



European
Commission

Does the EU need more STEM graduates?

Final Report

A report submitted by [Danish Technological Institute](#)
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Does the EU need more STEM graduates?

Final report

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Executive summary

1. Policy context of the study

The broad educational fields of science, technology, engineering, and mathematics, also known by the acronym 'STEM', have received growing attention in Member State and European policy discourses during the past decade for a number of reasons:

- STEM skills are associated with advanced technical skills, which are seen as strong drivers for technology and knowledge-driven growth and productivity gains in high-tech sectors, including ICT services.
- Due to demographic developments, there will be a high replacement demand for high-skilled professionals working in STEM-related occupations in the coming years. This has led to concerns that Europe could lack an adequate supply of STEM skills to enable its future economic development (European Parliament - Committee on Employment and Social Affairs, 2013).
- Europe has a comparatively poor record of attracting top-level STEM professionals from abroad. Whereas, in the USA, 16 % of scientists come from outside the USA, only 3% of scientists in the EU come from non-EU countries (The Observatory on Borderless Higher Education 2013).¹
- Concerns about the quantity and also at times the quality of STEM graduates.
- In spite of a series of measures, female participation in STEM studies, in particular in engineering, remains low in most Member States.

Numerous studies have been published on the perceived STEM challenge, such as a report from the High-level Group of Human Resources in Science and Technology in Europe formed by the European Commission's Research DG (Gago, et al., 2004) and the 2011 Business Europe document '*Plugging the skills gap - The clock is ticking*' (Business Europe, 2011). The EU's *Competitiveness Innovation Union Report 2013* (European Commission, 2014c) raised concerns about the quantitative and qualitative challenges regarding future STEM supply due to the demographic changes that will result in a major replacement need of the existing science, technology and engineering professionals and associate professionals in the coming years. The Innovation Union Report furthermore highlights that in the coming years, skills demands will likely change considerably in *qualitative terms* because of such factors as technology convergence, the Internet of Things, and pressures to exploit technologies in innovative ways to meet more diversified demands from global markets.

The supply of STEM skills is an element in the European Commission's strategy for a job-rich and sustainable recovery and growth. A 2014 motion from the European Parliament specifically refers to STEM skills as being critical to boosting jobs and growth (European Parliament - Committee on Employment and Social Affairs, 2013). An insufficient supply of STEM skills and a low participation rate of women in STEM studies are perceived as barriers, which could impede a job rich recovery and growth:

"...and that the supply of STEM skills (science, technology, engineering and maths) will not match the increasing demands of businesses in the coming years, while the declining rate of women participating in those subjects has not been properly addressed".²

However, STEM skills shortages do not appear to be universal in the EU, but rather tend to be particular to regions with a high concentration of high-tech and knowledge intensive companies, including ICT services. Furthermore, the demand for STEM graduates is concentrated on particular qualification profiles within the broad field of STEM. Furthermore, there is evidence that STEM graduates, in spite of demand for STEM skills, are confronted with a number of

¹ http://www.obhe.ac.uk/newsletters/borderless_report_january_2013/global_race_for_stem_skills

² <http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+REPORT+A8-2015-0222+0+DOC+XML+V0/EN&language=en>

barriers in the transition to labour markets, which could explain why so many STEM graduates seemingly end up in non-core STEM sectors.

Assessing the supply of - and demand for - STEM professionals therefore requires a more fine-grained look at the context and evidence of STEM skills supply and demand to inform future policy making. This is the background to this study.

2. Objectives of the study and study approach

The European Commission, DG Education and Culture, commissioned this study in the spring of 2015 with the title '*Does Europe need more STEM graduates?*'

The tender document specified that the study should include the following elements:

1. An overview of the **current supply of and demand for tertiary STEM graduates** in EU Member States, based, to the extent possible, on comparable graduation data and relevant indicators of labour market demand, distinguishing between STEM disciplines as far as data allow. The analysis has included an assessment of the quality of existing comparable data on supply and demand for STEM graduates - and at a disciplinary level;
2. An assessment, based on international literature, including skills forecasts and projected future graduation rates, of overall **trends in projected demand and supply for graduates** in STEM, including an analysis of factors that could influence the nature of supply and demand in the short to medium term;
3. A more detailed analysis of the **situation in six Member States** with varying economic structures, focusing on the question of whether a STEM graduate shortage exists now and/or is likely to emerge in the future through a case study methodology.

Initially the study set out to define and break down what constitutes STEM from a supply and demand perspective, in order to specify which fields of studies can be characterised as STEM fields of study at the tertiary level, and similarly to define STEM occupations and STEM labour markets.

The projected demand for science, technology, engineering and maths graduates is often expressed at the aggregate level under the umbrella term 'STEM', without taking into account that STEM spans a considerable number of disciplines with quite different characteristics. The analysis has been based on more granular data where available, in order to analyse such questions as whether some occupations and sectors can meaningfully be characterised as core STEM occupations and core STEM sectors, and to assess whether the demand for STEM graduates varies across disciplines. The ultimate aim of the project was to examine critically the claims regarding future demand for STEM outlined above as a basis for drawing conclusions for future strategies in higher education.

3. Definitions and limitations in data

The analysis of statistical data has shown that there are limitations in the comparability of data at the EU level, due to different definitions regarding STEM in such areas as study fields, occupations and labour markets. At the EU level there is furthermore a lack of data at a sufficiently granular level on several key indicators. In some instances it has been necessary to rely on proxies and to draw on data sets that are not always comparable in terms of core definitions.

4. Key Findings

Business leaders, policy makers, researchers, and other stakeholders have diverse opinions about challenges regarding the supply and demand for tertiary STEM graduates now and in the medium-term future. Concerns about the sufficiency of current and medium-term future supply are linked to the importance paid to technological innovation as a critical enabler of growth following the economic crisis, and to the competitiveness of Europe in the medium term. Discussions do not merely concern the balance between supply and demand *in quantitative terms*, due to variations in the numbers studying in different fields within STEM and the fact that a large number of STEM graduates find employment in non-core STEM sectors. There are also concerns about mismatches of a *more qualitative nature*, for example driven by a growing ICT intensity in the economy, by technology convergence, and changes in the type of tasks involved

in STEM professions, which are not always reflected in the design of higher education programmes.

4.1. Evidence about current STEM supply and demand

Data analysed on current STEM skills supply and demand indicate that there are **no overall quantitative shortages of STEM skills at the aggregate EU level**. There are however **geographically defined shortages and skills mismatches and bottlenecks**, in particular found in **engineering and ICT**.

There is some evidence that the notion of 'employability' – and the characteristics of "employable" graduates, including STEM graduates – is very broad meaning and differs across sectors, companies of different sizes and management and according to the work organisation practices deployed. The professional identity and employability of STEM graduates cannot, therefore, be reduced to a list of generic employability skills that can be ticked off if they are covered in curricula. A UK study (Hinchcliffe 2011) concludes that employers place value on a wider range of dispositions and abilities, including graduates' values, social awareness and generic intellectuality — dispositions that can be nurtured within higher education and further developed in the workplace.

The reported shortages and mismatches appear to be caused by a mix of a:

- A general drop in investment in continuing education and training of the *existing workforce with STEM skills*, in particular since the crisis;
- *Employer expectations having increased* over time and particularly during the crisis. An analysis of bottleneck vacancies indicates that they are linked to demands for highly specialised technical skills and labour market experience.
- *Geographically defined shortages*, with STEM skills playing a central role both in high-tech and in ICT services, and graduates who prefer to work in and around the larger cities;
- Barriers to *transition of recent graduates* due to lack of labour market experience and an ill-defined notion of employability skills, according to a range of surveys;
- Some evidence of *under-employment of mobile STEM graduates*, and a mistrust among employers of foreign STEM qualifications;
- *Career guidance* that is oriented towards the public sector and large companies, *leaving out SMEs* as a potential labour market destination;
- A large number of graduates that end up in sectors that are considered *non-core STEM sectors*, and insufficient knowledge about the underlying dynamics and causes of this.

4.2. Evidence about future STEM supply and demand

CEDEFOP projects that employment in STEM occupations in the EU will increase by 12.1% by 2025: a much higher rate than the projected 3.8% increase for other occupations in the EU. Across Member States and sectors, patterns of demand for high-skilled STEM professionals are projected to vary between Member States and occupations. However, at an aggregate EU level, projections indicate that there will be a match between supply and demand up to 2025. Looking into the future there are a range of critical uncertainties which could quantitatively and qualitatively impact on demand, such as: more advanced levels of automation; the characteristics and nature of technology convergence; the relative data intensity and use of data-driven innovation; patterns of global mobility of STEM graduates; and changing patterns in sourcing skills and work. Forecasting future skills demands is associated with a high level of uncertainty, particularly when it comes to fast-changing high-tech occupational fields such as core STEM occupations.

4.3. Policy pointers

Six study findings should in particular be considered in any future action to promote STEM:

1. The *umbrella term STEM* is not a useful category for understanding the supply and demand dynamics in science, technology, engineering and mathematics as it tends to imply a high level of substitution between different education fields and occupations, which is not necessarily possible in practice. Furthermore, there is a lack of agreed

statistical definitions within countries and across the EU of what constitute STEM study fields, STEM occupations, and STEM sectors. There is also a *lack of sufficiently granular data on STEM vacancy rates and STEM mobility*. For some countries, there is a lack of data on STEM graduates and STEM labour markets. These data gaps mean there is often a lack of adequate data to inform policy making reliably.

2. The analysis has also focused on the debates and criticism about *STEM graduates' employability* and how this is shaped. In a wider policy context, the narrative on graduate employability mirrors shifting interplays between universities, the labour market, and HE policies. Demands to the higher education sector are being reshaped with a stronger focus on the economic value of higher education graduates and parallel to the expansion of higher education provision - also in the field of STEM. In that changing landscape, a question emerges as to *whose responsibility it is to enable a smooth transition* into the labour market and to productive and relevant employment for STEM graduates. What is the balance of responsibility between the government, employers, or individual graduates themselves? A fundamental question for policy making.
3. An increase in the supply of STEM graduates will not necessarily meet demand because *a large number of STEM graduates end up in non-core STEM jobs*. There is a lack of good evidence about the underlying factors that shape graduates' labour market transition and employment opportunities and whether it is out of choice or necessity that STEM graduates end up in jobs in non-core STEM sectors.
4. The growth of the higher education sector, cuts in the public sector and limited growth in recruitment in "traditional" graduate employers in many EU countries have led to a situation in which graduates increasingly will need to *orientate themselves towards SMEs*. While this could be positive from an innovation perspective, there is some evidence that SMEs in traditional sectors of the economy have difficulties in *absorbing and making productive use* of the increasing number of higher education graduates and their knowledge and skills. This can result in under-employment. This development illustrates that alongside "supply-side" skills policies, efforts also need to be directed at stimulating *absorptive capacity and skills use* across the economy.
5. Job vacancy data suggest that employers in several EU countries *may have overly high expectations of graduates*. Although higher education institutions can work with industry in many ways to ensure that graduates are prepared for a dynamic labour market, graduates cannot be expected to be highly specialised and have the full range of skills necessary for a particular post to allow them to be fully productive from day one. Furthermore, how "employability skills" are understood seems to depend upon such issues as size of company and sector, as well as work organisation and management practices, which makes it even more complex to ensure a match.
6. The *mobility of high-skilled STEM graduates* from within the EU increased during the crisis, but there is evidence that STEM graduates from other EU countries are at greater risk of ending up as under-employed or under precarious working conditions. Furthermore, outside the ICT sector employers seem hesitant to recruit graduates from other countries within or outside the EU.

Data-driven methods to capture emerging skills trends within STEM-intensive sectors, value chains and occupations, combined with a mix of quantitative and qualitative methods to forecast the demand for specific STEM profiles, can form a foundation for building better labour market intelligence at a more granular level in order to inform policy making in the field of STEM.

1. Introduction

1.1. Study context

The study was commissioned by the European Commission in the spring of 2015. The key research question the study should address is whether Europe needs more STEM graduates. In the tender brief 'STEM graduates' were defined as tertiary graduates with a degree in science, technology, engineering or mathematics. STEM skills are strongly associated with technology driven innovation and growth in high tech sectors including ICT services. They are therefore by many seen as indispensable to kick-starting a job rich and knowledge intensive growth after the crisis. Though higher education has expanded considerably across the EU in the past decade, industry has on several occasions raised concerns about the lack of STEM graduates, stating that this could hamper the recovery of the economy and consequently that the 2020 targets cannot be met. As part of the review of progress made under the 'Modernisation Agenda' for higher education, which sets a strategic framework for EU cooperation in higher education, the Commission has wished to examine the question of how far efforts should be intensified to promote increased participation in STEM at the tertiary level. This forms the policy context for the tender brief and this study.

1.2. Study tasks

To analyse the key research question the following tasks were undertaken as specified in the tender brief:

A statistical overview of the current supply of and demand for tertiary STEM graduates in EU Member States was undertaken, based on comparable graduation data and relevant indicators of labour market demand. In so far as data have allowed, the study has aimed to distinguish between STEM disciplines. The statistical analysis has included an assessment of the quality of existing comparable data on supply and demand for STEM graduates, including the level of granularity of comparable data.

An analysis and assessment of the supply of and demand for STEM graduates in the short to medium term based on international literature and policy studies, including skills forecasts and trends in projected demand and supply. The literature review has covered a range of contextual factors, which influence supply and demand such as study and career choice, gender aspects related to study and career choice, labour market mobility and migration, employment destinations of STEM graduates, reported bottlenecks and the nature of these across the EU, and policy measures to promote STEM and the impact of these.

A more detailed analysis of the situation in six Member State case studies has been undertaken, namely Bulgaria, Denmark, Germany, Poland, Spain and the UK. Those countries were chosen to gain a deeper understanding of the characteristics of the supply and demand situation for STEM graduates in countries with varying economic and institutional structures. Furthermore, the case studies have analysed policy measures to promote STEM and the characteristics of these, based on available data and interviews with 3-5 experts in each country.

1.3. Operationalisation of the research questions and tasks in the tender brief

In the implementation of the study design, the research question and tasks were operationalised into five sub-questions, which have been analysed through the different data sources (statistical data, interviews and literature review): The five sub-questions, which have also informed the design of the case studies, are:

1. What are the trends in the supply of STEM graduates?

To examine this question, we have analysed the following:

- Definitions, comparability, and granularity of data;
- The demographic profile of the current STEM labour force;
- Graduation data on STEM according to main fields of study and gender;

- International mobility of students, including measures to attract or retain students;
- Measures to promote STEM studies;
- Factors that influence choice of study.

2. What are the trends in the demand for STEM graduates?

To examine this question, we have analysed such questions as:

- Labour market destinations for STEM graduates;
- Job openings in STEM occupations for STEM graduates;
- Employer perceptions of STEM graduates;
- Opportunity costs of a STEM degree;
- Vacancy rates³ for STEM jobs (insofar data are available).

3. What evidence is there of skills shortages, skills mismatch, and/or educational mismatch?

To examine this question, we have looked into the following topics:

- The skills matching process and the quality of matching;
- Reported bottlenecks and the nature of these;
- The demand for STEM graduates as a whole or graduates from specific STEM disciplines;
- Mobility of STEM professionals;
- The relative attractiveness of STEM professionals across the economy;
- Geographical concentration of STEM graduates and level of mobility;
- International mobility of non-EU graduates;
- Policy measures to mobilise skills outside the EU;
- The relative importance of soft skills/transversal skills;
- If skills mismatches or skills under-utilisation are identified – their nature and the type of evidence;
- Future projected demands and critical uncertainties.

4. What are the priorities and impact of major policy initiatives targeted STEM measures?

To examine this question we have analysed:

- The nature of and target groups for STEM policy measures;
- Impact of promotion efforts, where evidence exists;
- Lessons learned from promotion efforts.

5. What lessons can be deduced for policy-making?

The above research questions have informed the structure of the report.

Due to limitations of data and challenges regarding definitions of STEM related topics, it should be noted that not all the questions listed above have been addressed in equal detail.

The following section includes an introduction to definitions of STEM in relation to key indicators for the study, which are then applied in the subsequent parts of the study.

³ Definition (Eurostat) : The job vacancy rate (JVR) measures the proportion of total posts that are vacant minus job openings that are only open to internals.

2. Data on STEM – Definitions and limitations

2.1. An introduction

‘STEM’ is often used as an abbreviation and an acronym for study disciplines, labour markets and occupations with very different characteristics and definitions in the field of science, technology, engineering and mathematics. This chapter sets out definitions of the core terminology for STEM supply and demand used in this study. It then continues to discuss data availability and data quality in the field of STEM, which frame the study methodology.

2.2. Defining STEM fields of study

STEM skills supply is defined as degrees awarded in STEM studies at the tertiary level. Thus, it is necessary to define which fields of study that can be categorised as STEM core studies. A narrow definition of STEM studies is deployed based on Eurostat’s standard Classification of Fields of Education and Training⁴. The following fields of study at the tertiary level are defined as core STEM fields of study:

Definition 1 – STEM fields of study

- Life science (EF42)
- Physical science (EF44)
- Mathematics and statistics (EF46)
- Computing (EF48)
- Engineering and engineering trades (EF52)
- Manufacturing and processing (EF54)

Architecture and building (EF58) are excluded because architectural studies in some EU countries have very limited connect and relevance to core STEM sectors and occupations. However, it should be noted, that Cedefop includes architecture as a STEM field of study in its analytical highlight on STEM skills (Cedefop, 2014). In consultation with the European Commission, health studies (EF72) from this study, even though other studies include it.

⁴http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=CL_FIELD99&StrLanguageCode=EN&IntPcKey=&StrLayoutCode.

2.3. Defining STEM occupations

The demand for STEM skills is difficult to define, as STEM skills are deployed in a range of economic sectors and occupations. Cedefop defines STEM skills demand based on occupation classifications and has identified “core STEM occupations” adapted from an earlier US study (Koonce, et al., 2011).⁵ The definition of core STEM occupations used in this study is similar to the one adopted by Cedefop, which is based on the International Standard Classification of Occupations (ISCO-08). The following occupations are categorised as core STEM occupations in this study:

Definition 2 – STEM occupations

- Science and engineering professionals (ISCO 21)
- Information and communications technology professionals (ISCO 25)
- Science and engineering associate professionals (ISCO 31)
- Information and communications technicians (ISCO 35)

Health professionals (ISCO 22) and health associate professionals (ISCO 32) are not included in this study, although they forms part of STEM occupations in other studies.

In this study, the researchers have made a differentiation regarding STEM professionals and STEM associate professionals. A STEM professional will typically have a doctoral or Master’s degree, while an associate professional will typically have a bachelor degree from a university college or a short cycle tertiary qualification. Based on that distinction they conclude that the labour market for the two groupings has the following characteristics:

Table 2-1 STEM labour markets and STEM occupations

STEM professionals	STEM associate professionals
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.
There were 6.6 million employed in these occupations 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 employed 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.

Source: (Caprile, et al., 2015)

2.4. Limitations in data

Throughout this study, data have been compiled from different sources. The two main statistical sources for STEM supply and demand are the Eurostat database and Cedefop's detailed skills forecast database. Additional statistical sources include findings on STEM labour market outcomes, such as STEM unemployment rates and STEM wages, from various studies on the subject. However, STEM definitions in the other studies vary, not only from the definitions adopted in this study, but also between studies.

Even though this study applies narrow definitions on STEM supply and demand, the problem of inconsistency in STEM definitions still arises when using different sources. Data

⁵ The US study used the SOC-10 occupational classification to identify the core STEM occupation, which Cedefop translated into the ISCO-08 occupational classification. SOC-10 differs from ISCO-08 in many ways, even though both systems classifies occupations with respect to the type of work performed. Guidelines on crosswalks between SOC-10 and ISCO-08 are available at: <http://www.bls.gov/soc/soccrosswalks.htm>.

availability does not always allow for a consistent and narrow STEM definition as set out above. Additionally, there are major challenges regarding operational statistical definitions applied to the EU as a whole. For instance, STEM occupational groups at the associate professional and technician level may include graduates at the post-secondary non-tertiary level in some Member States, due to differences in national classifications of qualifications (Kirsch & Beernaert, 2011).

2.4.1. Limitations in STEM skills supply data

In some cases, data do not allow us to separate architecture and building (EF58) from defined STEM fields of study. This implies that data on STEM skills supply, based on graduates in STEM fields of study, are inflated when including architecture and building graduates. It is clearly indicated when this is the case.

2.4.2. Limitations in STEM skills demand data

The Cedefop detailed skills forecast data groups ICT professionals (ISCO 25) in a broader occupational group, which also includes business and administration professionals (ISCO 26) and legal, social and cultural professionals (ISCO 26). This poses a challenge, as ICT professionals is an important STEM occupation, with a growing importance due to the data intensity and digitalisation of the economy at large. If the entire Cedefop group of (ISCO 25) was included data would be inflated.

In order to focus on ICT professionals, data from the European Labour Force Survey (EU LFS) have been used to create a meaningful estimate for ISCO 25 employment and job openings, which covers the group 'ICT professionals'. The International Labour Organisation provides data from the EU LFS, from which it is possible to infer the current share of ISCO 25 as a proportion of the whole aggregated professional occupations group (ISCO 2) for each Member State and at the EU28-level. This share was applied to the Cedefop data to get an estimate on ISCO 25 and ultimately the aggregate STEM occupation group.

