist. Currently **48 % of STEM-related occupations require medium level qualifications** which are mostly acquired through initial upper-secondary level VET. This figure is forecasted to fall just to 46 % in 2025.

Professionals account for 40 % of current STEM jobs, whilst 60 % correspond to associate professionals. Table 1 shows the most salient employment trends and prospects for these occupations. **Employment is expected to increase especially for professionals** although **similar job opportunities for both occupations are foreseen** due to the need to replace retiring workers.

Table 1: Employment trends for STEM occupations

	STEM professionals	**STEM associate professionals**
Description	STEM professionals encompass a wide range of knowledge-intensive occupations including scientists (i.e. physicists, mathematicians and biologists), engineers and architects.	STEM associate professionals encompass technical occupations connected with research and operational methods in science and engineering, including technicians in physics, life science and engineering; supervisors and process control technicians in industry, ship and aircraft and ICT technicians.
Employment	There were 6.6 million workers in this occupation in the EU28 in 2013. They comprised 17 % of all professionals (ISCO-08 2) and 3 % of the total employment in the EU28.	There were 9.7 million workers in this group in the EU28 in 2013. They comprised 27 % of all associate professionals (ISCO-08 3) and almost 5 % of the total employment in the EU28.
Recent employment trends	Since 2008 employment in this occupation has slightly increased in EU28.	Since 2008 employment in this group has slightly declined in EU28. Demand has been highly volatile for some occupations.

[8] Burchell, B. Hardy, V., Rubery, J. and Smith, M. (2014): *A New Method to Understand Occupational Gender Segregation in European Labour Markets.* Publications Office of the European Union, Luxembourg.

	STEM professionals	STEM associate professionals
Qualification levels	More than 80 % hold high level qualifications. 16 % hold medium level qualifications and 3.5 % low level qualifications. This qualification mix has remained stable over the past decade.	The majority hold medium level qualifications (52 %). 37 % hold high level qualifications and 11 % low level qualifications. The share of workers with high level qualifications has increased over the past decade.
Estimated employment growth (2013-2025)	Over 1 million additional jobs are expected to be created from 2013 to 2025 in EU28. This means that by 2025, there will be 7.7 million STEM professionals. This is double the rate of increase for professional occupations. Employment is likely to rise in all EU28 countries but six: Belgium, Bulgaria, the Czech Republic, Cyprus, and especially Romania and the United Kingdom, where substantial job losses are expected.	Almost 0.25 million additional jobs are expected to be created from 2013 to 2025 in EU28. This entails that STEM associate professionals will experience a declining share of overall EU28 employment. The number of STEM associate professionals is forecast to increase in 13 out of 28 EU countries. The majority of new jobs are likely to be created in France, Spain and Italy. Germany, Bulgaria and Romania are expected to experience the most important decline in the overall number of jobs.
Estimated job openings (2013-2025)	Around 3.4 million job openings are forecast from 2013 to 2025. This includes not only the recruitments for new jobs (over 1 million), but also for replacing workers who will retire or leave for other reasons. Job openings are anticipated to increase in all EU28 countries[9]. Slovenia, Malta, Austria, Hungary, Finland and Luxembourg are the countries in which the share of STEM professionals in total jobs openings by country is expected to be highest - ranging from 9 % to 5 %. In absolute numbers, the majority of job openings are forecast in Germany (19 %), France (16 %), Italy (12 %) and Spain (8 %).	Although employment growth is likely to be relatively small, 3.6 million job openings are forecast from 2013 to 2025, due to the need to replace workers who will leave for retirement or other reasons. Job openings are likely to rise in all EU28 countries. Czech Republic, Denmark, France are expected to have the highest proportion of job openings for STEM associate professionals - ranging from 10 % to 5 %. In absolute numbers, the majority of job openings are forecast in Germany (20 %), France (17 %) and Italy (13 %).
Qualification prospects (2013-2025)	Employment is expected to rise for all qualification levels. An increased share of workers with medium level qualifications is anticipated.	The proportion of workers with high level qualifications is expected to continue to grow.

Source: EU Skills Panorama (2014a; 2014b); CEDEFOP Forecasts (2014).

[9] Data not available for Cyprus.

2.2. Supply of STEM skills

Recent EU data on university and VET graduates on STEM studies show a complex picture with relevant variation across countries.

At the EU level, **the share of STEM university graduates has remained basically stable** in relation to the total number of university graduates between 2006 and 2012: from 22.3 % to 22.8 % (see Figure 1). Yet this average masks **relevant variation across countries**. In the Netherlands and Luxembourg, the share of graduates in 2012 is below 15 % whilst it is higher than 27 % in Sweden, Finland, Greece and Germany. **The share of STEM graduates has increased in 15 countries**, although no clear pattern emerges. For instance, in Austria the share is well above EU average, but has experienced a marked decline (from 32.2 % to 25.6 %); on the contrary, this share has increased in Denmark although it is still below the EU average (from 18.1 % to 21.2 %). The only common and persisting trend is the **underrepresentation of women** among STEM university graduates: in 2012, graduates in STEM-related subjects account for 12.6 % of female graduates as compared with a share of 37.5 % among male graduates.

A **decline in the share of STEM VET graduates is the predominant trend at the national level**, with Lithuania, Bulgaria, Slovakia and Poland experiencing the sharpest decrease (see Figure 2). The EU average has slightly decreased from 32% in 2006 to 29.4% in 2011. Cyprus is the only country in which the proportion of VET graduates in STEM has substantially increased. The **share of STEM VET graduates also varies significantly across countries**. They account for more than 40% of upper-secondary VET graduates in Bulgaria, Estonia and Cyprus, compared to less than 20% in Belgium, Denmark and the Netherlands. VET studies tend to be male-dominated and the **proportion of women among STEM VET graduates is even lower** than for university graduates[10].

In the context of the expansion of higher education, **the number of STEM university graduates in EU28 increased by 37 %** from 2003 to 2012[11]. On the contrary, **the number of VET graduates in STEM-related subjects decreased by 11 % between 2006 and 2010, followed by a slight increase since then**[12]. According to CEDEFOP, the recent rise in absolute terms is probably due to more people staying on in education and training due to weak employment demand following the economic crisis[13].

According to BusinessEurope "the lack of STEM-skilled labour will be one of the main obstacles to economic growth in the coming years"[14]. Concerns about the supply of STEM skills rely on two basic facts: **the proportion of students going into STEM is not increasing at the European level and the underrepresentation of women persists**. So far, these trends have been mitigated by the expansion of higher education, leading to an increase in the number of STEM graduates. Most studies highlight that demographic patterns will lead to STEM shortages if these trends persist[15]: whilst high numbers of

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[10] Dobson, I. (2013): *STEM; Country Comparisons –Europe. A critical examination of existing solutions to the STEM skills shortage in comparable countries*. Australian Council of Learned Academies, Melbourne.

[11] EU Skills Panorama (2014a): Science and Engineering Professionals Analytical Highlight, prepared by ICF and CEDEFOP for the European Commission. Available at: http://euskillspanorama.cedefop.europa.eu/AnalyticalHighlights/, p. 2

[12] Data provided directly by CEDEFOP for preparing this note. EU averages are weighted averages of available country data (see Figure 3). STEM subjects include science, mathematics and computing, engineering and manufacturing but not architecture and building.

[13] Interview carried out with CEDEFOP representative.