The estimate has some clear limitations. First of all, when applying the current share of ISCO 25 to forecast data, the results will somehow be distorted as they will miss the internal dynamics of the subgroups within the main group in the forecast results. Applying the current share to historic data will also give a distorted picture, as the share of ICT professionals has increased during the past years.

Furthermore, science and engineering professionals (ISCO 21) includes architects at the three-digit level, which it has not been possible to separate from the data.

2.4.3. Limitations in data availability

Data availability has in particular been limited on aspects such as STEM labour market mobility and STEM vacancy rates, as data is simply not available at a sufficiently granular level. Labour market mobility would in particular be interesting because many STEM graduates seem to work in non-core STEM sectors. The use of proxy indicators has therefore been necessary in some instances.

In terms of STEM labour market mobility, the European Commission carried out a study in 2013 on attracting highly qualified non-EU nationals (European Migration Network, 2013). The Commission also conducted a study on trends in the geographical mobility of highly educated in the EU (European Commission, June 2014).

Even though these reports do not focus directly on the mobility of the STEM labour force, the findings on the mobility of highly qualified professionals can still act as a decent proxy.

It is not possible to estimate vacancies for STEM occupations, and we have turned to the EU vacancy monitor that provides an overview of the top occupations with the strongest employee growth across countries in the period from 2008- 2011. Even though this proxy is by no means ideal for STEM vacancy rates, it is possible to identify STEM occupations that showed the highest growth rates in the period.

The definitions that have been presented in this chapter will form the point of departure for the analysis in the following chapters.

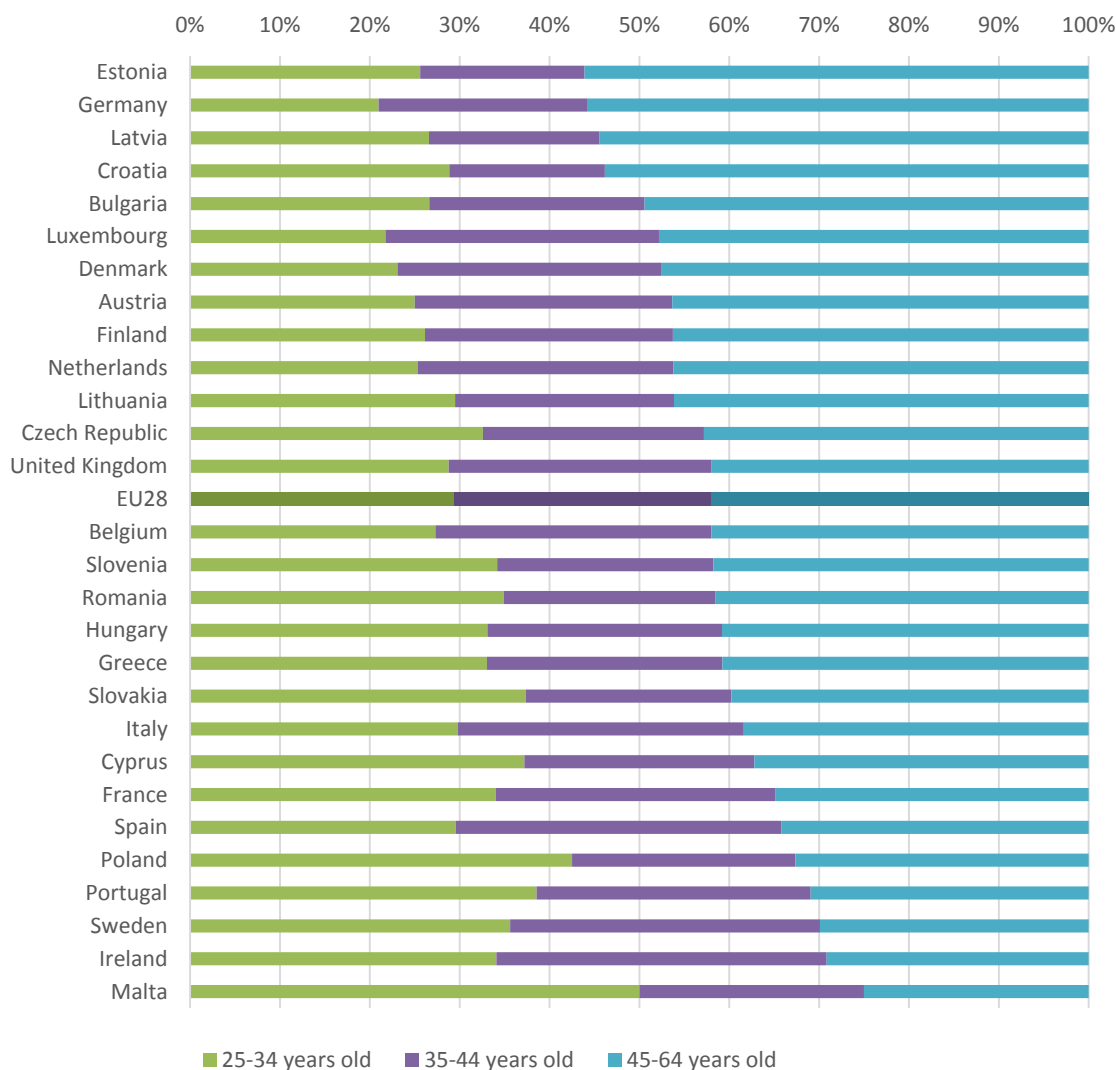
3. STEM skills supply

This chapter provides an overview and discussion of STEM skills supply in the EU and the range of factors that impact the supply such as educational choice across genders, developments in the number of tertiary graduates, demographics and aging, and mobility including inward student mobility. A number of indicators of STEM skill supply are analysed to highlight current trends.

3.1. Current stock of STEM professionals and associate professionals

STEM professionals and associate professionals are defined as graduates who hold a tertiary degree or a PhD in one of the defined STEM disciplines.⁶

Figure 3-1: STEM professionals age group distribution, 2013



Source: Eurostat (hrst_st_nfieage) and own calculations. Data retrieved 15/7/2015.

Note: Data from United Kingdom and EU28 refer to 2010 instead of 2013. 'STEM professionals' encompasses individuals who hold a tertiary education within science, mathematics, computing, engineering, manufacturing and construction (EF4_5).

⁶ Unfortunately, it is not possible to exclude 'Architecture and building (EF58)' from the STEM professionals in the HRST database. Thus, the STEM professional encompasses individuals who hold a tertiary education within science, mathematics, computing, engineering, manufacturing and construction (EF4_5).

As the figure above shows, there are substantial differences in the relative age composition of STEM professionals across the EU. However, one common trend across the EU is the overall aging of STEM professionals. This leads to a major replacement demand for STEM professionals currently and in the coming years if the development in demand continues as now and even more so if demand increases further as projected by Cedefop. In 2013, there were 20.7 million people aged 25 to 64 in the EU STEM labour force with a tertiary degree; 8.7 million were 'senior' STEM professionals between 45 to 64 years old, corresponding to 42% of all STEM professionals and associate professionals. The aging challenge is also seen in the 2.2% increase in the share of STEM 'seniors' between 2008 and 2013. There has been an increase in the 'senior' age group over the period in 19 Member States, with Malta, Luxembourg, Spain, Denmark, Ireland and the Netherlands all showing an increase of more than 5% (i.e. a particularly fast rate of aging).

Figure 3-1 also shows that Estonia and Germany have the largest shares in the 'senior' age group of all Member States, with around 56% of all STEM professionals and associate professionals. Croatia and Latvia also have more than 50% in the 'senior' age group. Apart from having a relatively large share of STEM 'seniors', Germany also has the lowest share of young STEM professionals and associate professionals, with only 21% in to the 25–34 year age group. In an assessment of the data it should be taken into account that several Member States are trying to delay the point and time of retirement to address the impact of changing demographics through legislative measures.

3.2. Flow of new STEM skills: choice of STEM studies

The choice of study and career orientation is affected by a range of factors such as socio economic background, choice of peers and guidance.

A recent European research study (Henriksen, et al., 2015) found that high school students, as well as STEM students rarely have an understanding of the career opportunities available to them if they have obtained a tertiary STEM degree. According to the study, university students mainly associate STEM careers with that of being a doctor or an engineer. The study concludes that effective promotion interventions need to send clear messages that illustrate the range of professions where STEM knowledge, skills, and competences are required. Furthermore, strategies to increase the number of students that choose a STEM study and a subsequent STEM career should take into account that study and career choice in many cases are affected by opportunities for self-realisation. The European study on career choice and gender (ibid) concludes that females tend to be more "values"-driven in their choice of studies and careers, and hence tend to prioritise applications of STEM in professions, which are perceived to bring value to the society such as diagnostics, climate research, and environmental research linked to the provision of clean water. Another conclusion is that high school students be able to see how a STEM career may fit with their personality and interests. Consequently, career guidance should present a range of 'STEM personalities' as diverse as possible with regard to ethnicity, gender and other identity traits. In this respect, work placements can play a major role in demonstrating the variety of professionals that have pursued a STEM career.

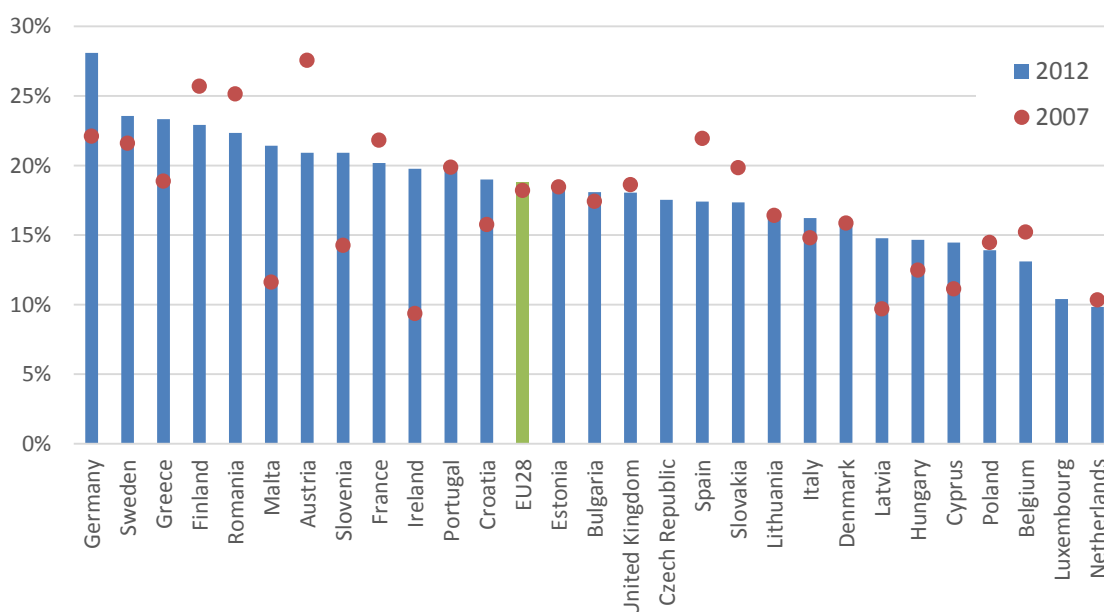
The same European study on career choice found that students' educational choice processes continue after they have entered the programme they have chosen to study. Most students surveyed in the research study believed there was a gap between what they had expected, and the actual characteristics of the STEM study they had enrolled in. The students' sense of match therefore plays a critical role in whether they are motivated to complete their study or not. Student surveys on well-being and their perceptions of the study environment can provide clues that can enable early intervention.

It can be concluded that any intervention to increase STEM participation requires a systemic and comprehensive approach over time, taking into account the nature and interrelationship between curriculum characteristics, the underlying values the curriculum communicates (the hidden curriculum), how the STEM agenda is communicated in society, grading practices and entrance requirements, and, as mentioned, the approach to career guidance. STEM promotion measures should be piloted and evaluated over several cycles of implementation, as a means to improve impact. Events that continue over time targeting individuals are more effective than one-off events.

3.3. Flow of new STEM skills: new STEM graduates

The most recent EU data on tertiary STEM graduates give a rather varied picture of the share of STEM graduates of the total number of tertiary graduates across Member States. While the share of STEM graduates remained more or less stable from 2007 to 2012 (around 18–19%) at the EU level, there were significant variations at country level. Figure 3-2 shows that Germany was in a lead position, with 28.1% that graduated in a STEM related discipline in 2012. In the second rank came Sweden, Greece, Finland and Romania with shares of STEM graduates exceeding 22%. At the other end of the spectrum, we find the Netherlands and Luxembourg with around 10% of STEM graduates. However, alongside the differing characteristics of national economies, the variation in the total number of graduates as a share of the relevant population needs to be factored in interpreting this indicator.

Figure 3-2: Share of ISCED 5-6 graduates in STEM disciplines, 2007 - 2012



Source: Eurostat (educ_grad5) and own calculations. Data retrieved 15/7/2015.

Note: Data for France refer to 2011 instead of 2012 for all fields of the study. Data for Ireland refers to 2005 instead of 2007 for all fields of the study. Data for Romania refer to 2008 instead of 2007 in Physical Science and Computing. Data for Greece refer to 2006 instead of 2007 for Manufacturing and Processing. No data were available for Luxembourg for 2007.

From 2007 to 2012, the share of STEM graduates increased in 13 countries, decreased in 13 countries and remained unchanged in one country.⁷ These developments should be seen in a context where there was a general expansion of higher education systems in the EU as well as globally. The figures therefore illustrate the overall perceived attractiveness of STEM studies in comparison with other tertiary fields of study. Several Member States experienced a rather insignificant increase or decrease. Ireland saw the largest increase in the share of STEM graduates, from 9.4% to 19.8%, while Austria accounted for the largest decrease from 27.6% to 20.9%.⁸ Some countries have seen rapid increases in graduation rates because of the Bologna process and the harmonisation among the systems of higher education in European countries and a general shift away from long programmes towards three-year programmes (Deiss & Shapiro, 2014).

In absolute terms, the total number of STEM graduates increased from around 755,000 in 2007 to 910,000 in 2012 at the EU level, corresponding to an average annual 3.8% growth

⁷ No comparison between 2007 and 2012 available for Luxembourg.

⁸ In an analysis of the data it should be taken into account that France, Ireland, and the UK prior to the Bologna agreement had a similar structure implemented, a structure that other Member States introduced during the period 2000-2010.

rate and an overall 20% increase over the period. In comparison, the share of STEM graduates in the USA was at 14.6% in 2012, but the absolute number of STEM graduates increased from around 386,000 to 482,000 from 2007 to 2012, with an average annual growth rate of 4.6%.

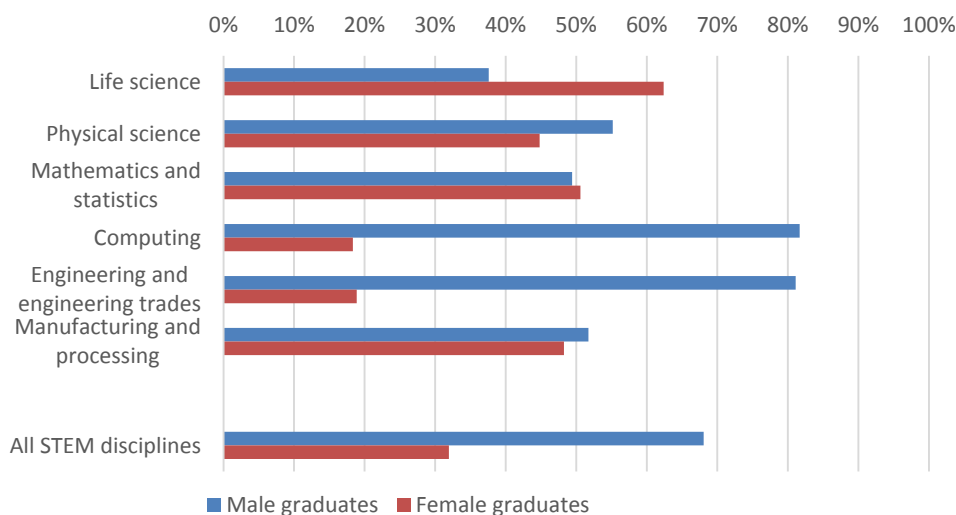
3.3.1. STEM graduates according to gender

There are more women in tertiary studies in the EU than men (Eurostat, 2015). This is not mirrored in the participation rates of women in STEM studies. In spite of numerous measures, both at EU level and in the Member States, the participation rates of women in STEM studies has continued to be considerably lower than that of men in most Member States. In the EU, women accounted for 59% of all tertiary graduates in 2012, but only represented 32% of all tertiary STEM graduates the same year. In other words, while 31% of all male graduates were from a STEM programme in 2012, only 10% of all female graduates had obtained a STEM degree.

The European Commission recently stated that it is 'a key challenge for Member States and for higher education institutions to attract a broader cross-section of society into higher education' noting that the need to make STEM education more attractive to women is 'a well-known... challenge' (European Commission, 2014a).

Figure 3-3 shows that computing and engineering are by far the largest STEM disciplines measured by the share of graduates. These two STEM disciplines are heavily male dominated with more than 80% male graduates in both disciplines in 2012. Life science, however, which is the third largest STEM discipline, is dominated by women. The remaining STEM disciplines have a fairly equal participation rate of males and females. In other words, it is particularly the male dominated STEM disciplines of engineering and computing that shape the overall picture of gender imbalance among STEM graduates, as these two fields of study are also by far the largest. It is also within computing and engineering that most bottlenecks are reported at the EU level. Women are more or less equally represented, or even overrepresented, in the remaining STEM disciplines. Needless to say, variations are found in the share of female STEM graduates in total and across STEM disciplines among the Member States as seen in Figure 3-3.

Figure 3-3: Share of male and female STEM graduates at EU level, 2012



Source: Eurostat (educ_grad5) and own calculations. Data retrieved 15/7/2015.

Note: Data for France refers to 2011 instead of 2012 for all fields of study.

A European Research project 'NEUJOBS' sheds some light on some of the contributing factors that may explain why there are fewer females in STEM studies than males (Beblavy, et al., 2013). The study builds on data from five EU countries (France, Italy, Hungary, Poland and Slovenia).

The share of STEM graduates in total remained constant in Slovenia, increased in Poland, and decreased slightly in France, Italy and Hungary according to the Neujobs study (ibid.).

The study shows, not only employment prospects and salaries play a role in an assessment of the net value of studies. Private returns to education should include a broader set of variables such as the personal cost of study to students in terms of years of education and weekly study workload, as these factors have a negative impact on opportunity costs of university education in STEM-related fields. Furthermore, the study found that the private returns of STEM studies were consistently lower for females than for males, which is a general tendency seen in other HE study fields (ibid).

3.3.2. Gender specific actions

The Commission initiative “Women in Science” is one example of a Europe-wide initiative to promote women in science. It forms part of a wider EU strategy for gender equality in research and innovation, and it was launched in June 2012 (DG Research, 2009). It includes ‘Science - it’s a girl thing’ that targets girls in compulsory education (European Commission, n.d.).

Some countries have women-specific guidance programmes in place within existing programmes. For example, Germany has launched *Go MINT!* – the National Pact for Women in MINT (STEM) Careers. It was established in 2008 as part of the federal government’s qualification initiative to increase young women’s interest in STEM and attract female university graduates into careers in business. 180 partners are at present supporting *Go MINT* with a wide range of activities and initiatives to advise young women on their studies and career (BMBF, n.d.).

In the framework of the ‘Talents Programme’ (2011) (Deloitte, 2014b), the Austrian government provides comprehensive support to STEM talent, and in particular female traineeships (FEMtech Traineeships Initiative and Traineeships for Pupils). The overall initiative comprises a number of measures:

- Networking (FEMtech Network);
- Enhancing the visibility of women experts (FEMtech Female Expert Database),
- Promoting the achievements of successful women in research (FEMtech Female Expert of the Month),
- Offering career support (FEMtech Career Initiative),
- Supporting research projects (FEMtech Research Projects Initiative)
- Seeking to improve women’s career opportunities in science and technology (FEMtech Dissertations until 2013).
- Supporting cooperation between academic institutions, research institutes and private companies with schools and kindergartens (*Talente* regional cooperation projects).

To address gender imbalances of tertiary students in STEM, the Polish Ministry of National Education has implemented the programme “*Girls for Technical Universities*” (Dziewczyny na politechniki). It aims to spark young women’s interest in STEM subjects. Data collected while monitoring the initiative show that it seems to have created some impact. According to data, the ratio of female STEM students had risen from 30% to 35.9% within the last six years (Attström, et al., 2014; Rambøll, 2014).

Research on gender participation in STEM (Henriksen, et al., 2015) recommends that interventions to improve recruitment should be designed with sensitivity to gender issues while at the same time avoid reproducing ‘self-fulfilling prophecies’ about STEM. The argument is that an overemphasis on gender issues risks ignoring other important factors relating to class, socio-economic status and ethnicity that impact choice of study. The research study concludes that the nature of the learning environment and reassurance of support from teaching staff may contribute to increasing female participation in STEM studies.

3.4. Mobility

3.4.1. STEM students’ mobility patterns

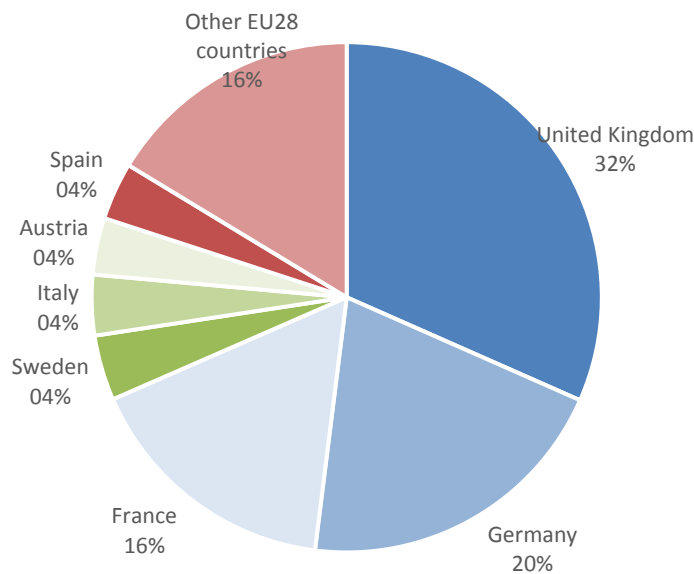
As participation in tertiary education expands in an increasingly globalised world, so does the number of tertiary students, who are enrolled outside their country of citizenship. The

supply of STEM graduates in the Member States can be affected by incoming students from third countries, provided they are subsequently allowed to work in the EU/national labour force, they find employment that matches their qualifications, and they are not employed in jobs that lead to underutilisation of their skills. The latter has been an ongoing discussion, for example, in Denmark regarding engineering and ICT graduates from non-EU countries. Cross-border student mobility plays a critical role in terms of developing students' STEM skills and is an important factor influencing labour migration of the highly skilled.

More than 1.8 million tertiary students were enrolled outside their country of citizenship in an EU-country in 2012. This group consisted of mobile students from within and outside the EU.⁹ The three most popular fields of study for foreign students, accounting for 70% of all enrolments for foreign student, are social sciences, business and law (35%), STEM-related subjects (21%)¹⁰ and humanities and arts (14%).

In absolute terms, the UK was in 2012 the preferred EU-destination for students studying STEM disciplines outside their country of citizenship. The UK had in 2012 close to 32% of all foreign STEM students in the EU. Germany has the second highest number with more than 20% and France with 16.5%, as illustrated in Figure 3-4. However, non-citizen immigrants who study in their country of residence are also counted as foreign students in some, but not all, EU countries. Thus, the number of foreign students might be relatively more inflated in large countries with many immigrants who retain their nationality of origin.

Figure 3-4: Distribution of foreign students in STEM disciplines by country of destination, 2012



Source: Eurostat (educ_mofa_fid) and own calculations. Data retrieved 15/7/2015.

Note: Data for the Netherlands refer to 2010 instead of 2012. No data available for Ireland and Croatia and these countries are therefore not included in the figure. Foreign students also refer to students from outside the EU.

The situation is somewhat different when looking at the number of foreign students in STEM fields, which is calculated as foreign students in STEM disciplines as a share of the total number foreign students in a country.

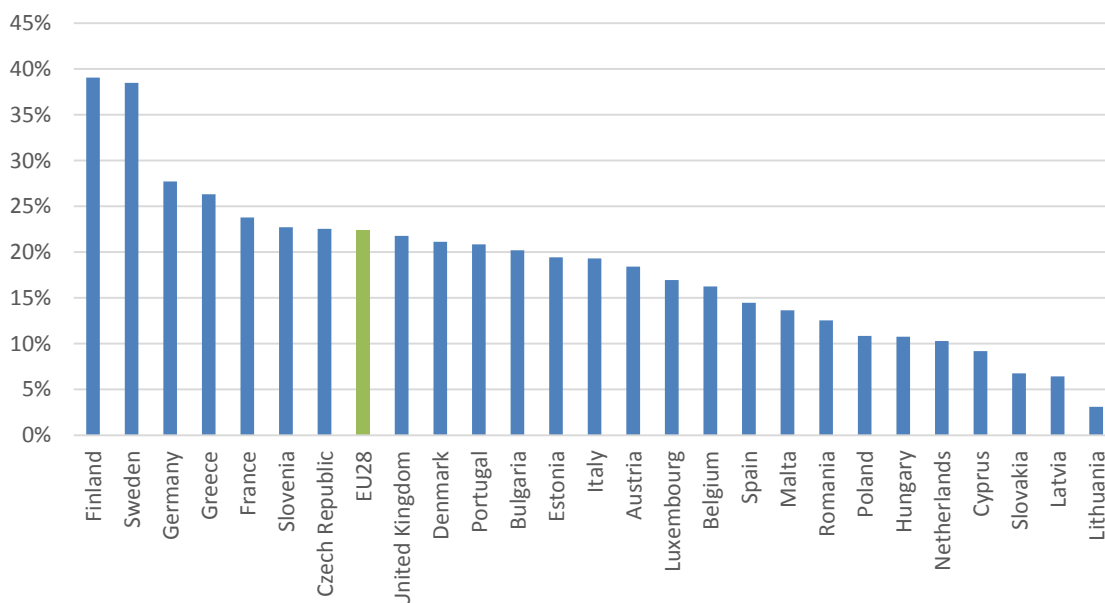
⁹ Eurostat distinguishes between 'foreign students' and 'mobile students'. Foreign students are defined as non-citizens of the country in which they study and comprises immigrants who are non-citizens but study in their country of residence. Mobile students are defined as foreign students who have crossed a national border and moved to another country with the objective to study. This study focuses on foreign students as the data basis is more complete, which implies that the data must be interpreted with caution.

¹⁰ As defined previously.

The crisis has also affected student mobility patterns, in that mobile students hope by studying in one of the Member States where the economy is better, they can also improve employment prospects in that country after graduation. From 2007-2009, Germany for example, saw an overall increase in students from another EU Member State. The students came from such countries as Bulgaria (7,500), Poland (7,500), Spain (4,500), Italy (4,300) and Romania (3,100) (Nedeljkovic, 2014).

Figure 3-5 shows that there are major variations in the number of foreign STEM students in the EU. This is impacted by policies concerning foreign students, costs of study and language requirements, and the reputation of study quality. The UK is the country in the EU that has traditionally received most students from outside the EU in spite of the UK's relatively high study costs (fees for non-EU/EEA students being higher than for EU/EEA students).

Figure 3-5: Foreign STEM students as a share of total foreign students by country of destination, 2012



Source: Eurostat (educ_mofo_fid) and own calculations. Data retrieved 15/7/2015.

Note: Data for the Netherlands refer to 2010 instead of 2012. No data available for Ireland and Croatia, thus they are not featured in this figure. Foreign students also encompass students from outside the EU.

In 2014, the Science and Technology Select Committee of the UK House of Lords published a critical report about the drop the UK has seen in foreign STEM students, "International Technology, Engineering and Mathematics STEM Students" (Science and Technology Committee, 2014).

The study acknowledged that it is difficult to tease out all the underlying causes of the drop in the number of foreign STEM students. However, the study found that changed immigration policies, foreign students' perceptions of an unwelcoming climate, and a contradictory policy framework that aims to reduce net immigration while encouraging international students to study in the UK, in combination have led to a downward spiral, which could impact UK's future 'soft power.'

World Education Services (WES) has analysed global mobility patterns of international STEM students, drawing on data from the Institute of International Education (World Education Services, 2014). The data show that in 2014 more than one out of three international students in the US were enrolled in science, technology, engineering, and mathematics (STEM). Over five years, the US saw a 27 % increase in the number of STEM students. Factors that have driven these developments in the US are:

- The availability of government scholarships from students' home countries, exemplified by the recent surge of students from Brazil and Saudi Arabia.
- A policy environment focused on attracting STEM students, as exemplified by the extension of Optional Practical Training (OPT) to a maximum of 29 months for international graduates with STEM degrees, and by the increase the number of work visas issued to STEM graduates from US universities, under proposed immigration reform bills (Mamun, 2015).
- Visa policies have a major impact on the number of STEM students. Due to the effects of tightened visa policies in the UK (Morgan, 2015), the UK witnessed a two percent decline in international STEM enrolments in 2013 compared to 2012, and the same happened in Australia that also tightened visa policies. In contrast, Canada has seen continuous growth in recent years enabled by immigration-friendly visa policies.

The analysis shows that differences in how international students from third countries are defined makes it difficult to get concise data on how large an employment potential non-EU STEM students represent in each of the Member States.

In recent years, China and India have been the two dominant countries when it comes to international students in the USA. An increase in GDP in Nigeria has resulted in more Nigerian students studying abroad. In the USA, the number of STEM students from Saudi Arabia grew by 143 percent from 2010 to 2013.

The above figures illustrate the extent to which divergent enrolment trends of international STEM students from different parts of the world depend not merely on the perceived quality/cost/ratio of STEM programmes offered across the world. Immigration, labour market, and economic policies in the receiving countries as well as grant and credit arrangements in the sending countries all influence whether enrolment of international students in STEM studies have an effect on the supply of STEM graduates.

3.4.2. Mobility and migration of the STEM workforce

In 2009, the EU adopted the Blue Card Directive¹¹ aimed at attracting highly-skilled nationals. This directive is a key feature of the Commission's policies of legal migration. The Blue Card Directive aims to attract and retain highly skilled such as STEM professionals. It is too early to assess its success, due to a late implementation of the Directive and the absence of national statistics for 2013. An evaluation carried out by the European Commission points out that the impact of the EU Blue Card so far has been limited (European Commission, 2014b) with only 3,664 Blue Cards issued in 2012 and 15,261 issued in 2013. Most Blue Cards were issued by Germany and Luxembourg, and the main countries of origin are India, China, Russia, the USA and Ukraine. The report underlines the need for much better data on high-skilled migration to inform European policy-making. Another study (European Commission, 2013) concludes that in particular in the EU 15 progress was achieved through policy making aimed at attracting high-skilled professionals.

Recent concerns about STEM professionals have led to greater focus on the intra-European mobility of STEM professionals.

Spain is one of the EU countries that is affected by migration of STEM graduates. High unemployment and temporary and part-time jobs aggravate labour market opportunities also for STEM graduates. The current Spanish emigration is dominated by higher education degree holders and PhDs, who are more likely to speak other languages than Spanish. Employment rates and job security are usually higher than average for Spanish STEM graduates. Nevertheless, the opportunity cost of graduating with a STEM qualification does not to justify the perceived extra effort for many students, especially when taking into account that some disciplines in social sciences and health sciences present the same or better employment rates than STEM disciplines, according to Spanish case study.

Engineering, production, ICT and telecommunications activities comprise around 70% of the international job offers listed in Spain. Among those graduates that are willing to move abroad to find a job, the preferred countries are the UK, US, France, Germany and Italy (Adecco, 2015; Esade, 2015). The main reasons given by Spanish graduates that have moved abroad are opportunities to gain professional experience and lack of job security in Spain. More than 50% of those surveyed by Adecco state that they would be willing to return to Spain if conditions improved or if they found a good opportunity to return.

Emigration of STEM graduates from Spain to other European countries is now constant, and interviewed experts suggest that Spanish STEM graduates are generally well thought of abroad and are in demand, especially in middle-management positions,¹² provided they are competent in the language of their destination country, according to the Spanish case study. Some of the qualities that are attributed to Spanish STEM graduates working abroad include

¹¹ <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=URISERV:l14573>

¹² See <http://www.idealista.com/news/finanzas-personales/laboral/2014/08/22/730679-soy-espanol-donde-quieres-contratarme-ingenieros-y-arquitectos-entre-los-mas> and <http://www.expansion.com/2012/06/22/empleo/mercado-laboral/1340377303.html> and http://www.elconfidencial.com/espana/2015-04-13/boom-de-ingenieros-espanoles-singapur-firma-un-convenio-para-facilitar-la-contratacion_757425/

good scientific backgrounds, project/time management skills, problem-solving skills, and the ability to learn new topics quickly and integrate new knowledge.

The Polish and the Bulgarian case studies report bottlenecks impacted by emigration of STEM professionals, even if there is anecdotal evidence that many Polish STEM graduates often end as underemployed in low-skilled service jobs when they emigrate, at the same time as foreign direct investments in both Poland and Bulgaria are driving up salary levels for STEM graduates.. The Polish economy is projected to continue to show positive growth rates; foreign direct investment in Poland and in Bulgaria are leading to pressures on the labour markets and the arrival of foreign firms tends to have a positive effect on the working and salary conditions of STEM professionals in the two countries. In both countries, the primary driver for foreign direct investments is the repudiated quality of STEM graduates in the two countries, which in Poland in particular stands in contrast to local employers complaints that Polish STEM graduates lack employability skills, according to the Polish case study. A spill-over effect in Poland has been for example than one of the US firms that has located in Poland has started to invest in Polish higher education through a grant scheme. The difference in expected wages and working conditions and opportunities in different countries in the EU is the main cause for the brain drain trends within the EU (Nedeljkovic, 2014). The realities of being a high skilled migrant - unable to find employment corresponding to ones skills - at times paint a quite different picture.

Some STEM graduates see short- term mobility can be a means to find better paid employment and career opportunities once they have gained some experience. This is for example the case for some Polish and Bulgarian STEM graduates. There are a range of factors that trigger STEM graduates from for example Poland, Bulgaria, Spain to look for temporary employment in the UK and Germany. These are the perceived volume of 'early career' entry positions in the two countries, the perception that recruitment processes are fair and transparent in the countries, and expectations that employment in the two countries will offer opportunities to work in world class industrial laboratories. (European Commission, June 2014).

Compared to the pre-crisis period there has been an increase in the overall level of educational attainment among those undertaking labour mobility within the EU. The proportion of highly educated among recent intra-EU movers has increased substantially (from 27 % in 2008 to 41 % in 2013) and the proportion of recent intra-EU movers, that work in 'high-skilled occupations' (ISCO 1-3), increased from 26% in 2008 to 34% in 2013 (ibid).

There has been an increase in intra-European mobility of professionals in 'professional, scientific and technical activities' (from 4.1% to 5.5% or +1.4 pp.) and education (from 3.6% to 4.9% or +1.4 pp). 'Information and communication technologies' has also seen an increase in the share of employment of recent intra-EU movers increasing (ibid). The data indicate that employment of intra-EU movers acts as a buffer for the economies of the destination countries.

3.5. Moving towards digitally mediated labour markets?

In the USA there is a growing tendency to source highly specialised STEM staff on an ad-hoc basis to cut costs and to expand access to a pool of highly specialised STEM professionals as needed and regardless of their location (Zysman & Kenney, 2015). If this trend becomes more prominent in Europe it could fundamentally change the dynamics of skills supply and demand in fields like STEM. The digital platform *Upwork*¹³ is particularly used by STEM freelance specialist and companies that deploy STEM skills across a range of sectors. The profile of the current users shows that the platform is increasingly used outside the USA to mediate highly specialised work. Recently, McKinsey claimed that the digital platform economy is likely to become an answer to managing the access to highly specialised talent (Manyika, et al., 2015). The downside of these platforms are that they leave the individual with little income security or social and health benefits, and current data indicate that these platforms drive down average wages gained per hour also for specialised

¹³ www.upwork.com

work mediated through platforms such as *Upwork*. Inno360 is another example of a digital service company that offers to identify global talent pools matched to a particular need and based on deep mining of the internet with references to individuals or groups through citations, patents, scientific journals, books, etc. In the medium term, matching talents to tasks through digitally mediated structures could have major disruptive impact on global high skilled labour markets (Accenture, 2014). The projected growth of STEM graduates in countries such as China and India could result in three quarters of the global STEM graduates being produced in the combined BRIC countries by 2030. The EU and the United States will be well behind with respectively 8% and 4% of STEM graduates by 2030 (OECD, 2015). This makes it more plausible that we will see other forms of mobility growing in the coming years enabled by the digital economy.

As the above shows, the economic crisis has driven mobility of STEM professionals of both students and graduates. On the one hand, improved mobility of high skilled professionals such as STEM professionals is at the heart of the European education and employment agenda, and can be one of the means to overcome shortages of professionals in different regions of Europe. On the other hand, there are also negative effects of inter-European STEM mobility seen from a graduate perspective. There is evidence that STEM graduates from countries such as Spain, Italy, Poland, Romania and Bulgaria who seek employment in EU countries with better employment prospects are at a bigger risk of ending up in temporary contracts or being underemployed in low wage service jobs with the greatest risk of becoming unemployed. Countries such as Poland and Bulgaria are also affected by a brain drain which impacts growth opportunities and potentially also foreign direct investments that are human capital driven, for example in ICT and software development.

How short and more permanent forms of mobility will play out in the future is highly uncertain. Developments in cloud technologies and digital platforms could pave the way for sourcing and *auctioning* human capital. In the high-skilled STEM labour markets, the risk of security breaches and loss of important tacit innovation know-how can be reasons for companies to refrain from making extensive use of the digital platform economy in job functions that are core to the business. However, for competitive reasons companies could move to even more advanced forms of automation and digitalisation to reduce costs of labour even further, and for specialised SMEs in remote regions of Europe the emerging digital platforms mediating skills and short-term tasks could from a company perspective present a viable option to gain access to the global STEM talent base. However, from a labour market policy perspective these developments should be monitored closely due to their potential negative impact on working and salary conditions.

4. Current STEM employment and unemployment

The previous chapter showed that the pool of STEM professionals within the Member States is composed not only of nationals. The mobility of EU and non-EU STEM students and STEM graduates has increased the high skilled labour reserve in some Member States while it has led to a brain drain in others. This chapter further discusses current trends in the STEM labour markets.

In spite of the economic crisis, employment of STEM professionals increased so that by 2013 the number of STEM jobs was around 13% higher in the EU than in 2000 in absolute terms (Cedefop, 2014 a).

At an aggregate level, data from Cedefop show that STEM employees constituted 6.6% of the total European workforce in 2013, up from 6.1% in 2003, with close to 15 million STEM employees.^{14 15} Around 3 million (21%) of the estimated 15 million STEM professionals were employed in high-tech industries while 12 million (79%) were employed in non-high-tech industries (Goos et. al, 2013).

The unemployment rate of STEM professionals has remained low compared to the overall unemployment rate. The STEM unemployment rate was consistently below 4% in the 2000–2010 period (Goos et al).

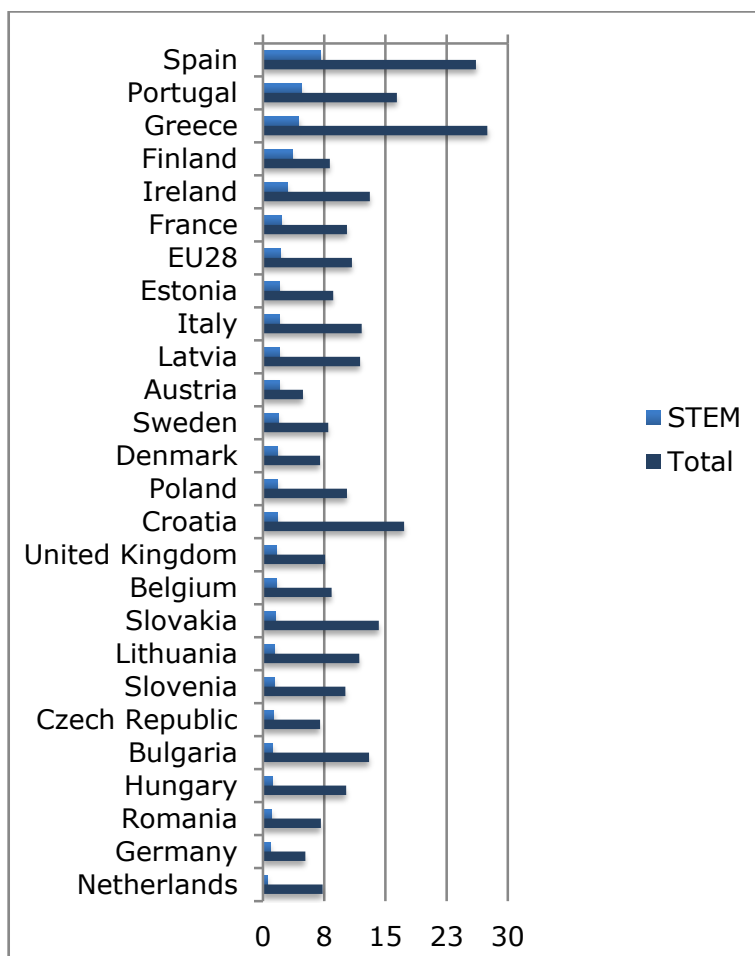
In a more recent study carried out for the European Union, the STEM unemployment rate was found to be as low as 2% at the EU level in 2013 (Caprile, et al., 2015).

Figure 4-1 shows the unemployment rate for STEM professionals and the total unemployment rate in 2013.

¹⁴ ISCO 25 employees are not included in this figure. Cedefop groups ISCO 24, 25 and 26 together in the group 'Business and other professionals' and it is not possible to separate ISCO 25 from this group. Thus, the figure includes ISCO 21, 31 and 35.