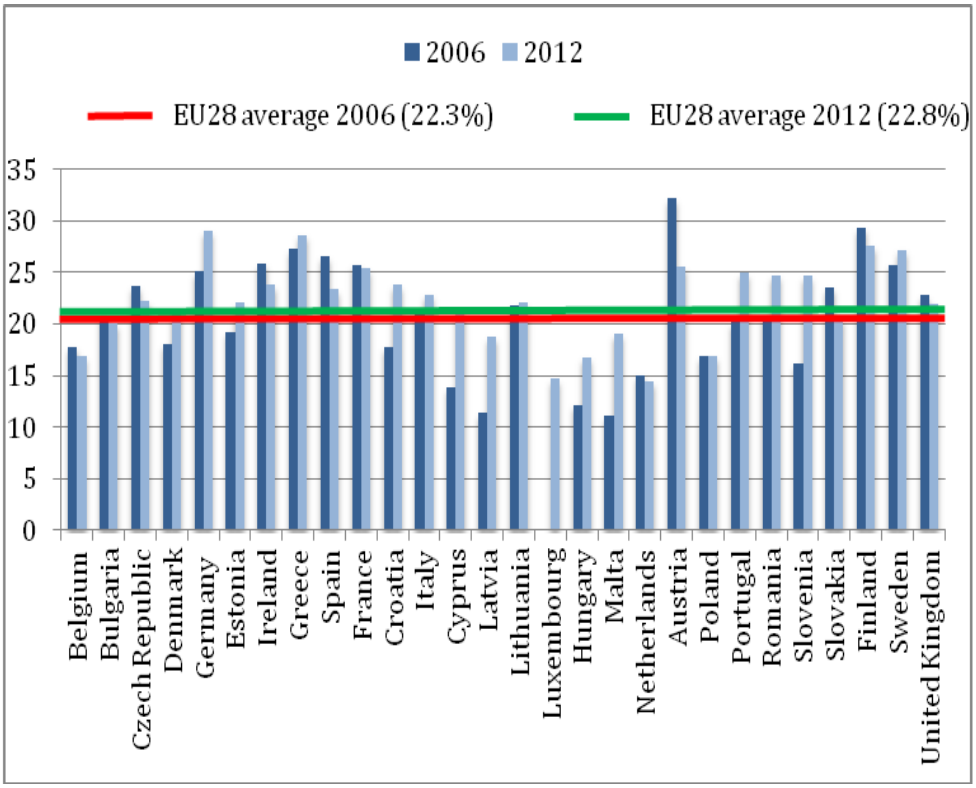
[14] Business Europe (2011): *Plugging the Skills Gap – The clock is ticking (science, technology and maths).* Business Europe, Brussels. Available at: http://www.businesseurope.eu/Content/Default.asp?pageid=568&docid=28659, p. 3.

[15] Dobson, I. (2013): *STEM; Country Comparisons –Europe. A critical examination of existing solutions to the STEM skills shortage in comparable countries*. Australian Council of Learned Academies, Melbourne.

current STEM skilled workers are approaching retirement, there will be relatively fewer young people to move through the education system towards labour markets.

Osborne and Dillon adopt however a more critical view and suggest that there is **insufficient evidence about the future STEM demand** to adopt policy initiatives to encourage young people to engage in STEM studies[16]. From a different point of view, Craig et al suggest "that the problem is not one of shortages. Instead, the problem is one of **location mismatch**. The three largest emerging economies (Brazil, India, China) already produce more STEM talent than three of the world's largest developed economies (US, UK, Japan) claiming a higher percentage every year"[17].

Figure 1: Share of university graduates in STEM-related subjects (%)

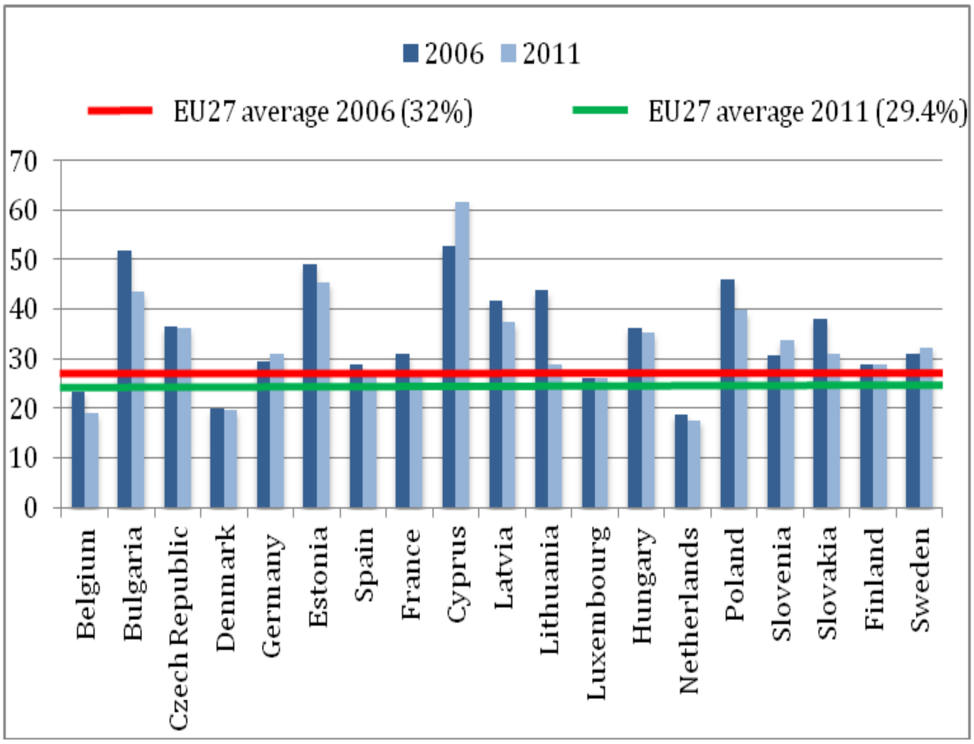


Source: Eurostat [educ_itertc] (Extracted 2.2.2015) Graduates (ISCED 5-6) in Maths, Science and Technology fields - as % of all fields. Data for Greece refers to 2005 instead of 2006; Data for France refers to 2011 instead of 2012.

[16] Osborne, J. and Dillon, J. (2008): *Science Education in Europe: Critical Reflections.* Nuffield Foundation, London. Available at: http://www.nuffieldfoundation.org/sites/default/files/Sci_Ed_in_Europe_Report_Final.pdf

[17] Craig, E., Thomas, R., Hou, C. and Mathur, S. (2011): *No Shortage of Talent: How the Global Market is Producing the STEM Skills Needed for Growth.* Accenture Institute for High Performance. Available at http://www.accenture.com/sitecollectiondocuments/accenture-no-shortage-of-talent.pdf, p. 2 and 5.

Figure 2: Share of VET graduates in STEM-related subjects (%)



Source: CEDEFOP[18]. EU averages are weighted averages of available country data. STEM subjects include science, mathematics and computing, engineering and manufacturing but not architecture and building.

2.3. STEM skill shortages

The European Commission report "Mapping and analysing bottleneck vacancies in EU labour markets" shows that **a large majority of EU28 countries have experienced recent recruitment difficulties in relation to STEM skills**[19]. As shown in Table 3, STEM-related occupations are among the 20 top bottleneck vacancies in EU28 - regardless the level of disaggregation used for analysing occupation's shortages[20].

[18] http://www.cedefop.europa.eu/en/publications-and-resources/statistics-and-indicators/statistics-and-graphs/rising- stems4

[19] European Commission (2014): *Mapping and analysing bottleneck vacancies in EU labour markets*. European Commission, Brussels.

[20] At ISCO 2-digit level, shortages are relevant for both professionals and associate professionals. At 4-digit level, important recruitment difficulties are only reported for professional occupations (mechanical and electrical engineers and ICT analysts and developers). However, this might be a result of a lack of good national disaggregated data: at 3-digit level, the physical and engineering science technicians figure on the 7th place in the rank of bottleneck vacancies.European Commission (2014): Mapping and analyzing bottleneck vacancies in EU labour markets, p. 89.

Table 2: STEM occupations among the top 20 bottleneck vacancies at European level

Vacancies at ISCO 2-digit level		Vacancies at ISCO 4-digit level	
Rank	**Occupation (ISCO-08 code)**	**Rank**	**Occupation (ISCO-08 code)**
2	Science and engineering professionals (21)	7	Mechanical engineers (2144)
3	Information and communications technology professionals (25)	8	Electrical engineers (2151)
7	Science and engineering associate professionals (31)	12	Systems analysts (2511)
		15	Software developers (2512)

Source: EC 2014.

Current shortages appear to be more pronounced for **technological fields (engineering and ITC).** They are also more widespread **for STEM professionals** than for associate professionals: out of 29 countries analysed, 21 report difficulties for science and engineering professionals, 20 for ICT professionals and 14 for science and engineering associate professionals[21]. This is consistent with recent employment trends in these occupations (since 2008, employment in the EU28 has increased for STEM professionals but decreased for associate professionals).

The main reason given for STEM labour shortages is a lack of applicants with the required qualifications (degrees and diplomas) and sufficient experience[22]:

- Challenges arise from **insufficient numbers of graduates** due to negative perceptions of STEM occupations, technological changes making "older" degrees out-dated and gender issues, because the image of most STEM occupations is not gender-neutral.
- Difficulties are also related to **a lack of experienced STEM staff**. This is especially relevant for ICT professionals (almost 50 % of bottlenecks) but also important for other STEM professionals.
- Employers are attempting to mitigate shortages in ICT more pro-actively than in other professional groups. This includes providing **additional training and development to existing staff** and **recruiting professionals in other EU countries and outside EU**[23]. Recruiting professionals in other countries is less widespread for science and engineering professionals. As stated by CEDEFOP, "one of the difficulties faced by employers is the level of specialist, high level expertise required for specific science and engineering roles - which can mean that the overall

[21] European Commission (2014): *Mapping and analysing bottleneck vacancies in EU labour markets*. European Commission, Brussels.