¹⁵ Please note that there are differences in the size of European STEM professionals due to differences in the definitions. According to Eurostat, the HRST workforce corresponds to 20.7 million. The definition of STEM professionals is based on qualification levels, while the definition of STEM employment is based on the occupation. STEM professionals also includes both employed and unemployed.

Figure 4-1: STEM unemployment rate and total unemployment rate, 2013 (%)



Source: Caprile (2015)¹⁶

There were approximately 400,000 unemployed STEM professionals and associate professionals in 2013 in the EU28 (Goos 2013). 56% of these were STEM associate professionals, typically graduates with a medium cycle or short cycle tertiary degree, and 44% STEM professionals typically with a long cycle Master’s degree. The number of unemployed was low in those STEM professional occupations with most pronounced reported skill shortages (see below). There were around 60,000 unemployed mechanical, electrical and other engineers and almost no unemployed ICT professionals.

4.1. Wage differentials and wage growth for the STEM workforce

Wages are another proxy used to show the relative demand for particular professionals. Table 4-1 shows that across the economy, STEM professionals earn on average more than other groups do (Goos 2013).¹⁷ Part of the large wage differential could be attributed to the STEM professionals' higher qualification levels. However, even after controlling for confounding factors to isolate the effect that employment in a STEM occupation alone has on wages, a substantial STEM wage premium is revealed. On average, STEM professionals across the EU earn a 19% premium, and a STEM premium was evident in all 26 examined

¹⁶ Source: Calculation Caprile – Fondazione Brodolini 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.

¹⁷ Excluding Malta and Croatia.

countries, after checking for confounding factors. The highest STEM wage premium was found in Latvia at close to 55%, while a 17% premium in Belgium was the smallest (ibid).¹⁸

Table 4-1: Wage differentials and wage growth

	Average STEM wage premium (2010)%	Average annual change (2005-2010)	
		STEM %	Non-STEM%
Austria	28	3.5	3.0
Belgium	17	1.4	1.4
Bulgaria*	45	24.6	18.3
Cyprus***	43	5.1	4.9
Czech Republic	28	9.9	9.3
Denmark	34	4.0	2.8
Estonia	35	13.5	11.3
Finland	35	3.7	3.7
France	42	0.9	2.2
Germany	42	0.7	0.1
Greece	42	7.7	6.9
Hungary	41	5.9	4.9
Ireland***	53	5.5	4.0
Italy	47	4.1	2.2
Latvia*	55	12.8	10.5
Lithuania	53	11.3	10.7
Luxembourg	33	2.0	3.4
Netherlands	20	2.1	3.4
Poland	48	10.1	8.1
Portugal	69	6.1	5.9
Romania**	69	7.2	7.4
Slovakia	26	13.6	13.6
Slovenia	46	6.4	6.5
Spain	50	3.4	3.0
Sweden	30	0.1	0.9
United Kingdom	36	-1.5	-1.7

Source: Replicated from: (Goos, et al., 2013)

Note: Malta and Croatia excluded. *Average annual change is for the years 2007-2010. **Average annual change is for the years 2007-2009. ***Average annual change is for the years 2005-2009.

¹⁸See Figure 12 in (Goos, et al., 2013) for the regressed STEM wage premium.

Table 4-1 also reveals that 21 countries saw the average annual wages for STEM occupations grow at a higher pace than wages for non-STEM occupations, while STEM wages in Sweden, France, Luxembourg, the Netherlands, Romania and Slovenia grew at a slower pace than non-STEM wages (Goos et. al, 2013).

4.2. Vacancy rates for STEM jobs

Based on available data it has not been possible to estimate the current vacancies for STEM occupations. The EU Vacancy and Recruitment Report has insufficient data to make a comparison of job hiring across educational fields and countries (European Commission, 2014 d). The European Vacancy monitor, however, provides an overview of the top occupations with the strongest employee growth in the period from 2008- 2011.

Table 4-2: vacancies for STEM occupations

Country	Rank	Occupation	Employment 2008	Job growth
AT	5 th	Computing professionals	39,400	+5.400
BE	1 st	-do-	99,300	+21.600
CZ	8 th	Ass. Computer professionals	61,500	+7,100
DE	1 st	Computing prof	451,900	+67,500
DE	7 th	Architects, engineers, and related prof	1,055,800	+47, 200
ES	6 th	Computing professionals	135,500	+15,500
FR	2 nd	-do-	372,700	+47,700
FR	6 th	Production and operations managers	738,600	+33,600
GR	5 th	Computer professionals	14,000	+3,900
GR	8 th	Computers ass. Prof	15,700	+3,200
HR	9 th	Computer professionals	7,800	+1,600
HU	10 th	Computer ass professionals	23,000	+3,700
IE	1 st	Production& operation managers-	69,700	+6,200
IE	2 nd	Computer professionals	25,900	+3,800
LU	1 st	Computer professionals	4,900	+1,300
LU	5 th	Architects, engineers, related prof.	6,500	+1,100
LU	10 th	Physical, engineering, science tech	3,000	+900
PL	3 rd	Architects, engineers, related prof.	227,500	+34,000
PT	4rh	Production& operation managers-	34,600	+10,100
SE	2 nd	Production operations managers	79,300	+9,800
SE	3 rd	Computer professionals	112,200	+9000

Country	Rank	Occupation	Employment 2008	Job growth
SK	4 th	Computer professionals	17,600	+5,900
SK	10 th	Production & operation managers-	36,400	+4,400
SI	6 th	-do-	10,400	+1,400
UK	6 th	Computer professionals	418,800	+23,000

Source: European Vacancy Monitor- 2014 - Statistical Annex

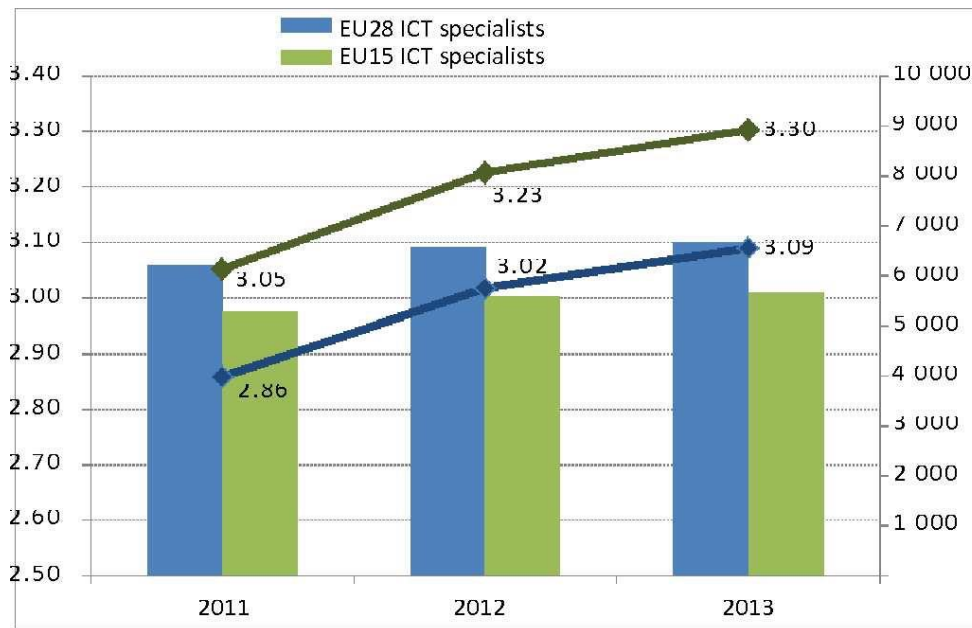
Table 4-2 shows that computer professionals were by far the professional occupational field with the highest growth rates in the period.

Parallel to the job growth there were also job losses within STEM fields in the same period, in particular among physics, engineering, and science technicians. The following countries reported job losses in those fields: BE (-10,000), BG (-4,600), DE (-92,200), also reporting the loss of 24,800 jobs among production and operations managers). DK reported job losses among physical, engineering and science technicians (-10,400). The same applied to FR (-36,800), GR (-11,400), HR (-6,900) and IT (-92,200). Lithuania was among the few countries that reported job losses in architect, engineering and related fields (-14,100 jobs). Job losses among physical, engineering and science technicians were seen in LV (-9,500), MA (-900), and NL (-12,100). At the same time NL also saw job losses among architects and engineers (-21,000), as did Sweden (-9,700). Finally, the UK saw job losses among physical, engineering and science technicians (-38,000).

The figures are unfortunately quite old. However, with the number of job losses seen among physical, engineering and science technicians in the EU, the question remains whether enough has been done to further train and educate those STEM associate professionals who lost their jobs in the beginning of the crisis. This is particularly important because recent country information on bottleneck vacancies indicates that employers are reluctant to hire STEM professionals or associate professionals with labour market experience if they have been unemployed for a period, out of fear that their qualifications are outdated (Attström, et al., 2014).

The current and recent situation regarding the STEM employment situation shows that the job growth has particularly occurred in ICT. Figure 4-2 shows the relative growth rate of ICT specialists from 2011 to 2013.

Figure 4-2: relative growth of ICT specialists, 2011-2013



Source: OECD 2014- Skills and Jobs in the Internet Economy

Note: ICT specialists are defined here by the OECD as the sum of the following ISCO 2008 codes: 215 Electrotechnology engineers, 251 & 252 ICT professionals, 351 & 352 Information and Communication technicians, 742 Electronics and Telecommunications installers and repairers.

Wage data, a proxy for demand, indicate that STEM professionals in the EU 28 are on average better paid than other professionals. However, this could also hide the possibility that STEM professionals who are employed in ICT and services, including in the financial sector and in consultancy, on an average are paid much higher salary levels than for example in advanced manufacturing. While the data show that there was job growth in the early phase of the crisis in many countries in the EU in computing professions, a parallel job loss occurred, particularly among physical, engineering and science technicians. Data do not allow us to track whether the large number of associate STEM professionals who were laid off in the early part of the crisis have found employment within their fields.

5. STEM skills demand

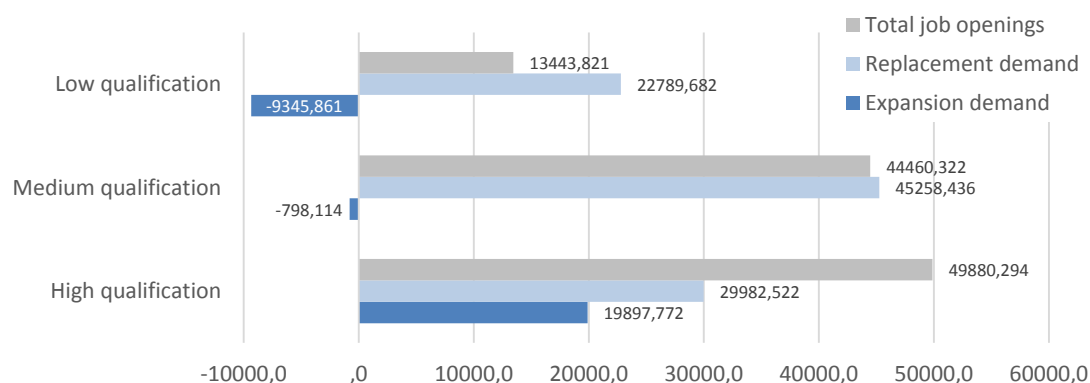
5.1. Projected STEM employment and job openings towards 2025

In the previous chapters, we showed how STEM skills supply at present is triggered by a complex range of factors. We also showed that the future supply could be impacted by major disruptive change in how skills supply and skills demands are mediated and matched. But future STEM skills demand is also impacted by a range of uncertainties which should be taken into account when skills projection figures are referred to in the policy discourse. The previous chapter showed that, in particular, in the occupational field of computing professionals there was a marked job growth in several countries in the EU during the early part of the crisis. Although it is estimated that the demand for STEM skills will continue to grow, projections indicate that at an aggregate EU level supply of STEM skills will meet demand. There could even be an over-supply, according to projections. There are uncertainties regarding future demand for STEM professionals and associate professionals, both in quantitative and in qualitative terms. The latter related to such factors as more advanced levels of automation, and a growing digitalisation of the economy. The match at an EU aggregate level does not imply that there could be shortages or mismatches related to particular study fields, occupations, and geographies.

Cedefop estimates around 3.4 million job openings from 2013 to 2025. This includes not only recruitments for new jobs (over 1 million), but also to replace STEM professionals who retire or leave for other reasons. Job openings are anticipated to increase in all EU28 countries according to Cedefop.⁹ Slovenia, Malta, Austria, Hungary, Finland and Luxembourg are the countries in which the share of STEM professionals in total job 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%) (see also the chapter below on bottleneck vacancies in the EU).

Cedefop's projections on skills demand up to 2025 illustrate that the majority of job openings are expected at higher skill levels. Parallel to these developments, it is projected that there will be 9.3 million fewer low-skilled jobs in 2025. Thus, Cedefop's projections build on the assumption that the structural changes in the economy will lead to increasingly knowledge-intensive employment in high-skilled jobs.

Figure 5-1: Job openings forecast by qualification at EU level in 2025 (in 000s)



Source: (Cedefop, 2015). Data retrieved 17/7/2015.

Table 5-1 shows that most countries are projected to experience a double-digit expansion in STEM employment, covering both high and medium level qualifications. However, a contraction in STEM employment is projected to various degrees in Bulgaria, Romania, the Netherlands, Germany, Sweden and Slovakia. In 2013, the largest STEM sectors were found in Germany and France, followed by Italy, the United Kingdom and Spain. Towards 2025, it is projected that France will surpass Germany as the country with the most STEM employees. The employment forecast comprises STEM professionals and associate professionals.

Table 5-1: Employment forecast in STEM occupations at the tertiary level, by country (in 000s)

	2013	2020	2025	Change 2013-2025 %
EU28	14,739.19	15,898.80	16,520.09	12.1
Austria	321.00	365.20	400.18	24.7
Belgium	281.90	328.49	366.72	30.1
Bulgaria	137.27	123.24	112.63	-17.9
Croatia	103.50	111.81	117.92	13.9
Cyprus	13.65	17.54	20.53	50.4
Czech Republic	475.27	543.10	592.87	24.7
Denmark	191.41	223.40	244.46	27.7
Estonia	34.26	36.94	38.11	11.2
Finland	185.46	205.52	214.66	15.7
France	2,696.55	3,117.46	3,344.30	24.0
Germany	3,174.06	3,166.61	3,106.21	-2.1
Greece	158.95	177.88	190.54	19.9
Hungary	210.09	212.78	215.85	2.7
Ireland	78.18	91.23	101.03	29.2
Italy	1,590.35	1,842.01	1,998.42	25.7
Latvia	47.36	72.34	88.22	86.3
Lithuania	43.63	44.36	44.87	2.8
Luxembourg	21.53	24.41	26.21	21.7
Malta	10.47	12.06	13.33	27.3
Netherlands	395.99	383.74	372.51	-5.9
Poland	784.44	847.66	864.21	10.2
Portugal	228.41	239.03	246.43	7.9
Romania	464.10	428.15	392.01	-15.5
Slovakia	156.87	156.52	156.07	-0.5
Slovenia	62.25	70.04	74.52	19.7
Spain	1,006.61	1,166.05	1,262.88	25.5
Sweden	341.32	341.03	340.95	-0.1
United Kingdom	1,524.29	1,549.28	1,573.98	3.3

Source: Cedefop (Skills forecast, 2015). Data retrieved 17/7/2015.

Note: STEM occupations are defined as science and engineering professional (ISCO 21) and science and engineering associate professionals (ISCO 31, 35).

Table 5-2 more or less tells the same story. It shows the projected job openings in STEM occupations in 2025. The data show that the replacement demand for STEM professionals

and associate professionals will be significant in scale for countries such as Germany, France, Italy, and the UK, while the expansion demand varies across the EU 28. It should be noted that only Germany has a negative projected expansion demand; at the same time an aging STEM workforce could create a massive replacement demand.

Table 5-2: Job openings forecast in STEM occupations (professionals and ass. professionals) by country in 2025 (in 000s)

	Expansion Demand	Replacement demand	Total job openings
EU28	1,780.90	5,062.06	6,842.97
Austria	79.18	76.54	155.72
Belgium	84.82	76.42	161.24
Bulgaria	-24.64	73.08	48.44
Croatia	14.42	63.08	77.49
Cyprus	6.88	3.79	10.67
Czech Republic	117.60	147.74	265.34
Denmark	53.05	97.13	150.18
Estonia	3.85	15.55	19.40
Finland	29.20	80.58	109.78
France	647.75	671.25	1,319.01
Germany	-67.85	1,271.01	1,203.17
Greece	31.59	66.80	98.39
Hungary	5.76	87.54	93.29
Ireland	22.85	25.63	48.48
Italy	408.06	462.64	870.70
Latvia	40.86	33.28	74.14
Lithuania	1.24	21.05	22.29
Luxembourg	4.68	10.49	15.17
Malta	2.86	3.43	6.29
Netherlands	-23.49	149.79	126.30
Poland	79.77	276.64	356.41
Portugal	18.02	55.78	73.80
Romania	-72.09	174.55	102.47
Slovakia	-	44.92	44.12
Slovenia	12.26	18.48	30.74
Spain	256.27	324.41	580.68
Sweden	-	163.06	162.69
United Kingdom	49.68	567.41	617.09

Source: Cedefop (Skills forecast, 2015). Data retrieved 17/7/2015.

Note: STEM occupations are defined as science and engineering professional (ISCO 21) and science and engineering associate professionals (ISCO 31, 35).

As Cedefop notes, projections in science, technology, and knowledge-intensive occupations are highly uncertain since a range of factors can impact demand. One example is an increase in the global sourcing of R&D, driven by increased specialisation in how knowledge is used and produced, which is already seen in countries like Denmark. Another factor that can impact future skills demands is the effects of advanced automation and digitalisation (Handel, 2014; OECD, 2014 a).

The job creation and job destruction effects of ICT have been widely debated (OECD 2014). Aside from that there is already existing evidence that digital technologies have a major impact on the nature of skills that are demanded of STEM professionals, for example in advanced manufacturing. The German experts interviewed underlined that the growing ICT intensity of STEM occupations may not be fully captured through the existing methodologies to forecast future STEM skills demands in Germany. The interviewed German experts suggest that from a curriculum perspective it is not sufficient to have a quantitative estimate of the future demand for STEM professionals. In order to future-proof the monitoring of STEM skills supply and demand, it is necessary to understand how work processes change as a result of a growing ICT and data intensity in STEM occupations in order to ensure a timely update of curricula, for example in different fields of engineering.

Skills projections should therefore not only look into the quantitative changes in demand, but they should also try to assess the factors that can influence demand in a qualitative way, so that policy makers, companies and higher education institutions can take timely action. The following chapter discusses some of the drivers and trends that could affect future demand in a qualitative way.

5.2. Summary – STEM skill supply and demand

The supply and demand of STEM graduates continues to be of major concern to industry leaders and policy makers due to the traditional importance of STEM graduates for technology- driven growth, and due to a major replacement need in the coming years as the senior STEM workforce gradually retires. Projecting the demand in high-tech sectors is complex, as a range of drivers can impact demand quantitatively and qualitatively as discussed above. Other critical uncertainties are the choice of study of future high school graduates, and the career choice and labour market destination of STEM graduates - including the relative attractiveness and opportunities offered in traditional core STEM sectors in comparison with a growing service sector. Furthermore, the relative mobility of STEM graduates within the EU and mobility of non-EU STEM professionals will impact supply and demand.

Cedefop's projections suggest that the STEM labour market will expand by 12.1% by 2025, a much higher rate than employment in other professions, due to an increasingly knowledge intensive economy.

Goos et. al (2013) show that STEM workers generally experience more favourable labour market outcomes expressed by lower unemployment rates, a clear STEM wage premium, and strong wage growth. In essence, this also reflects the relatively high demand for STEM workers compared to other professions across the economy.

The dominant discourse is that the overall STEM skills gap is growing, and enterprises generally cannot meet their STEM labour demand and skill needs. This is argued to be a big obstacle to economic growth in the years to come (Business Europe 2011).¹⁹ However, when comparing quantitative STEM skill supply and demand, as discussed in the previous sections, there are no clear indications of an overall shortage of STEM graduates in the EU at present or in the medium- to long- term future. This goes to show that better and more consistent data are needed to inform the future dialogue on STEM supply and demand. As

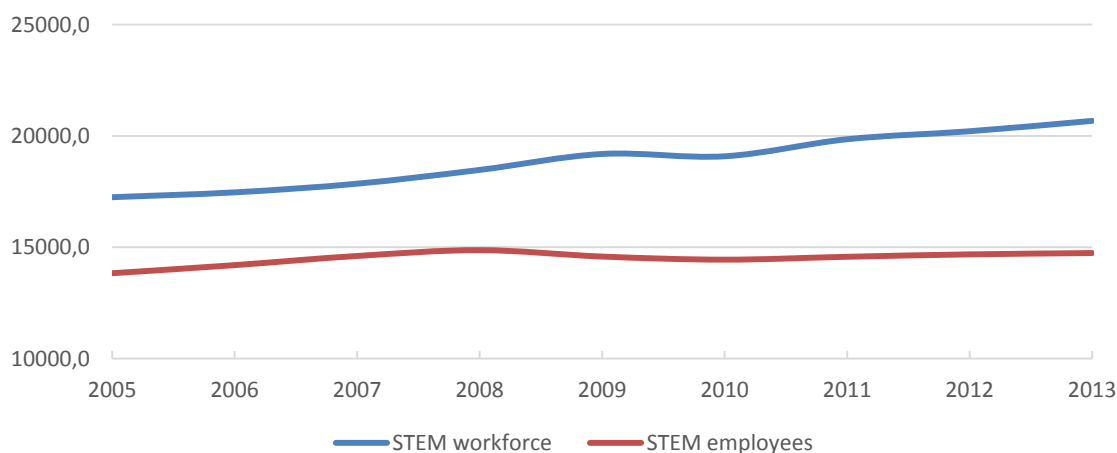
¹⁹ Business Europe (2011). Plugging the skills gap, the clock is ticking. <http://www.bussinesseurope.eu/Content/Default.asp?PageID=650>

figure 5-2 indicates, the current and historical STEM workforce stock covers the demand for STEM professionals sufficiently as expressed in STEM employment. However, these numbers should be interpreted with caution due to inconsistencies in STEM definitions.²⁰

In particular in the UK, there is evidence that the expansion of higher education has resulted in a growing employer differentiation between different ‘types’ of graduates, and with employers’ putting a higher premium on graduates from the traditional prestigious universities. This could explain why so many UK STEM graduates end up in relatively low paid service sector jobs with limited opportunities to deploy their STEM knowledge and skills. There is some evidence that the notion of ‘employability’ has a much wider meaning, and therefore cannot be reduced to a list of skills that can be ticked off in curricula if covered. A UK study concludes (Hinchcliffe 2011) that employers place value on a wider range of dispositions and abilities, including graduates’ values, social awareness and generic intellectuality — dispositions that can be nurtured within HE and further developed in the workplace.

The projected over-supply of STEM professionals and associate professionals is based on aggregate figures, but nonetheless could indicate that the quantitative supply of STEM employees is most likely sufficient to cover demand at the aggregate level, and there might even be an overall over-supply at the aggregate level. Projected developments in the aggregate supply and demand do not imply that there won’t be an under-supply of graduates with particular STEM profiles or shortages in some EU countries and regions of Europe, for example due to the high level of specialisation in many STEM-intensive professions. It should also be taken into account that current bottleneck vacancies (Attström, et al., 2014) are in particular found in ICT services and engineering. Furthermore, employer demands tend to be very specific and associated with particular fields of study. STEM is therefore not a very useful terminology to use as a basis for action on future supply and demand for professionals and associate professionals in the fields of science, technology, engineering and maths. From a qualitative perspective German experts suggest that ICT needs to be considered as an integrated element in future curricula for science, technology, engineering and maths, as the Germany case study shows.

Figure 5-2: STEM professionals and associate professionals and STEM employees at EU level, 2005 – 2013 (000s)



Source: Eurostat (hrst_st_nfieage) and Cedefop (Skills Forecast, 2015) and own calculations. Data retrieved 17/7/2015.

Note: STEM workforce defined by educational background in Science, Mathematics, Computing, Engineering, Manufacturing and Construction (EF4_5) at tertiary level. STEM employees defined by employees in ISCO 21, 31 and 35 (excluding ISCO 25) occupations. A few countries including the UK lacked data for STEM workforce in

²⁰ Please note that the definition of STEM professionals is based on the type of tertiary degree, while the definition of STEM employment is based on occupation. STEM professionals also include architecture and building (EF58), while STEM employment does not include information and communications technology professionals (ISCO 25), which are considered STEM occupations.

some years. In those cases, data for the individual countries refer to the nearest available year. This implies that the EU28 STEM workforce is an estimate for the years 2005, 2006, 2007, 2011, 2012 and 2013. Due to inconsistencies in STEM definitions, these numbers should be interpreted with caution.

The picture remains the same looking towards 2025, as indications are that the overall STEM skill supply is sufficient to cover the future STEM skill demand, which is seen in table 5-3. Total job openings equals the projected number of STEM jobs that must be filled towards 2025 due to either expansion or replacement demand. From this it is possible to infer how many STEM jobs need to be filled annually and on average. At EU level and in most Member States, the yearly inflow of new STEM graduates (based on 2012 data) point to that the supply will match the average number of STEM job openings to be filled towards 2025.

Inwards mobility can influence the relative supply of specialised labour such as STEM professionals. Evidence from the analysis of bottlenecks in Europe (Attström, et al., 2014) suggests that companies outside the ICT sector at present seem to be reluctant to recruit STEM professionals or associate professionals from another country from the EU or outside the EU. Reasons are, according to employers, that they do not have the same level of trust in international qualifications as in nationally awarded qualifications. Migrants with a tertiary qualification for example in STEM are also more likely of being under employed in jobs that do not match their formal qualifications. (European Commission, 2013a)

The literature review and data analysis clearly shows that companies tend to prefer to recruit future employees with labour market experience. This includes experience most likely to reduce the expense of introducing a new employee to the job plus it provides a guarantee of basic employability skills. The majority of the tertiary education programmes in STEM do not offer work placement opportunities, which is why it is so important that STEM students in other ways through curriculum design and pedagogical practices have opportunities to engage with external partners including SMEs as this can provide some insights the nature of work in STEM intensive occupations. As it is, even if STEM skills are high in demand, in most of the EU STEM graduates meet transition barriers (Shapiro Hanne, 2014), which are not well documented or understood at present, and for mobile STEM graduates the barriers may be even more fundamental in nature. Denmark, Latvia and Luxembourg are projected to have a deficit regarding their future STEM skill supply. Again, it must be stressed that the numbers should be interpreted with caution due to inconsistencies in STEM definitions and other uncertainties associated with fundamental assumptions.

Table 5-3: STEM Job openings (professionals and associate professionals) forecast and STEM graduates (in 000s)

	Total job openings (2025)	Average annual job openings (2013-2025)	STEM graduates (2012)
EU28	6,842.97	526.38	908.20
Austria	155.72	11.98	14.51
Belgium	161.24	12.40	14.47
Bulgaria	48.44	3.73	11.59
Croatia	77.49	5.96	7.56
Cyprus	10.67	0.82	0.89
Czech Republic	265.34	20.41	18.90
Denmark	150.18	11.55	9.45
Estonia	19.40	1.49	2.12
Finland	109.78	8.44	12.21
France	1,319.01	101.46	140.71

	Total job openings (2025)	Average annual job openings (2013-2025)	STEM graduates (2012)
Germany	1,203.17	92.55	155.71
Greece	98.39	7.57	15.48
Hungary	93.29	7.18	10.25
Ireland	48.48	3.73	11.87
Italy	870.70	66.98	62.16
Latvia	74.14	5.70	3.17
Lithuania	22.29	1.71	6.89
Luxembourg	15.17	1.17	0.13
Malta	6.29	0.48	0.74
Netherlands	126.30	9.72	14.95
Poland	356.41	27.42	88.85
Portugal	73.80	5.68	18.61
Romania	102.47	7.88	44.71
Slovakia	44.12	3.39	12.56
Slovenia	30.74	2.36	4.31
Spain	580.68	44.67	68.22
Sweden	162.69	12.51	16.29
United Kingdom	617.09	47.47	140.89

Source: Eurostat (educ_grad5) and Cedefop (Skills forecast, 2015). Data retrieved 17/7/2015.

Note: STEM professionals are defined according to the awarded degree in Science, Mathematics, Computing, Engineering and Manufacturing at tertiary level. STEM employees are defined by occupational field of employment in ISCO 21, 31 and 35 (excluding ISCO 25) occupations. Part

6. STEM and the labour market: current evidence

The EU-level projections on STEM skills supply and demand suggest that there are no overall shortages of STEM skills at the aggregate EU level. Nevertheless, even though there appears to be an overall balance (or possible surplus) between aggregate STEM skill supply and demand, this does not imply that there are no skills mismatches²¹ and shortages in specific countries and regions of Europe, as the case studies illustrate. The characteristics of these regional shortages do not relate to STEM graduates as whole. In fact the nature of employer demand suggests that aggregate data are not useful to inform future policy action, and employers tend to refrain from the use of the umbrella term STEM in discussions about supply and demand of science, technology, engineering and maths graduates. This is because employer demand is most often highly specialised, and one study field within STEM can most likely not replace another.

The analysis of data sources including the country specific case studies shows that skills shortages are primarily related to specific engineering disciplines and ICT studies. In the UK this is also linked to the size of financial services and consultancy services, while in Germany the experts interviewed noted that across the STEM disciplines there is a growing need to integrate ICT in curriculum parallel with a growing demand for ICT specialists in for example software engineering. These developments are driven by a growing digitalisation in industry and growing data intensity closely associated with Industry 4.0.

6.1. Transition rates for recent graduates

Data from the EU 28 show that reported bottlenecks within STEM refer to highly specialised skills profiles. Furthermore, findings from across the EU suggest that employers seem to be reluctant to hire recent graduates who do not have labour market experience. In fact, the German experts interviewed suggest that STEM university college graduates who typically have been trainees in an enterprise during their study tend to find a job much faster than their university counterparts do. In Denmark, statistics show that Danish STEM graduates two years after completion have much higher gross unemployment rates than the average unemployment rate within their fields.

Table 6-1: Average gross unemployment according to disciplines- DK

Field of graduation	Time of graduation Less than 1 year ago in %	Time of graduation 1-2 years ago in %	Time of graduation 2-4 years ago in %	Time of graduation 4-9 years ago in %
Engineering university degree	37,0	8,6	1,8	1,3
Engineering university college	28,4	10,0	2,0	1,2
Master's of Science information technology	41,1	15,1	6,4	3,5
Science & Technology	37,3	13,1	4,2	3,4
Natural Sciences	33,6	12,9	4,2	3,4

Source: AC (2015) Confederation of Professional Associations monthly unemployment statistics – August 2015)

In spite of reported skills shortages across STEM fields in Denmark, the unemployment levels for Danish STEM graduates up to two years after graduation are notably higher than the average figure for more senior professionals. It is also worth noting that the graduates of

²¹ See OECD on sources on the topic of skills mismatches

practice-based engineering degrees offered by university colleges have a lower unemployment rate than university graduates the first year after graduation, after which it evens out. As part of a national programme to boost the innovation capacity in Danish SMEs with up to 250 employees, but with no or few tertiary graduates, companies can receive salary subsidy to employ a university or university college graduate for up to a year to work on a defined innovation project that the company and the graduate jointly have agreed on.²²

It is not sufficient to only consider overall supply and demand for STEM skills when examining the STEM skills mismatches (Sattinger, 2012). A number of other factors need to be taken into account; the general expansion of the higher education system, the graduate transition rate into labour markets and the factors that influence its speed, and employer recruitment patterns and what motivates these, including companies' absorptive capacity, which the Danish InnoBoster programme²³ described above addresses. Another factor is the sector differences in recruitment strategies. The UK case study reports a drop in company based training in recent years, which has also led to employers to a greater extent to look for new employees that can match demands on all parameters, in order to reduce the costs and productivity losses of workplace introduction. A European-level analysis of bottleneck vacancies indicates that, outside the ICT sector, employers tend to be reluctant to hire graduates from another EU country to meet their recruitment needs (Attström, et al., 2014). The engineering profession has devoted much attention to reduce international barriers to recognition of a profession (Dixon M 2013). There is some evidence from the interviews conducted and from data analysed that highly qualified STEM graduates without labour market experience are confronted with entry barriers to the core STEM labour market, leading to initial unemployment or the risk of underemployment, or employment in sectors and jobs with limited opportunities to further develop their core STEM skills. In many Member States, higher education systems have been expanded considerably in recent years leading to a growing number of graduates. The ambition has been to increase tertiary attainment as a driver of transformation towards a more knowledge-intensive economy. One of the limitations is that these policies have not sufficiently considered the other side of the equation, the European companies' absorptive capacity understood as their ability to make productive use of and further develop recent graduates. The annual European Innovation Scoreboard²⁴ illustrates the major differences that remain in the absorptive capacity of companies across the EU 28, which is for example illustrated in the scores in areas such as organisational innovation.

6.2. Under-employment

One of the negative effects of a low absorptive capacity is that it can lead to under-employment, which is a term used when graduates are employed in job positions where they do not fully make use of their level of knowledge, skills and competences. In the UK, the mass expansion of computer sciences courses have led to concerns about the proportions of undergraduates in computer science that end in low-paid jobs or under-employed (Shadbolt, 2015). The UK government has commissioned an independent review to assess the situation.

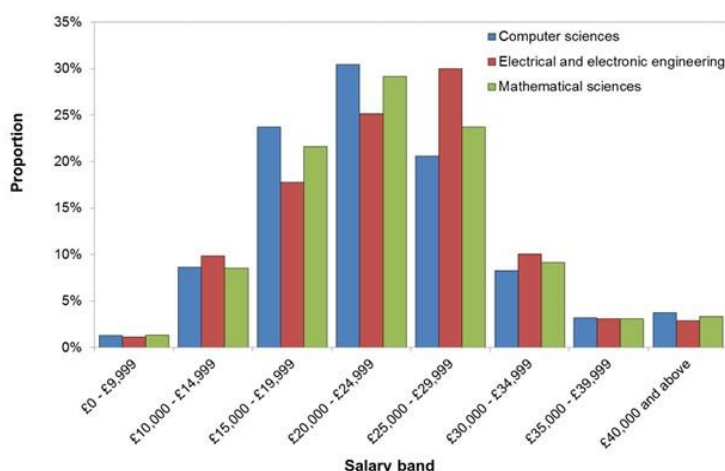
Figure 6-1 shows the distribution of salary levels for three groups of STEM professionals in the UK.

²² <https://aka.dk/jobinspiration/andre-genveje-til-nyt-job/videnpilotordningen>

²³ <http://innovationsfonden.dk/da/investeringstype/innobooster>

²⁴ ec.europa.eu/growth/industry/innovation/facts.../scoreboards/index_en.ht

Figure 6-1: Distribution of salary levels for three groups of STEM professionals



Source: (Shadbolt, 2015)

According to the review (which is expected to be finished at the end of November 2015) around 65% of computer science graduates who enter full-time paid employment within six months of graduating report earnings of less than £25,000. This compares with 55% of equivalent graduates from electronic and electrical engineering courses and 60% of those qualifying from mathematical sciences.

In parallel, there is some evidence that STEM professionals tend to receive less training than their colleagues who work in other job roles, which could affect employability in cases of layoffs as well as the overall mobility in the labour market (UCKES, 2015).

The OECD PIAAC study on adult skills reported several cases of under-employment in EU Member States such as Spain and Italy (Nieto, 2014). Often, this is a direct result of work organisation and managerial practices and reflects in general the lack of absorptive capacity in a firm.

In that context, it is interesting to note the value that companies attach to soft skills as shown in the Spanish and the Polish case studies. When companies state that they are not able to fill jobs, they point to issues such as *'lack of competences, a lack of experience and high salary expectations'*. The competences most valued for new recruits tend to be *'a positive attitude, work ethic, adaptation ability, teamwork and proactivity'* (Adecco, 2015). On the one hand, these company statements vary substantially from the analysis on job vacancies where employers tend to focus on very specific technical skills. On the other hand, these statements could also be 'code' for employer expectations of compliant employees who are willing to put in extra hours and undertake work for which they are over qualified, and they could signal that STEM graduates with little or no working experience are often not given proper support to take on their expected roles effectively. A recent study (Cabralles, et al., 2014) based on PIAAC data concluded in that respect that Spain presents one of the lowest on-the-job (OTJ) training rates in the EU27, 8% below the EU average rate and between 20-30% below the Scandinavian countries or the UK. Moreover, OJT rates are even lower for young graduates because of the Spanish de facto dual-employment structure. As young graduates are usually on fixed-term or temporary contracts, companies have fewer incentives to invest in their professional development (Lubin, 2014).

Hence, more research is needed to analyse the value of soft skills and what they mean in practice in labour markets for new graduates. Empirical research from 2013 on graduate identity and employability suggests that graduate employability not only varies depending upon the size of the company the sector, and management and work organisation practices, it also spans way beyond a set of 'employability' skills however broadly defined. What emerges instead is a multi-dimensional concept of identity and employment potential that comprises value, intellect, social engagement and performance (Hinchliffe Geoffrey 2011).

To inform the dialogue between higher education and industry, more knowledge is also needed regarding the labour market induction of STEM graduates and how the transition can

be facilitated through strong partnerships as part of the dialogue for modernisation of higher education in the EU.

The case studies include plenty of good examples of such partnerships. In Spain for example IBM Spain, Forética (CSR Europe's national partner) and the Polytechnic University of Madrid organised and participated in a 'Skills for Jobs' workshop, aimed at sharing good practice related to skills and 'employability' issues. Another example is the collaboration between the Spanish Royal Academy of Engineering (RAI) and the company Academy Cube. Academy Cube is a platform that combines e-learning materials with job-hunting, to facilitate the integration of young STEM graduates and professionals into European industry²⁵ (the initiative is focused mostly on ICT). The RAI welcomed the establishment of Academy Cube in Spain in 2013 and prompted companies, universities and public administration in Spain to participate in the platform. Currently 10 universities around Spain participate in this initiative.

The limitations of many of these initiatives are that they are small in scale, they are highly localised so they impact only very few of the overall annual STEM graduates. There is a need for examples of how such good practice partnerships have reached some level of scale and what have been the critical processes and steps.

The case studies and the data and analysed literature show that a large number of STEM graduates find employment in sectors that are traditionally considered as non-core STEM sectors. The German case study suggests that one explanation is that with the growing ICT intensity in many sectors of the economy the boundaries between what constitutes core STEM sectors and non-core STEM sectors converge as, for example, manufacturing becomes more service intensive with the development of Industry 4.0. Another explanation could be that STEM graduates have difficulties finding employment in traditional core STEM sectors and end up in a first job where they only make partial or no use of their core STEM skills. A survey conducted among Flemish STEM students found that a large number of STEM graduates started their careers in non-core STEM jobs (Van den Berghe & Martelaerede, 2012). The findings from the on-going UK review suggest that those STEM graduates who end up in micro-businesses are in jobs with managerial tasks, which is also one of the conclusions from the German case study. The mixed findings suggest that there is a need for much better data and more research on labour market transitions for STEM graduates. It is, however, not only graduates that are confronted with barriers in the transition to labour markets; companies - and particularly SMEs - may also be confronted with different types of barriers in their recruitment efforts of STEM graduates.

6.3. A company perspective on barriers to recruitment of STEM graduates

SMEs face very specific barriers to recruiting STEM professionals. First of all, SMEs will typically not have the internal resources to look for STEM graduates outside their country, and many graduates will be hesitant to look for employment in SMEs as they are often perceived to offer less attractive career options. Furthermore, a Danish study conducted as part of the review of the tertiary education sector in Denmark found that students - also in STEM disciplines - are most often not exposed to career opportunities in SMEs, for example through career guidance, joint projects or through placement schemes. In general, university professors report that they lack networks to SMEs and are not strategically supported to build these in most cases. Limited connections and networks to former graduates who may have found a STEM-related job in an SME are often an unexploited asset. The limited focus on SMEs as a career prospect for STEM graduates is a serious threat to kick-starting a job-rich growth in Europe and the transformation of Europe into a more knowledge-intensive and innovative economy. From a graduate perspective it is serious if this is a wider European phenomenon, due to the overall dominance of SMEs in the European economy. Apart from the trend of SMEs not being the preferred employment destination for STEM graduates, there is evidence that STEM graduates prefer to work in the bigger cities, which would impact how skill shortages play out in particular regions and could have a negative impact on knowledge driven growth in remote areas of Europe (Shapiro, et al., 2014).

²⁵ <http://www.academy-cube.com>

A study conducted by European Schoolnet and Intel (European Schoolnet, 2014) throws further light on STEM recruitment mismatches, in particular within engineering and IT. Barriers identified by employers are first of all associated with the high signalling value of a STEM qualification across the economy, which makes it more difficult to recruit candidates for some sectors, and in particular for SMEs, as the demand for STEM graduates increases STEM graduates' expectations as to employment conditions, as well as location. Another issue raised is the importance that employers attach to some form of relevant work experience through an internship. Some of the multinational companies suggest that STEM graduates should start their labour market career in an SME, where they will have the opportunity to become familiar with a range of tasks associated with a STEM professional occupation.

Graduates should then use such experience as the basis for entering a career in a multinational company. Such a model would imply that European companies would carry the induction costs of new graduates on behalf of the large companies.

According to the European Schoolnet Report, graduates have experienced a similar lack of trust in qualifications, particularly those graduates without work experience. Lack of paid internship is also reported as a barrier. Any lack of pay will most likely function as a socio-economic selection mechanism which will limit the talent pool, as not all graduates can afford to work for free as a transition pathway to the labour market. Employer organisations, including the existing Grand Coalition on Skills for Jobs, should take urgent action to develop and endorse a code of conduct and good practice regarding working conditions for STEM students and graduates during traineeship, whether during study or after graduation. Otherwise there is a risk that STEM graduates will find jobs sooner or later in non-core STEM sectors. Nevertheless, in spite of the often-cited mismatches regarding soft skills, the European Schoolnet study found that employers do not refer to lack of soft skills as a mismatch issue, but they emphasise that they prefer graduates with cultural understanding and language skills. The European Schoolnet/Intel study concludes that as a result:

Questions remain as to whether the issue of skills mismatch should be regarded as a hard fact characterising our economy or whether it pertains more to the realm of perceptions. While the first hypothesis calls on researchers and policy makers to improve their understanding of the skills required by employers in STEM professions, the second hypothesis calls for an improvement in the communication between students, employers and Higher Education Institutions (European Schoolnet, 2014).