[22] (Ibid).

[23] European Commission (2014): *Mapping and analysing bottleneck vacancies in EU labour markets*. European Commission, Brussels.

supply of professionals with STEM skills is less important than the **local availability of the right specialist skills**"[24].

- Recruitment difficulties vary greatly depending on the **national context and STEM fields**. For instance, Bulgaria is currently experiencing bottlenecks for most professional occupations in science and engineering - stemming from a lack of graduates. Many specialists in these fields lost their job in the 1990s, due to structural change in economy; as a consequence, STEM studies become unpopular among young people and shortages appeared when demand turned to increase. In contrast, Ireland is the country with most bottlenecks in ICT professional occupations, but overcoming these shortages in the short term seems more feasible: the 2012 FIT ICT Skills Audit reports that short-term training programmes (6-24 months) could address many intermediate level vacancies[25].

National data show that **employers' difficulties to recruit STEM staff vary greatly according to STEM fields, level of education, sectors, expertise requirements, personal and behavioural attributes as well as STEM-related skills such as creativity, team working, communication and problem solving**. For instance in the UK, the CBI/Pearson 6th Annual Education and Skills Survey 2013 shows that 39 % of employers that need STEM skills reported difficulties recruiting staff, although recruitment difficulties were more marked for experienced STEM staff (22 % of employers) than for STEM graduates (12 %)[26]. Current and future recruitment challenges appear to be more prominent for employers in engineering, high-tech/IT and science sectors - this trend applies to both technicians and graduates. Overall, employers stressed the lack of appropriate attitude and aptitude for working life and the lack of work experience as the most prominent barriers to recruitment.

Concerns about current and future skill shortages are widespread among employers. BusinessEurope provides evidence of shortages in several EU Member states - Germany, Austria, UK, Belgium and Poland. This evidence suggests that STEM skills shortages were experienced before the recession and have to be considered a **structural problem**. The report also stressed that shortages in Europe are not only due to insufficient supply of home-grown talent, but also related to difficulties in **attracting talent from other parts of the world**[27].

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[24] EU Skills Panorama (2014a): Science and Engineering Professionals Analytical Highlight, prepared by ICF and CEDEFOP for the European Commission. Available at: http://euskillspanorama.cedefop.europa.eu/AnalyticalHighlights/, p. 2.

[25] European Commission (2014): *Mapping and analysing bottleneck vacancies in EU labour markets*. European Commission, Brussels, p. 63.

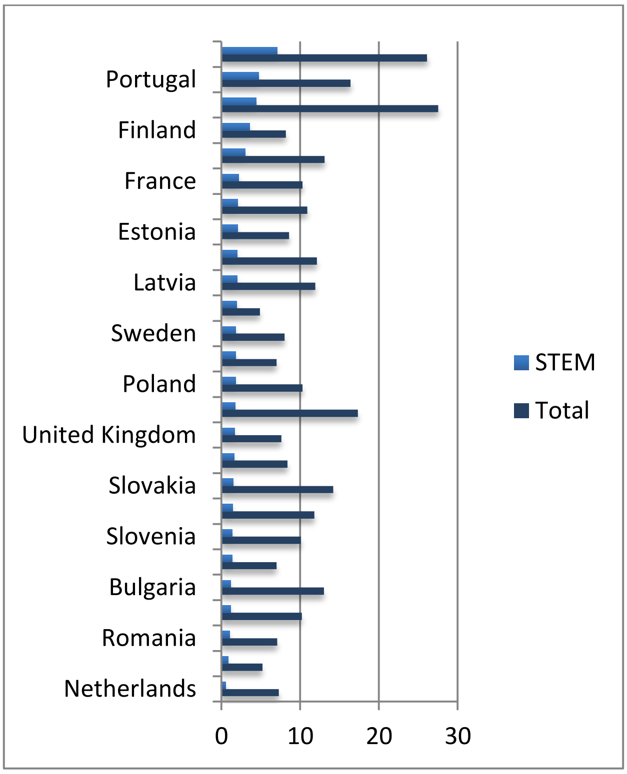
[26] CBI (2013): *Changing the pace - CBI/Pearson Education and skills survey 2013.* CBI (2013): *Changing the pace - CBI/Pearson Education and skills survey 2013.* CBI, London. Available at: http://www.cbi.org.uk/media/2119176/education_and_skills_survey_2013.pdf

[27] Business Europe (2011): *Plugging the Skills Gap – The clock is ticking (science, technology and maths).* Business Europe, Brussels. Available at: http://www.businesseurope.eu/Content/Default.asp?pageid=568&docid=28659

2.4. STEM unemployment

The unemployment rate for STEM skilled labour has been very low and well below the total unemployment rate since the beginning of the 2000s at the EU level[28]. **In 2013, the STEM unemploymet rate was as low as 2% for EU28**, whilst the total unemployment rate was 11% (see Figure 3). This fact shows the high demand for workers with STEM skills, with unemployment just reflecting workers moving or changing jobs. **This is also the predominant trend at the national level**. STEM unemployment rate was consistently low in all the countries, with **only those most affected by the economic crisis with rates above 4 %:** Greece, Portugal and Spain. Even in these countries, however, STEM unemployment is very low as compared to total unemployment.

Figure 3: STEM unemployment rate and total unemployment rate, 2013 (%)



Source: Own calculation on the basis of data provided by Eurostat to prepare this note and data from EU Skills Panorama. Data refer to ISCO-08 21 'Science and engineering professionals'; ISCO-08 31 'Science and engineering associate professionals' and ISCO-08 35 'Information and communication technicians'. Cyprus, Luxembourg and Malta not included due to low reliability of unemployment data.

According to Eurostat, there were around 400,000 STEM unemployed skilled workers in 2013 in the EU28[29]: 56% correspond to STEM associate professionals and 44% to STEM professionals. In those STEM professional occupations with most pronounced skill shortages, the number of unemployed workers was very low: there were around 60,000 mechanical, electric and other engineers and almost no ICT professionals.

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[28] Goos, M., Hathaway, I., Konings, J., and Vandeweyer, M., (2013): *High-Technology Employment in the European Union*, Discussion paper no 4 December 2013, Vives, Leuven. According to these authors, the STEM unemployment rate at the EU level has been lower than 4% in the 2000s. STEM occupation are selected on the basis of the old ISCO-88 at 2 digit level and include health care professionals. For this reason, this figure is not directly comparable to other figures provided in this note.

[29] Data provided by Eurostat to prepare this note. Data refer to ISCO-08 21 'Science and engineering professionals'; ISCO-08 25 'Information and communications technology professionals'; ISCO-08 31 'Science and engineering associate professionals' and ISCO-08 35 'Information and communication technicians'.

3. INITIATIVES TO ENCOURAGE STEM STUDIES AND CAREERS

KEY FINDINGS

- Different social, cultural, economic and educational institutional factors explain why STEM studies and careers are unattractive for young people. This combines with gender related issues to explain the persisting under-representation of women.
- There are three main policy approaches related to encouraging STEM studies and careers in Europe: a) curricular and teaching methods, b) teacher professional development and c) guiding young people to STEM.
- Most countries use a mix of these three policy approaches albeit to varying degrees in efforts to encourage a better take-up of STEM studies.
- Increased school-industry partnership is stressed as imperative in advancing all these three policy approaches – but is particularly important in career guidance initiatives.
- The majority of policies and initiatives being undertaken to encourage STEM take-up are carried out in the educational sphere. There are surprisingly few initiatives or research focusing on the labour market and industry settings.
- Despite the various policies, initiatives, programmes and projects developed in order to encourage STEM studies – it seemed as though little progress was made until the mid-2000s. Evaluations of recent trends however indicate more positive results.
- The lack of a common framework for the evaluations that are undertaken in this field hinders solid comparative research that examines the effects of different types of policy approaches, practices and initiatives.

3.1. Setting the problem

As the OECD notes, the relative share of STEM students among the overall student population started to decrease from the mid-1990s in Europe, US and other developed countries[30]. That mostly applies to tertiary education, but also to upper secondary education in many countries. The **decline of pupils' interest in STEM subjects is particularly noticeable at the secondary school level**[31].

Researchers have identified different social, cultural and economic factors to explain the shortages in young people's engagement with STEM subjects and careers. Factors related to different education systems have been also taken into consideration. Finally, attention has been paid to persisting gender differences in the choice of study field and the under-representation of women among STEM graduates.

[30] OECD (2008): *Encouraging Student Interest in Science and Technology Studies.* OECD, Paris. Available at: http://browse.oecdbookshop.org/oecd/pdfs/product/0308011e.pdf.

[31] Rohaan, E. Taconis R. and Jochems, W. (2010): "Reviewing the relations between teachers' knowledge and pupils' attitude in the field of primary technology education", *International Journal of Technology and Design Education*, no. 20, pp15–26. Available at: http://download.springer.com/static/pdf/775/art_%253A10.1007%252Fs10798-008-9055-7.pdf?auth66=1422967857_6bb18c45c8fe6896950c6c373d576798&ext=.pdf.

National differences in STEM uptake have not been consistently analysed, although appear to be related to differences in the economic structure and the educational policies[32]. From a worldwide perspective, it has been noted that **interest in STEM careers appear to decline with development and the attainment of higher standards of living**. This emerges as a common trend as economies mature[33].

Social factors

Social factors, for instance, are stressed within the project ASPIRES[34]. This project builds on the **concept of science capital** in order to understand how pupils' aspirations are shaped. Science capital relates to the level of interest, knowledge and understanding of science issues embedded in the pupil's immediate environment (family and friends). Accordingly, it is assumed that increasing science capital can make a pupil more disposed to learning STEM subjects after 16 years and to consider a STEM-related job in the future. Being a powerful heuristic category, the concept also implies that the most important factors that influence the pupils' aspirations lay outside the classroom. Therefore, increasing science capital is an important but also a complicated task that requires structural social changes.

Cultural factors

With regard to the cultural factors, the existence of a **changing attitude of society toward science and technology** has been pointed out. In this sense, Winckler and Fieder suggest the existence of a reaction against science and technology due to the increasing opaqueness of modern technologies and the rise of the environmentalist movement[35]. This trend is also related to the emergence of a more pessimistic vision that rejects the belief that 'the future should be better than the past' and 'that everything can and should be improved'.

Economic and working conditions factors

As far as economic factors are concerned, some authors have noted that fears about a shortage of STEM workers have **not been accompanied by wage increases** in professions such as engineering[36]. They also note the problems derived to the fact that in some technologically oriented companies, in which the environment should be favourable, training as an engineer or scientist is **far from being the best career track to a top position**, as it demonstrates the relatively low proportion of scientists as managers. STEM studies are said to report higher private returns on education (employment prospects and salaries of graduates) than many other study fields. However research suggests that to **explain study choices private returns should include a broader set of variables, namely the different cost of study to students in terms of time**, either in terms of study hours or years in education, both with a strong negative impact on the opportunity cost of STEM university education in the short- to medium-term[37].

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32 Dobson, I. (2013): *STEM; Country Comparisons –Europe. A critical examination of existing solutions to the STEM skills shortage in comparable countries*. Australian Council of Learned Academies, Melbourne.

33 McNeely and Hahm. Available at: http://www.globality-gmu.net/archives/2972

34 http://www.kcl.ac.uk/sspp/departments/education/research/aspires/ASPIRES-final-report-December-2013.pdf

35 Winckler, G. and Fieder, M., (2006): "Declining demand among students for science and engineering?" In: L.E. Weber and J.J. Duderstadt, eds. *Universities and business: Partnering for the knowledge society*. Economica, London.

36 Becker, F.B. (2010): "Why don't young people want to become engineers? Rational reasons for disappointing decisions", *European Journal of Engineering Education,* Vol. 35, No. 4, August 2010, pp. 349–366. Available at: http://www.sefi.be/wp-content/uploads/Becker %20EJEE %20Why %20dont %20young %20people %20August-2010.pdf.

37 Beblavý, M., Lehouelleur, S. and Maselli, I. (2013): "Useless degrees or useless statistics? A comparison of the net present value of Higher Education by field of study in five European countries" *Neujobs Working Paper* No. D4.4 / July 2013. Available at: http://www.neujobs.eu/sites/default/files/4.4.2_a.pdf.

Educative institutional factors

It has been also noted that the **way in which science subjects are taught** has a great influence on students' attitudes towards science and on their motivation to study and, consequently, their achievement. For example, an **inquiry-based approach to learning centred on project work** has been linked to greater motivation[38]. There is also a debate on the question of whether science teaching should be organised in distinct subject areas or as a single, **integrated programme** during later school years. Researchers in favour of integrated science teaching argue that it motivates both teachers and students[39]. Besides, other research studies state that integrated systems tend to be more favourable to gender and social equality[40]. On the contrary, critiques of integrated science teaching centres stress the lack of empirical evidence of its positive impact on student motivation and achievement, highlighting also the difficulties to isolate the effects of integrated teaching from other variables that affect student learning[41].

Gender-related factors

Persisting gender segregation across study fields is the result of a **mix of social, cultural, economic and educational institutional factors**[42]**.** The literature highlights the role of gender socialization of boys and girls to explain their uneven distribution across study fields. **Family and especially parents play a key role** as they often bring up their children to conform to traditional gender roles, while the education system, teachers and peers, tend to reinforce these stereotypes, giving support to gendered choices with regard to studies and career prospects[43]. Research links segregation across scientific fields at the university level to segregation downstream across choice of study fields at the secondary school level. This **early segregation hinders girls' and women's later study and career opportunities**.

3.2. Initiatives to encourage STEM: scope and policy focus

Since the 1970s there has been a wide-range of initiatives to make STEM studies and professions more attractive to young people. Long-term concerns around ensuring that Europe is able to provide sufficient labour supply with STEM skills have led to policy focus on three broad areas: developing **basic competences** (reading, mathematics, and science)[44], increasing the **uptake of STEM studies** and improving **career guidance** to ensure a smooth transition into the labour market.

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[38] Beres, P. (2011): "Project- Based Learning and its Effect on Motivation In the Adolescent Mathematics Classroom" Education and Human Development Unpublished Master's Theses. The College at Brockport, Paper 39.

[39] St. Clair, B., and Hough, D.L., (1992): *Interdisciplinary teaching: a review of the literature*. ERIC Document. Reproduction Service No. 373 056. Jefferson City, MO. Available at: http://files.eric.ed.gov/fulltext/ED373056.pdf.

[40] Van Langen, A. Bosker, R. and Dekkers, H. (2006): "Exploring cross-national differences in gender gaps in education", *Educational Research and Evaluation,* vol. 12, no.4, pp.155-177.

[41] Eurydice (2011): *Science Education in Europe: National Policies, Practices and Research*. Education, Audiovisual and Culture Executive Agency, Brussels. Available at: http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/133en.pdf.

[42] Caprile, M., Addis, E., Castaño, C., Klinge, I., Larios, M., Meulders, D., Muller, Sagebiel, F., Schiebinger, L., Valles, N., Vazquez-Cupeiro, S., Larios, M., Meulders, D., Muller, J., O'Dorchai, S., Palasik, M., Plasman, R., and Roivas, S. (2012): *Meta-Analysis of Gender and Science Research*. Office for Official Publications of the European Communities, Luxembourg. Available at:https://ec.europa.eu/research/science-society/document_library/pdf_06/meta-analysis-of-gender-and-science-research-synthesis-report.pdf.

[43] Sáinz, M., Palmén, R., and Garcia, S. (2012): "Parental and Secondary School Teachers' Perceptions of ICT and their Role in the Choice of Studies". *Sex Roles*. Vol. 66, no. 3-4, pp235-249.

[44] Strategic Framework for European Cooperation in Education ('ET2020'), Council Conclusions, May 2008: In 2009 and EU-wide benchmark in basic skills was adopted in response to concerns about low student performance demonstrated by international surveys. This benchmark stated that the percentage of 15 year olds with 'insufficient abilities in reading, mathematics and science should be less than 15 %'.

Initiatives include awareness raising campaigns, career guidance, gender equality and gender concepts, incentives to attract young people, the design of study and training courses in order to facilitate the transition into jobs (including the labour market integration of unemployed), partnership approaches particularly with social partners and companies to link to labour market needs.

Initiatives have been designed, implemented and funded by a wide range of bodies including the European Commission, Member States, public authorities, professional associations and networks of interested stakeholders.

How different types of initiatives and programmes are implemented varies between Member States. **Some countries have adopted national strategies whilst others favour the setting up of dedicated national/ regional or local centres** to improve the quality of STEM teaching[45]. Kearney notes that most countries have a global approach to deal with STEM issues at national level[46]. National strategies tend to specify objectives within a given timeframe and cover a wide range of areas of science and science education[47]. Germany, the Netherlands and Norway have additionally placed a real focus on attracting girls and women to science[48].

Several European initiatives attempt to chart the practices pursued in Member States and provide a platform to facilitate knowledge exchange[49].