The findings of the European Schoolnet match those from both UK and Belgian research. Graduates that have not had the opportunity to undertake STEM-related work while studying tend to have no or limited knowledge about what STEM core jobs and careers are really like, and what the wider opportunities are if they choose a STEM career. Students' level of insight in STEM career opportunities largely determines whether STEM graduates end up in a STEM career or not (BIS, 2011; Van den Berghe & Martelaerede, 2012). It is, however, not only in Europe that a large number of STEM graduates tend to end up in non-core STEM occupations. The US Census Bureau reported in July 2014 that 74% of those who have a bachelor's degree in science, technology, engineering and maths are not employed in STEM occupations.²⁶ Whereas some studies point to different causes of skills shortages and skills mismatches, there is no universal agreement on the reality of the problem. However, a number of countries point to particular bottleneck vacancies in STEM related occupations.

6.4. Bottleneck vacancies in STEM recruitment

Although there is limited evidence of an overall lack of STEM graduates at present and in the medium term, there are numerous reported bottlenecks across the EU. A recent report prepared for the European Commission by Rambøll (Attström, et al., 2014) finds that

²⁶ <http://www.census.gov/newsroom/press-releases/2014/cb14-130.html>

recruitment difficulties in STEM occupations, as defined previously, are widespread across the majority of EU and EEA countries²⁷.

6.4.1. Science and engineering professionals

In ISCO group 21, science and engineering professionals, recruitment difficulties were identified in 21 out of 29 countries and in particular for mechanical engineers, electrical engineers and civil engineers. The bottlenecks for science and engineering professionals were ranked in the top-5 in Sweden, Denmark, Belgium, Austria and Slovakia. It should be noted that several countries with a high demand for labour in the science and engineering field, notably Germany, have not been able to produce a ranking. Spain, the Czech Republic, Latvia, Iceland, Cyprus, Malta and Hungary were the only countries that did not report bottlenecks among science and engineering professionals. In particular the manufacture of electronics, computers, and optical products reported bottlenecks. Various factors have been seen to cause the bottlenecks such as lack of suitable graduates or lack of graduates with experience. The study concludes that it is mostly for highly specialised technical skills there are bottlenecks, and not for STEM graduates as a whole. For a country such as Bulgaria, outdated qualifications have been cited as a cause combined with an insufficient number of graduates with relevant degrees. In Germany, underlying causes are a high dropout rate from STEM studies and a lack of female interest in STEM studies. In Germany, there are also concerns that the problems will be aggravated due to a future replacement need of an aging workforce and a rapid growth of the electronics and mechanical industries. Companies have chosen a number of reported mitigation strategies. However, it is striking that only 6% have tried to recruit staff from another country within the EU.

6.4.2. Information and telecommunications

In information and telecommunications (ISCO group 25), bottlenecks have been identified in EU and EEA countries and Switzerland. Bottlenecks are particularly prominent among software developers and systems analysts. The bottlenecks are ranked at top-5 in Belgium, Denmark, Italy, Latvia and Sweden. However, it should be noted that there are many countries where bottlenecks have been identified within this occupational category, but where a ranking of those bottlenecks has not been possible.

The study on bottlenecks in the EU (Attström, et al., 2014) shows that Ireland reports the highest number of bottlenecks. According to the study, the bottlenecks mirror a growth in the ICT industry over several years and a drop in computer and engineering graduates since 2002. Hard-to-fill occupations include software developers and programmers, mobile technology application programmers, IT project managers with technical backgrounds, and network security specialists. It is worth noting that an ICT skill audit conducted in Ireland, The FIT ICT Skills Audit (2012), found that many of the reported vacancies could be remedied with short-term training programmes (6-24 months). This signals that the demand is vocationally oriented, very specific, and hence unlikely to be included in the curriculum of a tertiary qualification in order to avoid rapid obsolescence. Future demand is expected for roles related to cloud computing, service design, database management, social networks and media, and development of e-commerce applications. IT user support positions are also identified as hard to fill due to multi-language requirements. In Greece, the bottlenecks are associated with even more specific technical requirements, many of which can be met through certifications. The demand covers specific programming languages, developments, and applications, especially mobile applications, Java, J2EE, .NET, C#, PHP and Drupal Framework, web user interface designing, Web Developments, LINUX and system testing for specific protocols (e.g. TCP/UDP/GTP/SIP). New graduates cannot be expected to possess such specific technical skills, as this would likely lead to too high a level of specialisation which could impede labour market mobility as well as limit the broader STEM

²⁷ It is important to note that the study design in itself leads to a risk of 'over-identification' of bottleneck vacancies. The study is compiled by individual country studies where the aim was to identify 20 occupations that were the hardest to fill, without any means or possibilities of comparing the severity or importance of the deficit between countries or occupations.

foundation skills. Nevertheless, the demands do raise the question of whether there is a basis for developing European curricula for continuing training purposes across some of those STEM occupations and sectors with the biggest skills bottlenecks. This could contribute to transparency in STEM continuing education and training supply beyond the current ICT certifications. However, it will require further analysis to assess the magnitude of these very technical skills demands.

Bottlenecks tend to be aggravated by employers being highly cautious about the quality of the match and the preference for employees with experience to avoid the costs of introduction and on-the-job training of a new graduate and avoid the costs of failed recruitment. This is seen in Spain, where employers want experienced staff, while potential applicants prefer employment in the larger cities, resulting also in spatial mismatches. Almost 50% report bottlenecks due to a lack of experience, which is higher than for other sectors, and though companies in ICT services prefer employees with experience, there are concerns that older job seekers who typically have job experience but possess outdated qualifications.

The main mitigation strategy is additional training. It is worth noting that compared to the science and engineering professionals, a little more than 1/3 of the companies have tried to recruit from other countries within the EU and outside the EU.

6.4.3. Science and engineering associate professionals

Science and engineering associate professionals (ISCO code 33) is the occupational group that has the most identified bottlenecks at 4-digit level. Fourteen of the 29 study countries reported bottlenecks within this occupational group, and the 29 bottlenecks are divided rather equally between the different specific occupations within this occupational group.

Bottlenecks are ranked in the top-5 positions in Austria, Belgium, Sweden and the UK. The countries with the highest number of reported bottlenecks among science and engineering associate professionals are Austria with five and Norway with four specific occupations. France, Sweden and the UK each reported three specific occupational bottlenecks. The bottlenecks are found in manufacturing and construction, in manufacturing in the pharmaceutical sector, and in the manufacturing of metals. An aging workforce and gender issues are contributing factors. In terms of mitigation strategies, training plays a moderate role with only 17% using that as a strategy, recruitment from other EU countries applies to less than 1/3 of the countries, whereas recruitment outside the EU only represents 10%.

To sum up, bottlenecks are for two of the three occupational groups linked to specific occupations, and the lack of a workforce with up-to-date experience plays a major role in explaining the perceived bottlenecks. Apart from the ICT sector, the use of recruitment within and outside the EU plays a relatively moderate role, which could confirm that STEM skills mismatches are associated with spatial mismatches. There are variations in the relative importance paid to re-organisation of work combined with investment in training. There are indications that since the crisis employers have cut their investments in training for cost reasons and out of fear of inter-firm poaching. The combined effects of employers' search for candidates with work experience and the fact that many new graduates will not have any form of work experience can lead to employers reporting difficulties recruiting STEM professionals parallel to reported STEM vacancies.

The above discussion shows how complex it is to understand the dynamics of the supply and demand of STEM graduates. Some country studies where the STEM debate has been intense even conclude that there is no evidence of STEM skills shortages. This is the case of a 2015 UK study²⁸ which builds on a rich data set and concludes that there is no evidence of overall skill shortages in STEM in the short or medium term. However, there are acute shortages in specific occupational areas, which the study sees as a result of underinvestment in training of the existing STEM professionals.

The findings presented above show that there are an array of factors and data which shape the views of different stakeholders. Currently, there is thus no universal agreement as to the

realities of STEM skills shortages and STEM skills mismatches at present; and should these exist, there is no agreement as to underlying causes. The nature of supply and demand challenges varies across and within EU countries, across sectors of the economy, and across companies. Several factors are at play: the expansion of higher education systems; a global trend for graduates to seek towards the larger cities, and; a too limited perception of the wealth of careers a STEM qualification can offer, potentially coupled with out-dated career advice systems not sufficiently embedded throughout higher education programmes and in cooperation with industry. On the other hand, there is substantial evidence to suggest that employers, since the crisis, have become more selective in their recruitment practices, which has a negative impact on graduates without labour market experience. Furthermore, there seem to be inconsistencies in employer demand. The two main reported causes of bottleneck vacancies are graduates' lack of specific technical skills and lack of experience. In interviews, however, employers most often refer to a lack of soft skills as a critical issue, and this is also found in some employer surveys (Toland, 2011). This could indicate that STEM graduates with little or no working experience are increasingly starting out in jobs where they are expected to come '*ready-made*' and are therefore not given proper support to take on their expected roles effectively, particularly if STEM graduates in their entry to the labour market end up in short term contracts.

7. Qualitative changes in the demand for STEM skills

The previous chapter gave an overview of some of the factors, which influence the current view on the nature and scale of the STEM skills supply and demand challenge. This chapter looks into some of the emerging trends, which could impact the demand for STEM professionals and associate professionals in a disruptive way.

7.1. Drivers shaping the demand for future STEM skills

A number of societal, technological, economic and policy factors impact the demand for future STEM skills both quantitatively and qualitatively, and that makes it difficult and complex to project demands. Some of the trends are:

- Convergence of technologies, in particular key enabling technologies such as nanotechnologies, material technologies, and microelectronics sensor technologies;
- A growing digitalisation of working tasks;
- Growing data intensity and data velocity, for example due to the use of sensors;
- Specialised jobs that are broken down in tasks and mediated through digital platforms such as Upwork;
- More advanced robotics and forms of automation, undertaking tasks that were formerly carried out also by specialists; and
- A growing global labour pool of STEM specialists that can lead to further sourcing of R&D tasks, as well as an increase in the global mobility of STEM specialists.

The above trends are presented in a summarised form in table 7-1 to illustrate the fact that quantitative and qualitative forecasts about future skills demands in technology-intensive occupations should be interpreted with caution, as a number of trends can have disruptive impact on the assumptions underlying the projections.

Table 7-1: Trends affecting the demands for a future STEM workforce

Technological change - convergence of key enabling technologies (KETs)	Key enabling technologies such as nanotechnologies, sensor technologies, microelectronics, advanced materials, and photonics are at the core of Europe's strategy for revitalisation of manufacturing. These technologies are generic technologies, which in different combinations can result in products and technological services with entirely new functionalities. The term ' <i>Converging technologies</i> ' refers to specific examples of actual technologies, which in different combinations impact research activities, competitiveness and innovation. (OECD, 2014; Butter, et al., 2014)	Converging technologies change the nature of skills demands for STEM professionals in terms of their ability to work with specialists in different scientific and technical fields on a joint problem, and is seen as critical to breakthrough technological innovation. Transdisciplinarity and interdisciplinarity are used in the literature an interchangeable manner to express the changing skills demands, though the two terms do not mean the same. (European Commission, 2014 c)
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Big data and digitalisation of production and services

Cloud computing and the internet of things (IoT) enable a pervasive and integrated uptake of digital technologies in advanced manufacturing (industry 4.0) as well as in services, also for SMEs. These developments lead to a greater service intensity of manufacturing, and they hold the potential to transform business models, which for example are seen in the growing number of apps embedded in different products and business services (Murray, 2015).

The growing digitalisation of occupations and working tasks has a major impact on the demand for skills of STEM professionals; for example in the way in which R&D and innovation activities take place based on an increase use of data and in teams that may be located in different geographies supported by ICT. Digitalisation of manufacturing and services requires high-level technical expertise to fully exploit for example sensor technologies in new products. It also requires skills related to design and innovation in order to assess and spot market potentials. There is already evidence of a growing global demand for data analysts, data visualisation experts with hybrid qualifications in statistics, maths and computer science, combined with business management and innovation skills (Teknologisk Institut, 2013).

New ways of work

Cloud technologies are the driver of new digital platforms which mediate a range of services including job tasks offered by companies and on the other hand individuals looking for job opportunities. In the EU it has mainly been Über and Airbnb that have spurred debates and protests. However, in particular in the USA platforms such as Upwork are growing in outreach day by day brokering highly specialised jobs tasks in STEM related fields and registered suppliers in different STEM fields, also from the EU.

These platforms have been launched under the umbrella term of the “sharing economy”, though they in fact have little to do with sharing. The gains are made by the platform investors. Companies source job tasks as a way to cut costs, but also to access highly specialised skills with some level of embedded quality guarantee through a rating system. Service providers are free to set their price, but in reality data show that specialist services are sold at times for a couple of dollars per hour. Some claim that the new platform economy will make obsolescent prior concerns about unmet vacancies or localised surpluses of high skilled supply (Manyika, et al., 2015). Some believe that the platform economy is an expression of a growing digitally enabled entrepreneurial economy, whilst other raise concerns about the disruptive effects on working conditions of the new digital platform economy (Zysman & Kenney, 2015).

Transdisciplinarity

The growing demand for STEM professionals who can work across disciplines in a unified manner is not just an effect of technological convergence.

Growing

R&D specialisation globally and pressures to speed up innovation processes within global value chains increasingly lead to teams that work together across organisational boundaries and geographies and cultures in open models of innovation.

Breakthrough technological innovations typically draw on the expertise of many different fields. Often they would not have materialised without high-risk investments. The ability to work in a transdisciplinary manner implies a team that is capable of working on complex or wicked challenges in unified ways - each contributing with a specific expertise, but with a common focus on creating results of value to the market. Besides transdisciplinarity, emerging STEM profiles are therefore also associated with design thinking and creativity and a strong business orientation, and they are value driven, seeing STEM as a means to solve wicked challenges associated with food security, climate, clean water, and preventive health measures (Shapiro, et al., 2013).

Source: the Authors

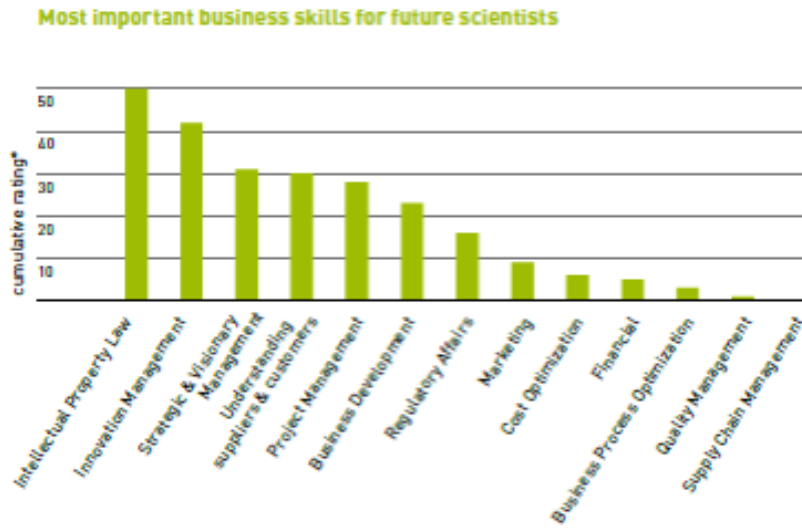
7.2. Technological change - the convergence of technologies

The European strategy on advanced manufacturing and technological services is based on *Key Enabling Technologies* or KETs (KETs HLG, 2015). The main driving force behind KETs is a vision about a revitalisation of manufacturing through a low-carbon knowledge and technology-intensive and data-driven economy. KETs comprise technologies such as nanotechnology, micro- and nano-electronics including semiconductors, advanced materials, biotechnology and photonics. These technologies have similar properties, which make them inter-disciplinary in nature (multi KETS). Due to their converging nature these technologies have a huge innovation potential, bridging advanced manufacturing and services. STEM skills are receiving increasing policy interest, since STEM skills and advanced e-skills form the foundation for KETs. STEM skills are often associated with higher order analytical skills and the ability to process complex data.

The High Level Expert Group formed to support the European Commission in developing forward-looking KETs policies concluded that to fully exploit KETs, advanced science, technology and engineering programmes need to be more interdisciplinary from a technical discipline perspective. They will also need to include technical project management, innovation management, communication, problem solving, and the ability to understand and work with customers and suppliers. Many of these industrially focused competences are hard to acquire in a traditional higher education context. Therefore, the Expert Group also recommended stronger collaboration among universities, engineering schools and industry in the production of KET graduates and PhDs (ibid). Given the speed of technological obsolescence and the complexity of KETs, the key questions are which components should be included in graduate curriculum and which should rightly be part of an advanced postgraduate modular training programme to avoid curriculum overcrowding and ensure that graduates have sufficient in-depth technical interdisciplinary competences.²⁹ The European Chemistry Industry has conducted a study on skills requirements for scientists within the field (CEFIC 2011).

²⁹These findings emerge from a recent study completed on future of engineering 2020, Danish Technological Institute for the Danish Confederation of Engineers.

Figure 7-1: Most important business skills for future STEM specialists working as scientists in the chemistry industry

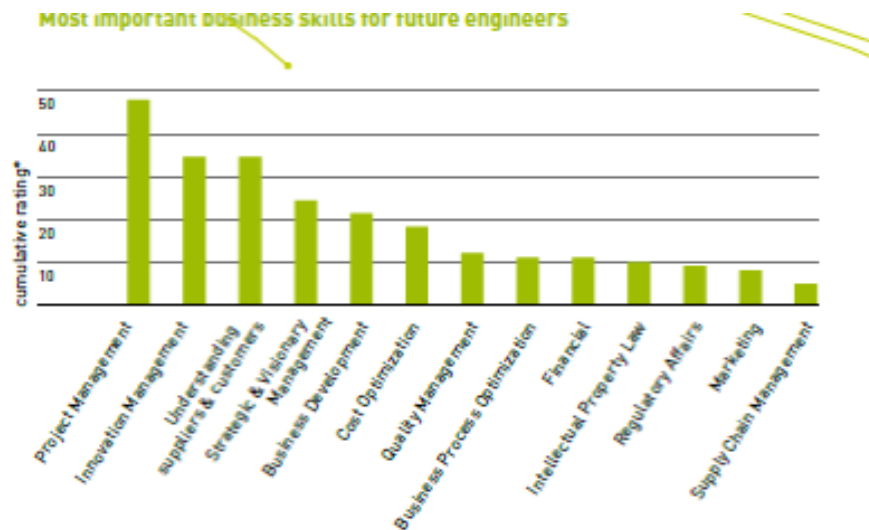


Source: European Chemical industry

The projected skill demands for engineers and scientists are quite similar, but the relative importance of the skill sets differs.

For both profiles, it is worth noting the importance paid to innovation management. Firm-based case studies regarding innovation management skills of the HRTS workforce within the bio-economy value chain underline that innovation management skills in these industries critically depends on deep technological and discipline expertise, and curricula reform should not occur at the expense of in-depth technological and discipline expertise.