3.3. Relevant policy approaches to encourage STEM

There are three main policy approaches that frame initiatives that aim to encourage young people to STEM studies and professions. Kearney[50] identifies two of these main approaches in the education sphere and a third concentrating on the transition to the labour market:

- Developing effective and attractive STEM curricular and teaching methods
- Improving teacher education and professional development
- Guiding young people towards STEM careers.

This latter approach includes initiatives that tackle the social perception of science and STEM professions, high quality career guidance and labour market information - mostly developed through collaboration between different stakeholders, and promoting partnership between school and employers.

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45 Member States which have adopted a national strategy are Austria, Germany, France, Italy, the Netherlands, Norway, UK, Italy, Ireland, Spain. See Eurydice (2011): *Science Education in Europe: National Policies, Practices and Research*. Education, Audiovisual and Culture Executive Agency, Brussels. Available at: http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/133en.pdf, p. 26.

46 Kearney, C. (2011): *Efforts to Increase Students' Interests in Pursuing Science, Technology, Engineering and Mathematics Studies and Careers: National Measures Taken by 21 of European Schoolnet's Member Countries'*. European Schoolnet, Brussels. Available at: http://www.fisme.science.uu.nl/publicaties/literatuur/2011_european_schoolnet.pdf.

47 Eurydice (2011): *Science Education in Europe: National Policies, Practices and Research*. Education, Audiovisual and Culture Executive Agency, Brussels. Available at: http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/133en.pdf

48 Eurydice (2011): *Science Education in Europe: National Policies, Practices and Research*. Education, Audiovisual and Culture Executive Agency, Brussels. Available at: http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/133en.pdf, p. 27.

49 See Scientix, inGenious, STELLA.

50 Kearney, C. (2011): *Efforts to Increase Students' Interests in Pursuing Science, Technology, Engineering and Mathematics Studies and Careers: National Measures Taken by 21 of European Schoolnet's Member Countries'*. European Schoolnet, Brussels. Available at: http://www.fisme.science.uu.nl/publicaties/literatuur/2011_european_schoolnet.pdf.

3.3.1. STEM curricular and teaching methods

Curricula for STEM vary between Member States and can refer to different elements of the learning process. Dobson notes that curricular methods "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"[51]. The Eurydice report highlights how science curricular reforms at the school level have been subjected to much **debate and reform** in many Member States[52]. The main motivation for these reforms has been the desire to adopt the European key competences approach[53].

Reforms of the curricula in the field of science have been more and more linked to **'inquiry-based' science education.** The Rocard Report – commissioned by the EU - highlighted inquiry-based science education as providing a possible solution to a lack of interest in science[54]. It described inquiry based science education as an approach which emphasises "observation, experimentation and the teacher guided construction by the child of his/ or her own knowledge"[55]. Kearney identifies that an inquiry-based learning approach can be specifically seen in the initiatives and reforms undertaken in six Member States[56]. A complementary way of making science more attractive involves the push for **greater contextualization** in science education[57]. This approach attempts to embed science education within current social issues. For example concerns about the environment and demonstrating how scientific advances are applied to everyday life – have become important recommendations for science education in almost all European countries[58].

At the **European level** there have been various projects developed in the push for an inquiry-based approach to education in order to attract more students to STEM (such as **INQUIRE**, **Mind the Gap** and **PRIMAS** projects). **Scientix** is a major player in this field. It is funded by the European Commission's 7th Framework Programme for Research and coordinated by European Schoolnet (a non-profit established by ministries of education). It was created to facilitate sharing of know-how and best practices in inquiry based science across the European Union through its web-platform. These projects have been complemented by approaches which seek to develop more innovative pedagogical practices in an attempt to attract, retain and further stimulate interest in STEM subjects (for example the **SPICE** project).

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[51] Dobson, I. (2013): *STEM; Country Comparisons –Europe. A critical examination of existing solutions to the STEM skills shortage in comparable countries*. Australian Council of Learned Academies, Melbourne, p. 9.

[52] Eurydice (2006): *Science Teaching in Schools in Europe, Policies and Research*. Directorate-General for Education and Culture, Brussels. Available at: http://www.indire.it/lucabas/lkmw_file/eurydice///Science_teaching_EN.pdf.

[53] Eurydice (2011): *Science Education in Europe: National Policies, Practices and Research*. Education, Audiovisual and Culture Executive Agency, Brussels. Available at: http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/133en.pdf, p. 3.

[54] Dobson, I. (2013): *STEM; Country Comparisons –Europe. A critical examination of existing solutions to the STEM skills shortage in comparable countries*. Australian Council of Learned Academies, Melbourne.

[55] European Commission (2007): *Science Education Now: A Renewed Pedagogy for the Future*. European Commission, Brussels. Available at: http://ec.europa.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf, p. 9.

[56] Estonia, France, Ireland, Norway, Portugal, and the Slovak Republic. Finland has integrated inquiry-based learning throughout all curricular subjects including STEM since 2004. See Kearney, C. (2011) *Efforts to Increase Students' Interests in Pursuing Science, Technology, Engineering and Mathematics Studies and Careers: National Measures Taken by 21 of European Schoolnet's Member Countries'*. European Schoolnet, Brussels.p22.

[57] Eurydice (2011): *Science Education in Europe: National Policies, Practices and Research*. Education, Audiovisual and Culture Executive Agency, Brussels. Available at: http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/133en.pdf, p. 64.

[58] Eurydice (2011): *Science Education in Europe: National Policies, Practices and Research*. Education, Audiovisual and Culture Executive Agency, Brussels. Available at: http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/133en.pdf, p. 9.

3.3.2. education and professional development

Improving teacher education and professional development is pursued through various means in Member States:

- Those countries which have a strategic framework in place to promote science education often include a key objective specifically related to improving teacher education[59].
- In several countries science centres deliver formal CPD (Continuous Professional Development) activities for teachers. In the majority of countries CPD for in-service science teachers is included formally in official training programmes[60].
- National initiatives, however, that target initial education of science teachers are much less common[61].

Beyond the realm of official CPD activities, a Eurydice report highlights that science promotion activities carried out by **partnerships – industry or research bodies** can provide strong support for teacher professional development through either increased exposure to applied research or the provision of extra resources[62].

A range of initiatives have been developed to improve teacher education and professional development at the **European Level**. An innovative project funded by the European Commission's lifelong learning programme provides a database of 'good practices' throughout Europe. The project **STELLA** (Science Teaching in a Lifelong Learning Approach), "supports educational authorities, school-heads and science teachers in fostering and adopting innovative practices within the field of science education at Pre-Primary, Primary, Lower Secondary and Higher Secondary school levels". Its main aim is to encourage a better science teaching throughout schools in Europe by principally encouraging young people, particularly females to pursue science studies and professions. The **GRID** (Growing Interest in the Development of Teaching Science) project is funded within the framework of the EU Socrates Programme. Its' objective is to create a network for the exchange of good practice in the field of science teaching within Europe and has identified and made accessible more than 500 science education initiatives through its' online database.

3.3.3. Guiding young people towards STEM careers

There have also been initiatives developed to tackle issues that transcend the education institutional level and are more related to **stereotypes and the negative perceptions of science / STEM careers** that function at the socio-cultural level[63]. Several EU funded projects challenge the negative perception of science. For example the **MOTIVATION** project aimed to facilitate a cross-country exchange about the range of factors that

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[59] Austria, France, UK (Scotland). [59] Eurydice (2011): *Science Education in Europe: National Policies, Practices and Research*. Education, Audiovisual and Culture Executive Agency, Brussels. Available at: http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/133en.pdf, p. 110.

[60] France, Ireland, Lithuania, Norway, Poland, Slovenia, Spain, Sweden and the UK. See [60] Eurydice (2011): *Science Education in Europe: National Policies, Practices and Research*. Education, Audiovisual and Culture Executive Agency, Brussels. Available at: http://eacea.ec.europa.eu/education/eurydice /documents/thematic_reports/133en.pdf, p. 110.

[61] See the Danish initiative in Table 3 for an example of this type of initiative.

[62] Examples of this approach include the French programme 'La main à la pate' or the Spanish El CSIC – Consejo Superior de InvestigacionesCientíficas – en la Escuela (The High Council for Scientific Research in Schools). See http://www.csic.es/web/guest/el-csic-en-la-escuelafor the latter. [62] Eurydice (2011): *Science Education in Europe: National Policies, Practices and Research*. Education, Audiovisual and Culture Executive Agency, Brussels. Available at: http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/133en.pdf, p. 110.

[63] Dobson, I. (2013): *STEM; Country Comparisons –Europe. A critical examination of existing solutions to the STEM skills shortage in comparable countries*. Australian Council of Learned Academies, Melbourne, p. 19.

influence images of science. Another innovative project, **YOSCIWEB**, promoted a positive image of science through various websites. These types of projects are common in the field of gender equality where a great deal of research has been carried out confirming the effects of negative stereotypes linked to science in relation to girls' subject choices[64]. It is exactly this problem that the European Commission's 'Science: It's a Girl Thing' attempts to address.

Initiatives to guide students towards STEM careers increasingly aim to develop **effective cooperation with employers**:

- BusinessEurope stresses that companies and employers' organisations should play a more prominent role in this field. This includes providing a **context for science studies** by being more involved in education at all levels and to provide **positive role models** from STEM skilled occupations from the business world – in order to challenge negative or misleading perceptions of STEM careers[65].
- Many **school and business partnerships** are being forged to encourage interest in STEM careers at primary, secondary and upper secondary school levels, as well as at the university level - i.e Jet-Net (the Netherlands), Wissensfabrik (Germany), C.Génial (France), Science Team K (Denmark), Næringsliviskolen (Norway) and MATENA (Sweden)[66]. In both Germany and Norway partnerships have been developed in this field to focus specifically on girls to encourage their involvement in science education activities and pursue science as a career[67]. **InGenious**, the European coordinating body in STEM education, acts as an umbrella and coordination centre for these initiatives. InGenious is a joint initiative launched by European Schoolnet and the European Roundtable of Industrialists (ERT). It aims "to reinforce young European's interest in science education and careers and this addresses anticipated future skills gaps within the European Union".
- Building **links between pupils and teachers in schools and STEM professionals in the workplace** is key to guiding students towards STEM. Greater links between the place of learning and world of work can be encouraged by visits from STEM professionals and university students to the place of learning or by teachers and students to the place of work[68].
- Recent education reforms have also been taken to fortify links between education and training and the labour market through "**involving companies and social partners in curricula development in VET**" in numerous countries in order to

[64] Eccles, J. (1994): "Understanding Women's Educational and Occupational Choices", *Psychology of Women Quarterly*, vol 18, no. 4, pp 585-609. Available at: http://pwq.sagepub.com/content/18/4/585.short?rss=1&ssource=mfc

[65] Business Europe (2011): *Plugging the Skills Gap – The clock is ticking (science, technology and maths).* Business Europe, Brussels. Available at: http://www.businesseurope.eu/Content/Default.asp?pageid=568&docid=28659

[66] ERT (2009): *Mathematics, Science & Technology Education Report. The case for a European Coordinating Body*. Available at: http://www.ert.eu/sites/default/files/MST_%20Report_%20FINAL.pdf. Kearney, C. (2011): *Efforts to Increase Students' Interests in Pursuing Science, Technology, Engineering and Mathematics Studies and Careers: National Measures Taken by 21 of European Schoolnet's Member Countries'*. European Schoolnet, Brussels. Available at: http://www.fisme.science.uu.nl/publicaties/literatuur/2011_european_schoolnet.pdf

[67] Eurydice (2011): *Science Education in Europe: National Policies, Practices and Research*. Education, Audiovisual and Culture Executive Agency, Brussels. Available at: http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/133en.pdf, p. 39.

[68] Kearney, C. (2011): *Efforts to Increase Students' Interests in Pursuing Science, Technology, Engineering and Mathematics Studies and Careers: National Measures Taken by 21 of European Schoolnet's Member Countries'*. European Schoolnet, Brussels. Available at: http://www.fisme.science.uu.nl/publicaties/literatuur/2011_european_schoolnet.pdf

ensure that provision keeps pace with the changing needs of the economy[69].

- In some cases **employers in sectors with skills shortages** are actively developing **marketing campaigns and initiatives to attract young people** to the relevant educational paths. For example these kind of initiatives have been developed by employers in the mining and IT industries in Sweden[70].

Some initiatives also address **career guidance and labour market information**. The focus is placed on counteracting prejudices about STEM careers and providing good quality information so that young people are able to make **well-informed decisions - free from bias**. "High quality career guidance, based on accurate labour market information about the careers available to people with STEM qualifications and skills, is important if all young people – especially those with no immediate family with STEM qualifications – are to keep open the option of following STEM careers"[71]:

- Career guidance policies are particularly important **at transition points** from one level of education to another, including continuous vocational training and adult education[72]. Improving **vocational orientation** is a relevant issue because paths that lead to STEM careers through vocational education and apprenticeship are not well-known by young people and their families[73]. High quality career guidance and good labour market information are a pre-condition for effective active labour market policies addressed to training / upskilling young people in STEM related fields where shortages are foreseen.
- There are also recent initiatives to develop **skills forecasting and monitoring systems** – in order to address skills mismatches. These types of initiatives have been developed in Ireland, Latvia, Poland and Portugal[74].

Active labour market policies can also have an impact in this area. For instance, nine Member States have recently launched measures "to provide more opportunities to **upgrade young people's skills** in particular, in relation to sectors with labour market potential or shortages"[75]. These initiatives tend to target the unemployed and early leavers from education and training into short-term training courses. In both Portugal and Belgium (Flanders) career guidance initiatives have been developed to target specific STEM areas to respond to local professional needs or shortages[76].

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[69] Belgium, Estonia, Ireland, Lithuania, Latvia. See European Commission/EACEA/Eurydice, (2013): *Education and Training in Europe 2020: Responses from the EU Member States.* Eurydice Report. Brussels: Eurydice. Available at: http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/163EN.pdf, p. 52

[70] European Commission (2014): *Mapping and analysing bottleneck vacancies in EU labour markets*. European Commission, Brussels, p. 93.

[71] Holman, J. and Finegold, P. (2010): *STEM careers review. Report to the Gatsby Charitable Foundation.* The Gatsby foundation, London. Available at: http://www.nationalstemcentre.org.uk/res/documents/page/STEM%20CAREERS %20REVIEW %20NOV %202010.pdf, p. 5.

[72] OECD (2010): Learning for jobs. OECD, Paris.

[73] Holman, J. and Finegold, P. (2010): *STEM careers review. Report to the Gatsby Charitable Foundation.* The Gatsby foundation, London. Available at: http://www.nationalstemcentre.org.uk/res/documents/page/STEM%20CAREERS %20REVIEW %20NOV %202010.pdf, p. 5.

[74] European Commission/EACEA/Eurydice, (2013): *Education and Training in Europe 2020: Responses from the EU Member States.* Eurydice Report. Brussels: Eurydice. Available at: http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/163EN.pdf, p. 55.

[75] Belgium (Fr), Ireland, Finland, France, Greece, Slovenia, Spain, Malta, UK (Eng). European Commission/EACEA/Eurydice, (2013): *Education and Training in Europe 2020: Responses from the EU Member States.* Eurydice Report. Brussels: Eurydice. Available at: http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/163EN.pdf, p. 55.

[76] See Table 3.

3.4. Selected practices to encourage STEM

The impact of policies and initiatives encouraging STEM uptake were described as "still modest" in 2007 by the European Commission despite the efforts undertaken by Member States and at the European level[77].

Research on initiatives and measures provides a **more positive assessment of recent trends**. It shows that "**it is possible to turn the tide to a certain extent and increase the STEM outflow, including among girls**" although "it is arduous work that requires sustained efforts"[78]. National strategies in this field that have been formally evaluated were considered as "fairly, or even very successful"[79] although the impact on increasing STEM uptake had not yet been demonstrated. Evaluation also showed that 'streamlining' individual initiatives and making them more consistent was of great importance. A more coordinated approach was seen as necessary at national, regional and local levels[80].

Recent data about university graduates in STEM gives an indication of progress made, with 15 Member States showing a rise in the share of university graduates in STEM related subjects from 2006 to 2012[81]. Some of these countries have been quite active in the field, for example Denmark, Germany and Portugal have developed a wide range of initiatives under the umbrella of either a National Strategy or a National Centre. Portugal set up the National Agency for Science and Technology Centre (Ciência Viva) in 1996[82], Germany has had a national strategy in place since 2006[83], and Denmark set up a Centre for Science, Technology and Health more recently in 2009[84].

Table 3 identifies practices that may help to increase the supply of skilled labour in STEM fields. European coordination and EU funded research has provided a collection of good practices identified by expert assessment[85] due to their promising approach or proved impact on encouraging STEM studies. They have been selected to demonstrate the variety of initiatives carried out in the three policy areas and at different stages of the life-course. The table also includes a good practice in the field of the active labour market policies.

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[77] European Commission (2007): *Science Education Now: A Renewed Pedagogy for the Future*. European Commission, Brussels. Available at: http://ec.europa.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf, p. 5.