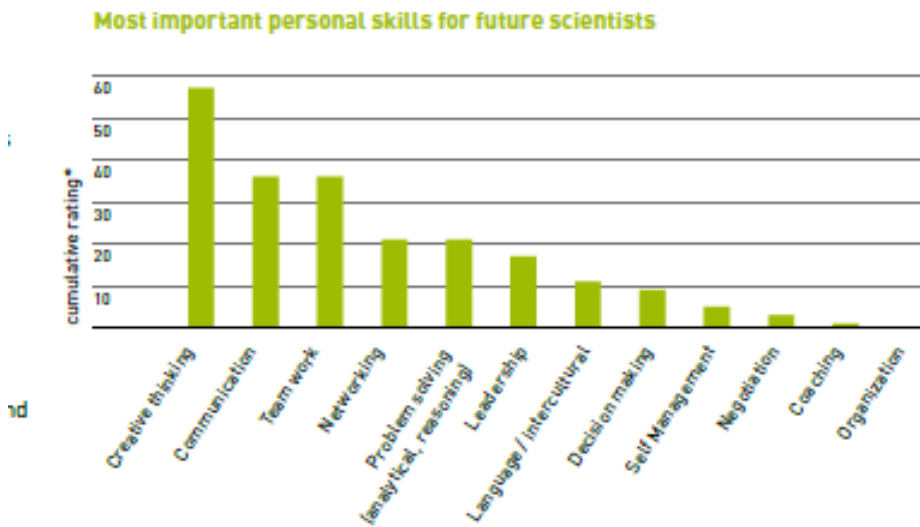
Figure 7-2: Most important business skills for future engineers in the Chemistry industry



Source: European Chemical industry

The skills anticipation study conducted for the chemical industries (CEFIC, 2011) finds that the demand for skills is impacted by drivers similar to those found in other industries:

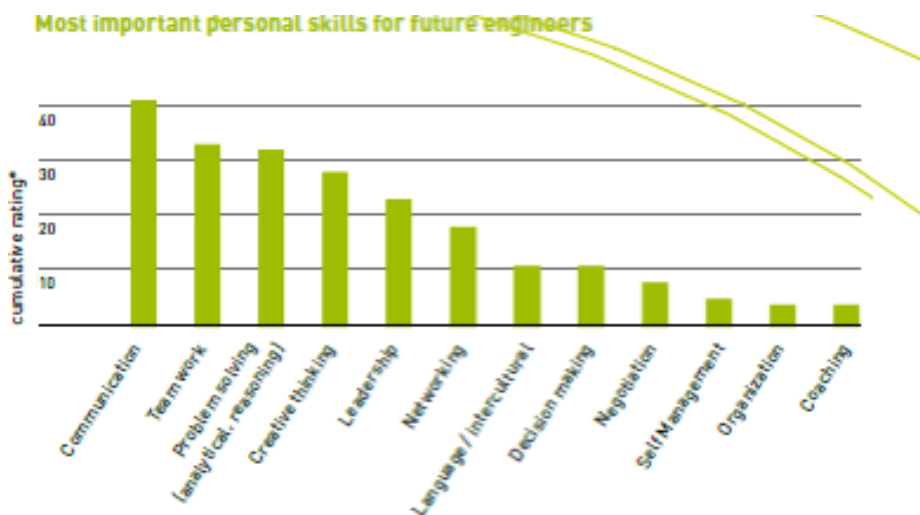
Figure 7-3: Important personal skills for STEM professionals working as scientists



Source: European chemical industry

Creative thinking and the ability to translate discipline-based knowledge into innovation is a critical future skill for STEM professionals such as scientists. Communication skills are necessary as scientists from different disciplines collaborate on R&D processes, also with commercial partners. With projects getting more complex and involving different disciplines to develop solutions, teamwork skills will be the key to effective innovation.

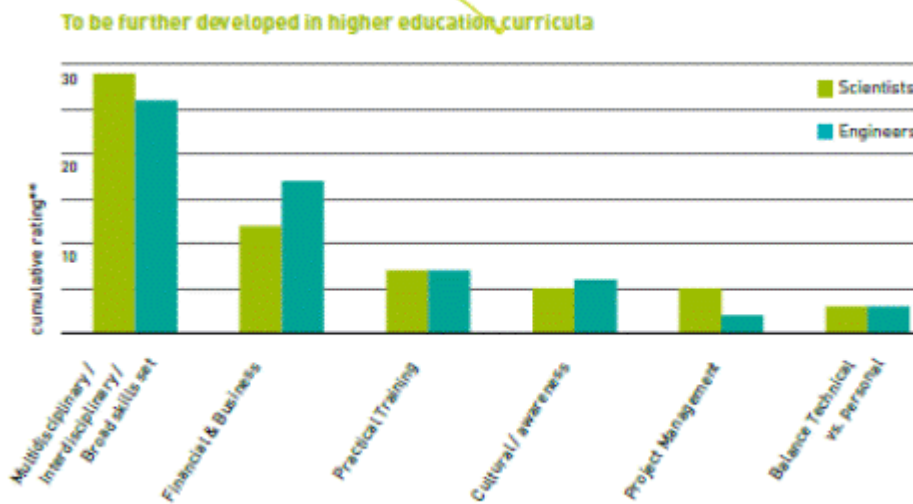
Figure 7-4: Important personal skills for future engineers



Source: European chemical industry

Communication skills will be critical for STEM professionals such as engineers to promote ideas internally and externally and deduce latent needs in the market. Problem-solving and teamwork mirror the interdisciplinary organisation of R&D and changing patterns of innovation, which will increasingly occur in collaboration with external partners.

Figure 7-5: To be further developed in higher education curricula



Source: European Chemical Industry

To develop the critical skills, knowledge and competences of the future STEM professionals - whether in their role as scientists or as engineers - the survey found that higher education needs to be reformed to allow for STEM professionals who:

- can work in multidisciplinary/transdisciplinary teams,
- have strong technical skills,
- have project management skills, and
- understand business.

These demands pose a challenge to a continued modernisation of the higher education sector and to a strong and strategic cooperation between higher education institutions and the industry sector.

7.3. Big data

The diffusion of sensors, communication, and processing power into everyday objects and environments will unleash an unprecedented volume in data. Every object, every interaction, everything we meet can be converted into data. As a result, we could be moving into an era, which is powered by computational, programmable, and designable solutions. The collection of enormous quantities of data will enable modelling of social systems at extreme scales, both micro and macro, helping uncover new patterns and relationships that were previously invisible. Businesses can use the data to understand emerging trends in global markets or for technology forecasting purposes. Mobile phones, automobiles, factory automation systems, and other devices are designed to generate streams of data on their activities, which can be used to create business intelligence. For graduates with STEM skills, this has created job opportunities in an otherwise depressed job market in the USA as data analysts or as developers in industrial laboratories. It has also led to automation of job functions that previously were undertaken by university graduates. The result is that an increasing number of higher education institutions in the USA are beginning to offer programmes and courses in data analytics (McKenna, 2011). However, how an increased data intensity and associated automation will play out is uncertain (OECD). It will depend upon such factors as companies' innovation strategies and whether these are efficiency-driven or whether they use the increasing data velocity as a means to increase agility. In the latter case, the skills and capabilities of STEM graduates will become a critical parameter to finding innovative and value adding use of the vast amounts of data generated. The German case study shows

how the internet of things is rapidly making obsolete distinctions between manufacturing and services (Schilling, 2011). The Danish toy producer LEGO is an example in this respect. Cloud technologies, mobile applications, and the increased digital literacy of potential customers will likely enhance these models of co-design of product-service solutions spanning from energy to health solutions or other service areas with diverse demands and values. In the USA, these developments have led to a considerable debate about whether future engineering studies should be STEM- or STEAM-based,³⁰ the latter to denote that arts and creativity should be integrated in engineering and technical education. In the EU, this could also have implications for the skill demands of STEM professionals across a range of industries, as companies look for new avenues to spur demand in saturated markets and increase their market value through new innovation models. High-skilled staff involved in open models of innovation involving customers and suppliers must be able to manage processes, translate, and filter tacit insights and ideas from many different internal and external sources into the early stages of envisioning a new product. To pursue open, collaborative innovation, companies must find ways to tap into the potential of people around the globe. The skills to manage an R&D project or a division based on crowdsourcing are more complex, and the processes entail risks that are very different from the risks associated with traditional forms of R&D in industry or in a university environment (Trompette, et al., 2008). Digital collaborative platforms that can support knowledge creation and knowledge management in distributed and dynamic environments grow in importance, but the type of communication skills that are required go beyond lecturing or face-to-face communication. This also explains why industries across sectors value communication and risk management skills (Lameros, et al., 2012).

7.4. The digital platform economy

Cloud technologies and the internet are driving new developments in how work may be organised, and this has potentially major implications for national labour markets, how job openings are posted, and the very idea of what constitutes employment - also in high-end labour markets such as STEM occupations. In the USA there is a marked growth in the so-called platform economy - digital platforms which offer short-term projects to 'freelance' individuals who list their previous experiences and their hourly salaries - which negatively impacts the job supply for high-skilled STEM graduates. The motivation of employers to make use of task-based sourcing of STEM skills is that they thereby can gain access to highly specialised skills while at the same time reducing costs, as they only pay for the specific task that a contractor undertakes and bear no expenses related to health insurance and other social security benefits. The employees have no guarantees concerning minimum hours per week, no social security, and no health coverage, and there is a clear tendency for this kind of employment to provoke a race to the bottom because STEM professionals from all over the world can profile themselves as long as they have access to the internet (Zysman & Kenney, 2015). US researchers such as Zysman and Kenney argue that cloud computing and 3D print will accelerate this labour market transformation and deconstruction of jobs even in sectors such as advanced manufacturing.

There is a range of digital platforms specialised in different segments of the labour market. For STEM-related jobs, the most important digital platform is UPwork with 4 million registered professional STEM professional freelancers and 3 million jobs posted annually.³¹ A search conducted on Danish professionals within STEM-related fields shows that skills are solicited down to USD 5 per hour, and that about 1000 'freelancers' located in Denmark are presently registered. In Europe there is limited empirical research on to this labour market as it applies to high-skilled professionals, whereas Über and Airbnb have seen quite a lot of media coverage. There is an urgent need to analyse these phenomena in the labour market for high-skilled people, from both an education and employment policy perspective. Emerging empirical research from the USA suggests that despite the rhetoric of the '*sharing economy*' there are vast numbers of individuals who register on the digital platforms to solicit work not out of choice, but out of necessity.

³⁰ steam-notstem.com

³¹ www.upwork.com

7.5. Transdisciplinarity - an emerging concept

As some of the studies analysed for this report have shown, the skills requirements for STEM graduates are changing above and beyond demands for deep disciplinary skills and specific key competences, even though the reported bottlenecks are often associated with very specific and highly specialised skills. Increasingly, STEM professionals will be expected to work in environments requiring collaboration across multiple fields of disciplines and interact and work with people outside academia to identify innovation opportunities and collaborate to bring them faster and more efficiently to the market (Deiss & Shapiro, 2014). Transdisciplinarity was identified in a report written by the Institute for the Future (Institute for the Future, 2011) as one of ten advanced workplace skills that will help organisations handle disruptive technological and societal change. Professionals who can correlate material from diverse knowledge bases and extract tangible results - whether for new business initiatives or massive global issues such as resource scarcity or pandemics - are seen as future critical R&D and innovation resources.

Transdisciplinary education and research is different from interdisciplinarity (Scholz & Stauffacher, 2010):

- It goes beyond sciences.
- It organises processes of mutual learning between science and society (going beyond 'speaking truth to power' or cash for consultancy).
- It relates and integrates different types of epistemologies, in particular experiential knowledge about concrete real-world systems from practitioners (from societal stakeholders) with science knowledge about theoretical, abstracted systems (from scientific stakeholders), whereas interdisciplinarity fuses methods and concepts from different disciplines.

Transdisciplinarity refers to knowledge and skills that transcend and unify different disciplines. It is driven by the view that complex, ill-defined real world challenges call for multiple perspectives to generate new knowledge that can lead to innovations in the way particular challenges are dealt with. Another critical defining characteristic of transdisciplinary research is the inclusion of stakeholders in defining research objectives and strategies to incorporate the diffusion of innovation as an outcome of research.

Transdisciplinarity therefore requires the integration of *problem framing*, *problem solving*, *communication* and *collaboration* that cuts across disciplinary and organisational boundaries, in addition to deep disciplinary skills to meet demands for a growing technological specialisation. These types of meta-competences emerge as future requirements across the studies analysed for the Innovation Union Competitiveness Report for DG Research. However, they are not easily acquired in traditional lecture hall modes of instruction or classical lab work. The basic argument therefore is that the identified emerging skills requirements go well beyond a simplistic discussion about breadth versus depth in curriculum or whether a particular key competence is more important than another one is. The "Science with and for Society" programme³² within Horizon 2020 that aims to build effective co-operation between science and society, to recruit new talent for science, and to pair scientific excellence with social awareness and responsibility, could be seen as a measure to increase transdisciplinary thinking.

Cases analysed for the chapter on future skills of the Science Technology and Engineering Workforce in the 2014 Competitiveness Innovation Union report show that a transdisciplinary learning environment may enable students to learn to research real world challenges that promote:

- Science-based problem framing and problem solving;
- Dealing with the challenges of relating and integrating epistemologies and methods from a discipline, a systemic, a stakeholder, and societal value perspectives working towards common goals;
- Collaboration, communication and dealing with professional disagreement; and

³² <http://ec.europa.eu/programmes/horizon2020/en/h2020-section/science-and-society>

- Coping with and respecting different modes of thought (experimental versus analytical) as a way to reach new solutions.

7.6. Summing up

At the EU level, employment in STEM occupations is projected to increase 12.1% by 2025, but the forecast development at country levels is very diverse. By comparison, employment in other professions (excluding STEM employment) is expected to increase at 3.8% at the EU level. However, it is interesting to note that employment demands in other professional and associate professional and technicians occupations (excluding STEM occupations) are projected to increase by 18.0% by 2025. Hence, it outpaces growth of employment in STEM occupations.³³ Thus, even if the economy is becoming more knowledge-intensive with more high-skilled jobs, it is uncertain how the demand for STEM graduates will play out in the EU. Furthermore, even if STEM employment may increase in the EU, technological change and growing data intensity could lead to a demand for STEM professionals that are more T-shaped; that is, graduates who possess in-depth STEM skills as well as skills that span different competence fields.

Current reported STEM skill shortages and mismatches are not universal, but they are geographically defined and are associated in particular with ICT and engineering. In spite of reported shortages, apart from in the ICT sector employers seem reluctant to recruit graduates without labour market experience or unemployed STEM professionals with labour market experiences that may be outdated. Reasons are that employers fear that such recruitment practices could increase induction costs and hence negatively impact productivity. Apart from in the ICT sector, employers seem hesitant to recruit employees from other EU countries. This also applies to companies and regions where there are claims of STEM skills shortages and STEM skills mismatches. Unemployment rates are much lower for STEM graduates than for graduates in other fields. Nevertheless, these dynamics lead to inefficiencies in the matching processes in the labour market, as they may cause that STEM graduates end up in non-STEM occupations, and STEM graduates that seek employment in another EU country are at risk of being under-employed, at the same time as employers have difficulties recruiting STEM graduates.

Macro-economic projections such as the Cedefop projection on STEM skills demand have a number of embedded uncertainties:

- Macroeconomic projections tend to build on current demand patterns, and although they can include scenarios as a way to illustrate the potential impact critical uncertainties, macroeconomic projections are not suitable for analysing the combination of quantitative and qualitative effects of for example advanced forms of automation and digitalisation (OECD, 2014 a).
- Cloud technologies enable the creation of digital platforms, which can broker a range of services – including working tasks and skills possessed by individuals. Particularly in the USA, we see firms - also in high-tech fields - that downsize and increasingly source jobs in the form of temporary ‘gigs’ via dedicated digital platforms (Zysman & Kenney, 2015), paving the way for what is called *the gig economy*. One of the many specialised platforms is ‘UPwork’,³⁴ which brokers specialised ‘gigs’ in STEM related fields.³⁵
- The impact of ‘software as a service’ makes physical proximity unnecessary for a growing range of occupations, not only in ICT services but also in advanced manufacturing (Murray, 2015). The result is that assumptions about supply and demand within national labour markets may be fundamentally flawed.
- Globally, there is an increase in the high-skilled STEM labour pool. Geopolitical factors and visa policies will to a large extent influence the degree to which a growing global STEM talent base will seek employment opportunities in Europe. This applies to short-

³³ These other high-skilled occupations include ISCO 22, 23, 24, 25, 26, 32, 33 and 34. Please be aware that Information and communications technology professionals (ISCO 25), which are considered STEM occupations, cannot be separated from the high-skilled non-STEM occupations in the Cedefop data.

³⁴ <https://www.upwork.com/>

³⁵ <https://www.upwork.com/>

term and migrant movement, and at present we have limited ideas about how and to which extent new ways of work will fundamentally alter global mobility dynamics.

- The growing internationalisation of R&D may also impact the demand for STEM employees. This will particularly be true in industrial research, as firms outsource their R&D activities to gain access to global centres of excellence within a particular highly specialised STEM fields and to gain access to growing emerging markets.

All these factors combined leave a number of critical uncertainties unanswered, and hence the often-heard arguments about a growing future risk of STEM skill shortages in the EU.

An increase in the number of STEM graduates will not necessarily alleviate those STEM skills shortages that are found in some regions of Europe and in some sectors, in particular engineering and ICT, as long as substantial numbers of graduates choose jobs and careers in sectors that are not traditionally defined as core STEM sectors. This could be due to many employers supposedly being are reluctant to employ graduates without labour market experience and graduates with foreign STEM qualifications.

There continues to be concern in most parts of Europe that an insufficient number of young women choose STEM studies. In particular, there are mismatches between the overall number of female students in tertiary education and the number of female students in ICT and engineering fields of study. Apart from equality of salary and career opportunities, which seems to remain an on-going problem, education and career advice from early school age which promotes the variety of opportunities a STEM degree can be a key to engaging more women in STEM. Research on students' perceptions about STEM shows that many students, in particular those without practical experience through collaborative projects or traineeships, do not bear in mind that STEM fields of study can lead to jobs that deal with a range of global challenges regarding water resources, food security, preventive health, and climate and the environment, which - when solved - can contribute to a more sustainable world. A recent European research study conclude that such insights and such a focus on STEM promotion campaigns could attract more young women to a STEM career. Germany provides in that respect a leading example not only to attract more women to STEM studies, but also to promote STEM towards minority groups from early childhood. Furthermore, the German case study shows that Germany has taken a coherent approach to monitoring STEM supply and demand, which is also the case for the UK.

The following chapter describes some of the current priorities and policy measures taken, also drawing on the case studies conducted.

8. What are the priorities and impact of the major policy initiatives?

In recent years, a series of European studies and policy reports has been published dealing with concerns that a kick-start of growth and innovation could be hampered by skills shortages and skills mismatches in the fields of science, technology, engineering, and maths (STEM). Looking into the future the same reports warn that the projected growth rates for STEM graduates combined with the major replacement for STEM professionals and associate professionals due to retirement could result in Europe not being able to compete as one of the leading knowledge economies in the world due to the lack of STEM professionals and associate professionals. Furthermore, reports argue that the revitalisation of European manufacturing and the further digitalisation of the economy will be endangered if we do not take action now to solve the skills shortages and skills mismatches associated with a more technology and knowledge intensive economy (ALLEA, 2012; European Commission, 2004; ERT, 2009; Business Europe, 2011; FEANI, 2010; VDI, 2010; Eurydice, 2011; Caprile, et al., 2015). In addition, a plethora of publications and studies has been produced by Member States and national organisations in Member States concerned with STEM supply and demand. Many studies focus on STEM supply and demand taking into account the supply chain leading to STEM careers as adults (Eurydice, 2011; European Schoolnet, 2014). Others focus on a particular sector - for example the school sector - and measures taken there to promote STEM studies, or they focus on the higher education sector and the impact of STEM on the economy (Goos, et al., 2013) or the discrepancy between number of graduates that choose STEM and those that actually end up in what is considered as a core STEM career (Van den Berghe & Martelaerede, 2012). Still others focus on gender related aspects (Henriksen, et al., 2015).

While some studies have very elaborate definitions of STEM as the basis for their analysis (Goos, et al., 2013; Caprile, et al., 2015; Cedefop, 2014) others are less grounded in statistics, and that tends to impact the quality and the reliability of these. There has also been interest in STEM policies in the EU from stakeholders outside the EU. The Australian Council of Learned Academies (Acola) has, for example, carried out a review of science education policies and strategies in selected Member States in the EU from 2012-2014 (ACOLA, 2014).

In The UK and in Germany in particular, STEM skills are high on the agenda as seen in several policy documents further analysed the country case studies (UK Department of Education, 2009; UK Department of Education, 2011; UK Department for Employment and Learning, 2011; BIS, 2015; Hetze, 2011; Anger, et al., 2014; Nationales MINT Forum, 2015; Bundesregierung, 2015). Whereas the UK Policy papers mainly discuss supply and demand topics, one of the most recent German publications from the Federal Ministry of Employment, *Grünen Arbeit, 4.0* from 2014, also takes up the wider implications of work in a digital economy, particularly related to the increasing use of digital platforms to source work. Neither the Polish nor the Bulgarian case studies makes explicit reference to an overarching and comprehensive strategy relating to STEM skills, although it is a component in the two countries' strategies for Science and Technology and there is a general policy ambition in both countries to further spur a knowledge and technology driven growth. With growing foreign investments in ICT and in other technical fields, there are growing concerns and discussions in the two countries that the extensive emigration of graduates to other countries in the EU effectively is leading to a brain drain.

Denmark has a broad-based science and innovation policy framework in place and monitors performance on a number of criteria. In the National Growth and Innovation Strategy (Finansministeriet, 2014) the Government has prioritised advanced manufacturing, and has also recently launched a strategy for further digitalisation (Ervervsstyrelsen, 2015). STEM has not directly appeared in national policies, although indirectly STEM has been part of the agenda to encourage students to choose studies (Andersen, 2014) which are believed to result in better employment prospects and have a higher return to country productivity (Produktivitetkommissionen, 2013).

Spain has a science and innovation policy framework in place, but it does not specifically make reference to STEM skills. The policy debate is influenced by the high unemployment levels among tertiary graduates. However, the case study shows that several initiatives taken by individual institutions and companies.

The objectives of national STEM policies show some variation in focus and breadth rooted in the particular characteristics and challenges of the respective countries. The measures typically include some of the following actions:

- Promotion campaigns;
- Outreach activities to promote STEM with focus on the STEM talent pipeline;
- Address gender specific issues and under-representation of minority groups to increase the talent pipeline;
- Establishment of co-ordination across STEM-related ministries and agencies as well as public private partnerships;
- Metrics to monitor the supply and demand of STEM graduates;
- Grant schemes and visa policies.