[78] Van den Bergue, D. and De Martelaere, D. (2012): *Choosing STEM. Young people's educational choice for technical and scientific studies*. The Flemish Council for Science and Innovation, Brussels. p. 154.

[79] Eurydice (2011): *Science Education in Europe: National Policies, Practices and Research*. Education, Audiovisual and Culture Executive Agency, Brussels. Available at: http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/133en.pdf, p. 30.

[80] Ibid.

[81] See Figure 1.

[82] Van den Bergue, D. and De Martelaere, D. (2012): *Choosing STEM. Young people's educational choice for technical and scientific studies*. The Flemish Council for Science and Innovation, Brussels. p. 150.

[83] Dobson, I. (2013): *STEM; Country Comparisons –Europe. A critical examination of existing solutions to the STEM skills shortage in comparable countries*. Australian Council of Learned Academies, Melbourne. p. 59.

[84] Dobson, I. (2013): *STEM; Country Comparisons –Europe. A critical examination of existing solutions to the STEM skills shortage in comparable countries*. Australian Council of Learned Academies, Melbourne. p. 34.

[85] These good practices have been identified in various reports. See the table for details.

Table 3: Selected practices to encourage STEM

Developing effective and attractive STEM curricular and teaching methods	
Lithuania	The Education Development Centre in Lithuania implemented the following project: 'Providing Wider Possibilities for Students aged 14-19 to Choose a Learning Pathway'. It involved: **tailoring the curricula to individuals**; increasing the range of students' career options; designing the curricular to better match the demands of the labour market; making it more attractive; whilst developing students' professional competences. This approach aimed to broaden student's learning pathway[86].
Portugal	In 2014 New Technology-focused Higher Education short courses were established by the Ministry of Higher Education in order to **amplify the range of options** offered by polytechnics. These are level-five higher education courses that have strong links to the labour market, specifically in terms of the local and regional economy. The target group for these courses are graduates from upper-secondary vocational education and adults[87].
Finland*	The LUMA policy plan was launched by the Finnish government in 1996. It focused on improving STEM education and on increasing the number of STEM students. The LUMA programme took a **holistic approach to improving science education engaging all the major stakeholders** including the Ministry for Education, local government, (responsible for education in Finland), schools, higher education and the business community etc. The programmes objectives included: • To increase the number of STEM inflows and graduates in higher education • To increase the number of pupils who study advanced mathematics, physics and chemistry • To increase the share of girls in STEM study options • To increase the mathematical and scientific knowledge of pupils in vocational education Evaluation of the LUMA programme noted how despite the fact that not all of the objectives had been reached, the trend in most areas was positive. Most remarkably it noted how **the increase in the number of STEM students in higher education actually exceeded expectations**. It also recognised that the share of girls that chose STEM increased, even though it remained low (as elsewhere in Europe)[88].

86 Kearney, C. (2011): *Efforts to Increase Students' Interests in Pursuing Science, Technology, Engineering and Mathematics Studies and Careers: National Measures Taken by 21 of European Schoolnet's Member Countries'*. European Schoolnet, Brussels. Available at: http://www.fisme.science.uu.nl/publicaties/literatuur/2011_european_schoolnet.pdf, p. 19.

87 European Commission/EACEA/Eurydice, (2013): *Education and Training in Europe 2020: Responses from the EU Member States.* Eurydice Report. Brussels: Eurydice. Available at: http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/163EN.pdf, p. 91.

88 Van den Bergue, D. and De Martelaere, D. (2012): *Choosing STEM. Young people's educational choice for technical and scientific studies*. The Flemish Council for Science and Innovation, Brussels, p. 144.

Improved teacher and professional development	
Denmark	The continuing education of teachers in public schools was the target of the Danish Government. The objective of the initiatives was **to provide teachers with a specialisation in science or mathematics** – although other specialisations could be also followed. During the three year implementation period, more than 800 teachers gained a science subject specialisation. 430 teachers also finished courses which qualified them to be science guidance counsellors[89].
Ireland*	The Discover Science and Engineering (DSE) programme started in 2003. Its main objective was to **increase interest in STEM among young people, teachers and the general public**. The programme is run by Science Foundation Ireland and is led by a steering group comprised of major stakeholders. DSE has various thematic areas such as "My Science Career", "Discover Primary Science", "Greenwave", "Discover Sensors"etc. The Discover Primary Science sub-Prgramme (www.primaryscience.ie) is mainly comprised of additional training for primary school teachers. This element of the programme coordinates 27 Discover Science Centres throughout the country, intended for school and family visits. More than 4,000 teachers and 3,000 primary schools are already involved in the programme. Awards of Science excellence are bestowed to schools every year. The programmes' evaluation highlighted that: **The most measurable impact occurred in raising the level of student uptake in physical sciences at second and third level.** This is where DSE was most active[90].
UK (Eng)	England rolled out **The Transition to Teaching Programme** which was targeted at those wanting to change career to teach at the secondary school level in mathematics, science or information and communication technology (ICT). It's target group was those with STEM qualifications at the degree level who could also provide a recommendation by an employer. Enhancement courses were also offered their main aim being to enable graduates, wanting to teach physics, maths or chemistry- to develop sufficient subject knowledge to teach secondary level pupils[91].
Guiding young people towards STEM careers	
France	In July 2013 France passed laws to restructure schools and to regulate the field of higher education and research. One of the measures included in the laws aims specifically to **encourage and facilitate access to short cycles of higher education for those VET students** who graduate with honours[92].

89 Eurydice (2011): *Science Education in Europe: National Policies, Practices and Research*. Education, Audiovisual and Culture Executive Agency, Brussels. Available at: http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/133en.pdf, p. 122

90 Van den Bergue, D. and De Martelaere, D. (2012): *Choosing STEM. Young people's educational choice for technical and scientific studies*. The Flemish Council for Science and Innovation, Brussels, p. 145.

91 Eurydice (2011): *Science Education in Europe: National Policies, Practices and Research*. Education, Audiovisual and Culture Executive Agency, Brussels. Available at: http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/133en.pdf, p. 122

92 European Commission/EACEA/Eurydice, (2013): *Education and Training in Europe 2020: Responses from the EU Member States.* Eurydice Report. Brussels: Eurydice. Available at: http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/163EN.pdf, p. 89

Germany	**Long-term strategic partnership between science and business** is the main aim of an initiative developed by the Federal Ministry of Education and Research. They have recently launched two initiatives to further this aim: "Leading-Edge Cluster Competition" and "Public- Private Partnership to foster Innovation". Important components of these initiatives include: collaborative research and development; developing innovative academic training and degree programmes[93].
Belgium (Flemish)	The "World at your feet" project is aimed at stimulating **16-18 year old students to choose scientific or technical studies at the university level**. It specifically targets female students encouraging them to take-up careers in civil engineering. This responds to an identified lack of qualified engineers in the regional labour market. This project attempts to make students aware of the job content by encouraging students to take-part in web-quests whilst facilitating contact with professional engineers[94].
Portugal	'Hybrid' doctoral programmes and the establishment of national and international consortia of businesses, research units and universities are supported through the Programme for Applied Research and Technology Transfer. This programme is particularly innovative in terms of **allocating PhD scholarships to priority fields** whilst also providing **private companies with tax incentives to recruit PhD holders in science and technology**[95]**.**
Netherlands*	The government, education and business sectors have commissioned the BètaTechniek platform to ensure sufficient availability of people who have a background in scientific or technical education. The main objective is "to ensure that the future supply of knowledge workers will meet future demand, and that talented professionals already in the job market are more effectively deployed." They have **reached the target of a 15 % structural increase in scientific and technical education**. It takes a holistic approach to the problem by making scientific careers more attractive to young people whilst also developing innovations in the field of education in order to engage young people. It therefore targets industry, schools, universities, policymakers, and specific regional and economic sectors. Girls/women and ethnic minorities are specifically targeted[96].

93 European Commission/EACEA/Eurydice, (2013): *Education and Training in Europe 2020: Responses from the EU Member States.* Eurydice Report. Brussels: Eurydice. Available at: http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/163EN.pdf, p. 93.

94 Kearney, C. (2011): *Efforts to Increase Students' Interests in Pursuing Science, Technology, Engineering and Mathematics Studies and Careers: National Measures Taken by 21 of European Schoolnet's Member Countries'*. European Schoolnet, Brussels. Available at: http://www.fisme.science.uu.nl/publicaties/literatuur/2011_european_schoolnet.pdf, p. 30.

95 European Commission/EACEA/Eurydice, (2013): *Education and Training in Europe 2020: Responses from the EU Member States.* Eurydice Report. Brussels: Eurydice. Available at: http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/163EN.pdf, p. 93.

96 Eurydice (2011): *Science Education in Europe: National Policies, Practices and Research*. Education, Audiovisual and Culture Executive Agency, Brussels. Available at: http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/133en.pdf, p. 28.

UK	The STEM Cohesion Programme aimed to **bringing together the various stakeholders involved in the teaching and promotion of STEM subjects**. The STEM Cohesion Programme has 11 action programmes, each a key area of activity across STEM education (e.g. continuing professional development (CPD), careers, enhancement and enrichment activities). Each action programme is headed up by a relevant organisation which acts as a focal point, the aims of each action programme are to identify similar schemes and resources and develop new projects. Impact has been demonstrated by evaluation- teachers have reported improvements in relation to: **information coordination**, within and between schools; **raised awareness** of STEM-related opportunities and activities, and how to access these; and **engagement with STEM**-related provision. In terms of specific impact on STEM study uptake one Higher Education Representative stated, "our mathematics courses have gained an increase in student number going from 180 -300 in the last three years." However, the "stakeholder survey respondents found it difficult to isolate any difference the programme has made in increasing interest in STEM study and/or careers given the number of associated factors that could be influential in this" [97].
EU	inGenious is one of the largest and most strategic projects in science education funded by the European Commission. inGenious aims to increase young Europeans' interest in STEM education and careers, **addressing two challenges: lack of interest in STEM subjects and future skills gaps.** A few examples of successful Industrial Educational Practices that have been evaluated positively through the inGenious project, can be found below: "**Electronic Dice (Philips):** This practice covers the complete process of product design. Kits of materials and learning manuals were provided to teachers and pupils, who, individually or in teams, had to interpret the dice design, assemble the dice and test the final outcome applying basic electronics and welding skills. "**Sensor adventure (Intel):** This online interactive environment is composed by a collection of missions. Each mission involves a series of three science experiments which are designed to enhance students' understanding of various science principles. These experiments are conducted in such a way as to promote investigative thinking, and are based on the correct selection of a number of sensor technologies. These are presented in various real-world scenarios. Students are encouraged to experiment using various sensors and are required to select the best sensor for the task in hand. Some of the virtual sensors that are used in the adventure are: Temperature, soil moisture, infra-red light thermometer, light, wind." "**It is all about Energy (Shell):** Shell has produced a detailed series of lessons, featuring over 40 individual assignments, aimed at connecting pupils with the current realities – and future possibilities – of global energy. It's All About Energy is divided into three sections, dealing with the future of energy, looking for and extracting petroleum, and solutions to the problematic issue of carbon dioxide (CO2) emissions"[98].

[97] NFER (2010): The STEM Cohesion Programme Final Report. NFER, Slough. Available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/182142/DFE-RR147.pdf, p. Viii.

[98] Information provided by EUN Partnership AISBL representative.

Active labour market policies targeting STEM shortages	
Ireland	The Momentum Training Fund aims to assist up-to 6500 long-term unemployed (for 12 months or more) **jobseekers gain in-demand skills and access work in sectors of the economy where job opportunities currently exist**. The programme includes on-the-job training in the form of work experience modules as well as the provision of further education and training required to obtain and retain employment. One third of all places have been ring-fenced for the under 25s. Although these projects are not specifically in STEM areas -due to targeting sectors of the economy with expanding job opportunities, ICT invariably is a key targeted sector for this programme[99].

* These practices have been evaluated as having a quantifiable impact on STEM uptake.

It should nevertheless be noted that selecting 'good' practices is a difficult task. Whilst a great deal of effort has been channelled into collecting the wide-range of practices that exist to encourage STEM studies throughout different Member States, **effective evaluation of these practices – in terms of impact on STEM take-up are much more difficult to come across**. As Wynarczyk and Hale state: "whilst STEM's education budget, initiatives and schemes continue to increase in terms of numbers and activities, their real impact on improving the take up, performance and achievement in STEM subjects has not been investigated and, as such, their real contribution to STEM education may be undermined." There is a real lacuna in research and policy in this field[100].

The **lack of a common framework for the evaluations** that are undertaken in this field hinders solid comparative research that examines the effects of different types of policy approaches, practices and initiatives. The **UK's National STEM Centre is responding to this need** and has developed a guide to orientate organisations undertaking evaluations in the STEM field[101]. It provides a basic framework for evaluations in STEM initiatives with illustrative examples of its application to six case studies. This goes some way towards the development of a much needed common evaluation framework in this field.

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[99] European Commission/EACEA/Eurydice, (2013): *Education and Training in Europe 2020: Responses from the EU Member States.* Eurydice Report. Brussels: Eurydice. Available at: http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/163EN.pdf, p. 54.

[100] Wynarczyk, P. and Hale, S. (2009): Improving take-up of science and technology subjects in schools and colleges: A synthesis review. Newcastle University, Newcastle. p 7.

[101] National Stem Centre (UK), (2011): Does it Work? Evaluation STEM Initiatives –Case Studies. National STEM Centre, York. Available at: http://www.nationalstemcentre.org.uk/res/documents/page/STEM %20Case

4. CONCLUSIONS

In spite of national diversity we can see that common policies, initiatives and programmes have been pursued to encourage STEM studies. In 2011 Kearney noted how almost 75 % of those countries surveyed for their report had a global approach to dealing with STEM issues at the national level[102]. These have been complemented by a wide-range of European initiatives.

Despite the various policies, initiatives, programmes and projects developed in order to encourage STEM studies – it seemed as though little progress was made until the mid-2000s[103]. Evaluations of recent trends however indicate more positive results[104].

Data about university graduates in STEM also gives an indication of progress made with 15 Member States showing a rise in the share of STEM university graduates since the mid-2000s. However data shows that the share of STEM VET graduates has decreased in most countries.

European coordination and EU funded research has provided a collection of good practices currently being developed in Member States. The selected practices were identified by qualitative expert assessment and partly by showing a positive quantitative impact. These show a range of different initiatives that attempt to encourage STEM throughout the life-course, including initiatives developed at the primary school level, secondary school level, VET, higher education and active labour market policies.

Transforming young people’s attitudes to science is a long-term project that will not occur overnight - the effects will be seen in the long-term.

Durando[105] from European Schoolnet that co-ordinates InGenious states that national strategies should aim 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
- Strive for a better gender balance
- Provide employers with required skills

It proposes encouraging the following generic measures:

- Implementing curriculum reforms
- Creating partnerships between schools and companies
- Setting up science centres

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[102] Kearney, C. (2011): *Efforts to Increase Students’ Interests in Pursuing Science, Technology, Engineering and Mathematics Studies and Careers: National Measures Taken by 21 of European Schoolnet’s Member Countries’*. European Schoolnet, Brussels. Available at: http://www.fisme.science.uu.nl/publicaties/literatuur/2011_european_schoolnet.pdf.

[103] European Commission (2007): *Science Education Now: A Renewed Pedagogy for the Future*. European Commission, Brussels. Available at: http://ec.europa.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf, p. 5.

[104] Van den Bergue, D. and De Martelaere, D. (2012): *Choosing STEM. Young people’s educational choice for technical and scientific studies*. The Flemish Council for Science and Innovation, Brussels.

[105] Durando, M. (2013): *Towards 2020: Priorities for STEM Education and Careers in Europe*, powerpoint presentation. Available at:http://www.ingenious-science.eu/c/document_library/get_file?uuid=64d8c2fe-a4ea-449c-b6d7-15d21dd44f0f&groupId=10136

- Providing specific guidance
- Developing Continuous Professional Development (CPD) for teachers
- Initiatives dealing with career advisors (issue on the profession)
- The need to strengthen high quality career advice in schools
- Initiatives on recruiting new STEM teachers

The majority of policies and initiatives have been developed in the education sphere – although there **is an increasing recognition of the importance of school- industry partnerships** it would seem that initiatives in industry and the sphere of the labour market are few and far between.

In 2013 Marginson and colleagues state in their International Comparison of STEM Education that "there is **little discussion of the labour market and industry setting** which remains something of a 'black-box' everywhere"[106].

There seems to be **scope for developing active labour market policies** in the field, providing further training to those unemployed to tackle STEM shortages. This could be accompanied by an increased emphasis on initiatives aimed at encouraging uptake of **VET short cycles** of higher education in STEM.

More systematic evaluation is needed of the different types of initiatives and their impact on STEM uptake. This could be facilitated by a common evaluation framework – which would enable much needed comparative research to be carried out in this field.

[106] Marginson, S., Tytler, R., Freeman, B., and Roberts, K. (2013): *STEM Country Comparisons. Report for the Australian Council of Learned Academies.* Australian Council of Learned Academies, Melbourne. Available at www.acola.au, p. 53.

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