8.1. STEM promotion- targeting the primary and the secondary education sector

The case studies and the literature review show that most EU countries are concerned about the lower participation of females and minority groups in STEM. Bulgaria is one of the exceptions. STEM promotion activities often focus on the talent pipeline - that is, students in compulsory education and upper secondary education. Since this study mainly focuses on STEM at a tertiary level, only a couple of examples are provided:

Germany

The **ROBERTA**, (robotics for girls) campaign is an example of ICT job promotion in Germany, starting from the premise that robots are an ideal educational tool for hands-on introduction to technology. ROBERTA started in 2009 and is an initiative of Fraunhofer IAIS, supported by the EU and the German Ministry for Education and Research. It is widely considered a success as it has helped establish robotic workshops at a large number of schools, enabling teachers to qualify in the field and also often creating partnerships with companies

Spain

The science museum in Barcelona (CosmoCaixa) and the Spanish Foundation for Science and Technology (FECYT) have carried out joint activities to promote STEM education among high school students. The initiative was developed over two years and has involved the participation of more than 2.500 students. An evaluation of the outreach activities shows that they have a particularly positive effect on students with lower academic performance, which was also the group of students who generally had a lower socio economic status. In this group of students an additional 12.8 % have become interested in studying science, maths, engineering and technology.

UK

One of the best-known initiatives is Women into Science, Engineering and Construction (WISE). The WISE campaign collaborates with a range of partners to encourage school-age girls to appreciate and pursue science-, technology-, engineering-, and construction-related courses in school or college, and also to move on into related careers. In 2014, the initiative showed a slight increase in female employment in STEM, although still only at 13%.³⁶

Poland

³⁶ <https://www.wisecampaign.org.uk/resources/2015/07/wise-statistics-2014>

In 2008 an academic programme was introduced by the government to increase young students' interest in STEM studies. The best students of selected disciplines (IT studies, biotechnology, environmental protection and mathematics) received an additional grant of PLN 1000 (340 Euro) per month. In addition, higher education institutions received additional funding for modernising their curriculum, creating jobs, and collaborating with representatives of the relevant sector of the economy (Deloitte, 2014a).

8.2. Monitoring and anticipation of skills for STEM labour markets

Discussions and claims of skills shortages and skills mismatches emerge from several of the case studies. In some countries such as Germany there are specific monitoring mechanisms in place, while in other countries there are broader monitoring instruments implemented which focus on the transition rates to labour markets for graduates as a whole.

Germany

In 2008, Germany launched the **MINT meter**, a benchmarking instrument that tracks and publishes progress on STEM supply and demand in Germany against seven indicators:

- 1) STEM skills & competences
- 2) STEM graduates
- 3) General graduation rate
- 4) STEM proportion of women graduates
- 5) Quota of women in STEM subjects
- 6) STEM dropout rate
- 7) MINT replacement rate

Poland

In **Poland**, the Ministry of Higher Education has started a new project aimed at following graduates' labour market pathways including their employment situation and salaries. It will match the (anonymised) IDs of university graduates with the social security database and therefore enable a monitoring of the individual labour market situation. Currently, the project is in its pilot stage and a first report on results will be prepared for 2016. This is expected to start a debate on graduates' performance in the labour market, which might also affect future educational choices.³⁷

Spain

In **Spain**, the CYD Barometer analyses the role of universities in Spain and is based on a survey that includes university, company and public administration experts. Experts are asked to state and rank the activities and services carried out by Spanish universities that are seen as more valuable to Spanish companies. These are:

- Graduate training that meets the requirements of employees;
- The role of university education as a guarantee for obtaining qualifications and skills such as practical training, management skills, teamwork, language and analytical skills;
- Promotion of entrepreneurial attitudes of students and teachers by the Spanish university system;
- Provision of services to improve the employability of graduates and PhDs (employment counselling and information, centres for employment, etc.);
- Incorporation of internship programmes that introduce students to specific companies; and
- Appeal of universities for companies as providers of postgraduate training.

UK

³⁷ Interview Wojciechowski

A range of monitoring initiatives has been undertaken by the Government as well as professional organisation such as Royal Academy of Engineering (Royal Academy of Engineering, 2012). The Higher Education Statistics Agency (HESA)³⁸ regularly publishes data on higher education graduates by gender or subject area. HEFCE also provides data with a special focus on STEM provision.³⁹

In 2015, UCKES published on the STEM labour market need (UCKES, 2015). It concludes that the most urgent priorities are in the ICT and engineering professions, and secondly but not as urgently in production management. Based on survey data the report concludes that the government should consider how the skills needs of high-level STEM occupations could be covered through a skills standards process. This should take into account broader demands within an occupation as well as more niche and sector-specific needs. The report also points to a need to further analyse how changing sectoral contexts of STEM skills are changing the nature of STEM skills requirements, for example for engineers that work in consultancy services.

Denmark

IDA, the Danish Society of Engineers,⁴⁰ regularly carries out studies on skills and employment opportunities for engineers' and scientists. In 2013 it commissioned a study on Engineering Labour Markets 2020 with specific focus on highly internationalised labour markets and the change in job roles and skills up to 2020 for example for researchers, managers, and in development functions. The study was based on a major survey and on interviews in companies (Teknologisk Institut, 2013). The results of the study have laid the foundation for developments of new further education and training courses. In 2015 IDA commissioned a study to assess why so relatively few engineers in Denmark end in top management. The study - based on a literature review and an extensive number of interviews - has developed profiles for successful top managers in engineering, and the findings of the study will feed into different initiatives by the Danish Engineering Confederation to profile engineers' and scientists' career opportunities.

8.3. The higher education sector

The case studies show that the majority of initiatives focus on promotion efforts to reach the STEM talent pipeline. However, there are also a number of examples in the case study reports which focus on the tertiary sector.

Spain

The status of interns was recently regulated by the Royal Decree 592/2014⁴¹, and company internship programmes are nowadays common in most universities offering STEM degrees. This initiative was taken in light of the high unemployment rates of Spanish graduates.

UK

There are several good practice examples of university-business cooperation in the UK.⁴² Many businesses report that they have links with one or more schools or colleges. These activities range from the provision of sandwich-year and other placements to real-life projects and resources to help students understand the practical relevance of their courses (CBI, 2013). The National Centre for Universities and Business (NCUB) publishes an annual

³⁸ <https://www.hesa.ac.uk/>

³⁹ <http://www.hefce.ac.uk/analysis/coldspots/heprovision/stem/>

⁴⁰ <http://english.ida.dk/>

⁴¹ Real DecUK reto 592/2014, de 11 de julio, por el que se regulan las prácticas académicas externas de los estudiantes universitarios. Available at: <http://www.boe.es/boe/dias/2014/07/30/pdfs/BOE-A-2014-8138.pdf>

⁴² See for example the Business University section on the CBI website: <http://news.cbi.org.uk/business-issues/business-university-collaboration/>

report called "State of the Relationship Report"⁴³. This report contains other sets of examples of good practice in university-business collaboration

8.4. University industry cooperation on STEM

Germany

Academy Cube is an online platform targeting academics, young professionals and job seekers from across Europe. The platform provides job offers and information about what courses will qualify them best for their desired job. Users can participate free of charge in online courses. In particular, the platform provides e-learning-based training courses for professionals in the IT and engineering area. The Academy-Cube initiative is an alliance of international companies, e.g. DFKI, BITKOM, EIT ICT Labs, Festo Didactic GmbH, Society for Computer Science e.V., LinkedIn Germany GmbH, Microsoft Germany, Robert Bosch GmbH, SAP AG, Software AG, ThyssenKrupp AG, University Duisburg-Essen etc. and public institutions, e.g., the Federal Employment Agency.

The National STEM Forum (Nationales MINT Forum) was established in 2012 on the initiative of the German Academy of Science and Engineering (acatech) and the BDA/BDI initiative 'MINT Zukunft schaffen'. Today, the National STEM Forum brings together 24 stakeholders to advance education in the fields of mathematics, computer science, natural sciences and engineering. Members include major foundations, academic institutions, professional associations, and university alliances. The Forum deals with the entire STEM education chain from early childhood education and extra-curricular, vocational and academic education to further education and lifelong learning. The Forum supports the initiatives of individual members and promotes joint activities. A number of working groups develop strategies for how to promote and improve STEM education, resulting in policy recommendations, and common quality standards.

"Go MINT" – the National Pact for Women in MINT Careers is another German initiative which brings together policy makers, business, science and the media with the aim of changing the image of MINT(STEM) professions in society. "Go MINT" is part of the federal government's qualification initiative and was launched in 2008 by the Federal Ministry for Education and Research to increase young women's interest in scientific and technical degree courses and to attract female university graduates into careers in business. According to statistics, over 33,000 new female students opted for a degree in engineering in the academic year 2011, which is almost three times the number of new female students in 1995. The picture in mathematics and natural sciences is similar. Here the number of new female students has increased by a factor of 2.5 since 1996 to 54,000.

Spain

Due to the high employment levels of Spanish graduates there is a lot of focus on the transition to the labour market and the skills needed in that respect. In April 2015, IBM Spain, Forética and the Polytechnic University of Madrid organised and participated in a 'Skills for Jobs' workshop, aimed at sharing best practices related to skills and employability issues. Another example is the collaboration between the Spanish Royal Academy of Engineering (RAI) and the company Academy Cube. Academy Cube is a platform that combines e-learning materials with job-hunting to facilitate the integration of young STEM graduates and professionals into European industry⁴⁴ (the initiative focuses mostly on ICT). The RAI welcomed the establishment of Academy Cube in Spain in 2013 and urged companies, universities and public administration in Spain to participate in the platform (euroxpress, 2013). Currently 10 universities around Spain participate in this initiative.

Denmark

'Engineer the Future' is partnership between the Danish Engineering Association, higher education institutions, professional organisations, and a number of Danish companies. The

⁴³ The 2015 issue is available online at:

http://www.ncub.co.uk/index.php?option=com_docman&task=doc_download&gid=335&Itemid=

⁴⁴ <http://www.academy-cube.com>

aim of the initiative is to renew the image that engineers and scientists have in Danish society and to profile the role engineers and scientists as play in technological innovation which contributes to growth, sustainability and quality of life in Denmark. It is an umbrella initiative “to get the ball rolling” as stated by the director of the Danish Engineering Association. The website for *Engineer the future* has a number of portraits of younger engineers and scientists who are in the labour force, describing their motivation to choose a technical study, their job, and how they believe they can contribute to growth, sustainability and quality of life. In addition the website includes a test about the user’s ability to think like a scientist, and posts media stories relating to science and engineering.⁴⁵

UK

A range of business initiatives in the UK focus on developing company skills strategies or on improving the image of specific industry sectors. Programmes such as the Women and Work Sector pathways initiative are designed to enable women to progress in traditionally male-dominated industries⁴⁶. Within this programme, between 2008 and 2011 the sector skills council for agriculture, Lantra, provided information on career progression and new career pathways in STEM-related agricultural jobs to over 2,000 women.

Bulgaria

The practical orientation of STEM study programmes can be considered as a driver for the collaboration with companies. As opposed to the general trend described in the Strategy for Higher Education, the University of Chemical Technology and Metallurgy is one of the higher education institutions in Bulgaria that is at the forefront of cooperation with industry. The university maintains relations with 80 Bulgarian firms.⁴⁷ This collaboration facilitates access to internships and entry to the labour market for university graduates, and access to higher education for company employees who have the necessary practical skills but lack the corresponding HE qualification. The University of Chemical Technology and Metallurgy also regularly consults companies on the relevance of the content of its study programmes as well as on the need for new programmes.⁴⁸ Based on the feedback, the university can then prepare a proposal for a modification of an existing programme or a proposal for a new programme.⁴⁹

In 2014, an online information system was developed and implemented. The aim of the system is for students, universities and companies to be able to register to facilitate opportunities for internships.⁵⁰ The information system matches the skills profiles of students with the requirements of employers.

Poland

The ‘*Perspektywy Educational Foundation*’ and Siemens are conducting a research project on women in technology called ‘Women’s potential for the technological industry.’⁵¹ It aims to analyse the conditions of educational choices by women and their pathways. It will provide recommendations to support women’s careers in technological fields.⁵²

UK

TAS is a programme developed by Jaguar Land Rover (JLR) together with partner universities across the UK. TAS draws upon the specific strengths of each university involved and their expertise in various scientific fields. These collaborations add significant value by allowing JLR to keep up with the technological needs of the industry and to

⁴⁵ <http://www.dtu.dk/Nyheder/2014/06/Engineer-the-Future>

⁴⁶ Final report is available online here: <http://dera.ioe.ac.uk/1309/>

⁴⁷ Based on an interview.

⁴⁸ Based on an interview.

⁴⁹ Modification of existing programmes as well as launch of new programmes should be approved by the Ministry of Education and Science (MES).

⁵⁰ <http://praktiki.mon.bg/sp/?m=3>

⁵¹ <http://www.potencjalkobiet.pl/>[accessed 4.9.2015]

⁵² <http://www.potencjalkobiet.pl/>[accessed 4.9.2015]

integrate the latest research into its education and training activities. The training activities are delivered by the partner universities and comprise a portfolio of postgraduate study modules tailored to the needs of JLR employees. Since September 2010, 4,700 people have been accepted to the TAS programme, and 3,600 of JLR's own engineers have participated in at least one module. This represents about 15% of the research and development (R&D) workforce. Each of the modules involves one week at the higher education institution and around a hundred hours of personal study time and assignments

In this respect, a recent Danish study (Shapiro 2015) found that the requirements for further education in STEM-intensive occupations depend upon the strategies that manufacturing and installation companies apply regarding automation and digitalisation. Those companies that see automation as a means to not only improve the efficiency, but also to improve agility and customer involvement in innovation processes tend to have much more advanced skills demands to their workforce, and they approach further education as an innovation and competitiveness investment, not only for their engineers but also for their skilled workers. In fact, there is a growing demand for production workers that are skilled at a STEM associate professional level. Those companies that invest in automation and digitalisation primarily for efficiency gains tend to have less of a strategic approach to investment in further education, and these companies seldom take actions to encourage employees to participate in education and training. They are concerned with the potential 'poaching effects' of training and they are generally reluctant to invest in further education if it is not directly linked to a planned promotion or training linked to the use of specific equipment (Shapiro, et al., 2015).

The study shows that those companies that combine investments in automation and digitalisation technologies with extensive education and training stand a better chance of not only achieving efficiency gains, but also improving agility and speed of innovation. This is the underlying rationale for Industry 4.0 discussed in the German case.

Denmark

In 2014, the former government and the social partners reach an agreement on investments in the upskilling of the Danish workforce so that more unskilled workers could become skilled and more skilled workers could become technicians through further education and training. Following that decision, the Danish Agency for Higher Education commissioned a study to Danish Technological Institute to assess whether there was a need to develop new further education programmes in manufacturing and smart buildings at the tertiary level. The study found that companies' motivation to further educate skilled workers at a tertiary level to a great degree depended on the companies' automation and digitalisation strategy. Those companies that primarily invested in automation for cost-cutting purposes were concerned that skilled workers trained to a tertiary level would no longer want to work in the manufacturing line; whereas those companies that invested in automation and digitalisation to cut costs but also to improve innovation speed and agility believed that investments in training shop floor workers to a technician level were a precondition to manufacturing excellence in a 4.0 industry setting.

Based on the study a new modularised short cycle tertiary level education is currently being developed in automation in advanced manufacturing.

8.5. Commonalities in STEM policy actions

The literature review has identified some commonalities across countries or regions which actively aim to promote STEM:

- Have implemented reforms in curriculum and pedagogy in science and math to allow for problem-based and inquiry-based learning and emphasis on creativity and critical thinking;
- The majority of measures focus on the STEM talent pipeline including minority groups;
- A number of broad-based public-private partnerships that have initiated a wealth of promotion activities and outreach measures, but their impact seems rarely to be evaluated;
- A wealth of studies on supply and demand for STEM skills are published also by actors with vested interests in STEM provision, but the data quality in studies is seldom questioned;

- Specific monitoring mechanisms even when in place seem to be insufficient to capture underlying dynamics such as skills and occupational hybridisations in STEM-related fields driven for example by ICT; data on labour market transition for graduates do not address issues such as underemployment for native graduates as well as migrant STEM professionals.

The examples provided show that the provision and demand for STEM skills is high on the agenda in the EU. However, many initiatives have an ad-hoc character and there is generally a lack of evaluations to assess the impact of particular initiatives. Even in countries that have established ongoing monitoring mechanisms based on statistics, the rapidly changing working environment for STEM occupations makes it difficult to fully capture these changes.

From a human capital perspective it is surprising that current monitoring instruments only look at employment and unemployment of STEM graduates without analysing the perceived quality and degree of matching, which could throw further light upon potential risks of underemployment, which has been a topic that has gradually gotten more attention since the OECD PIAAC data became available. (Information.dk, 2015).

Developments in platforms for real-time analysis of labour markets could be a way to improve knowledge about fast moving occupations and labour markets such as within STEM. The US-based company Burning Glass, which also has an office in the UK, provides this type of analysis. In 2013, it conducted a major study on STEM entry-level positions in the USA (Burning Glass, 2013).

9. Policy-relevant conclusions and policy pointers

9.1. STEM will likely continue to be high on the policy agenda

STEM skills make and will continue to make a central contribution to growth and innovation in Europe. STEM skills are not only in demand in high-tech sectors, but are increasingly in demand across different sectors of the economy such as ICT, and in knowledge services. Policy makers and industry stakeholders have therefore become increasingly concerned about issues relating to demand and supply of STEM skills in the EU.

Concerns about imbalances in STEM skill supply and demand are driven by:

- A recognition of the role technological innovation can play in kick-starting the economy after the crisis;
- A major replacement demand for STEM professionals and associate professionals is projected due to the aging of the STEM workforce. However these macro-economic projections have not factored in future developments that could impact STEM demand quantitatively such as further and more advanced forms of automation and digitalisation;
- The fact that a large number of STEM graduates find employment in non-core STEM sectors. However, we have not been able to find studies that further analyse and document graduates' transition pathways, which in the UK for example suggest that a substantial number of graduates end up as under-employed in low-paid services jobs. The same could be the case for migrant STEM graduates, though the evidence is more anecdotal.

9.2. Evidence about current STEM supply and demand

Data projections on STEM skills supply and demand suggest that there are no overall quantitative shortages of STEM skills at the aggregate EU level at present. However, there is evidence of skills mismatches and shortages in specific sectors in specific countries and regions of Europe.

The analysis of data sources including the country specific case studies shows that skills shortages and reported bottlenecks are primarily related to specific engineering disciplines and ICT studies.

The acute reported shortages in specific occupational areas are likely caused by under-investments in training of the existing STEM professionals, as there has been a general drop in investments in continuing education and training since the crisis.

There are several factors which explain why STEM skill shortages and mismatches are so frequently reported despite a lack of quantitative shortages at the aggregate EU level. These are:

- Growing employer expectations regarding the quality of the match;
- Entry barriers for STEM graduates who do not have labour market experience;
- Risk of under-employment of non-native STEM graduates;
- Insufficient absorptive capacity in SMEs to make productive use of the skills of STEM graduates, making the SMEs a less attractive employment and career destination;
- Career guidance oriented towards the public sector and large corporations.

Current reported bottlenecks are aggravated by employers' caution about the quality of the match and their preference for employees with labour market experience (to avoid the costs of introduction and on-the-job training of a new graduate and avoid the costs of failed recruitment). Data on bottleneck vacancies suggest that employers increasingly expect new graduates to be fully productive from day one. Bottleneck vacancies in STEM-related fields show that employers prefer to hire STEM professionals and associate professionals with labour market experience and often with highly specialised skills. The result, as the evidence from interviews and the literature reviews shows, is that highly qualified STEM graduates without labour market experience are at a high risk of being confronted with entry barriers to the core STEM labour market, leading to initial unemployment or the risk of under-employment. Mobility of high skilled graduates such as STEM professionals is one of the

ways to overcome geographically defined shortages, and can in addition have important innovation spill-over effects. That being said, non-native STEM graduates, also from EU countries, have experienced a lack of trust in qualifications. This is particularly true of those graduates without work experience. This could explain why for example Polish and Bulgarian STEM graduates are at risk of being underemployed when they seek employment in another EU country to further their career and employment prospects. Lack of paid internships is also reported as a barrier to labour market transition. The case studies and the data and literature analysis show that a large number of STEM graduates find employment in sectors that are traditionally considered as non-core STEM sectors. The German case study point to that due to a growing ICT and data intensity in many sectors of the economy the boundaries between what constitute core STEM sectors and non-core STEM sectors converge as, for example, manufacturing becomes more service intensive with the development of Industry 4.0.

Another factor explaining why STEM graduates end up in non-core STEM sectors is that graduates who have not had the opportunity to undertake STEM-related work while studying tend to have no or limited knowledge about the wide variation in jobs and career prospects that a STEM qualification may offer. The literature analysis clearly shows that students' level of insight in STEM career opportunities influences their labour market orientation, and impacts whether STEM graduates seek employment in core STEM sectors or not.

In particular in the UK there is evidence that the expansion of higher education has resulted in a growing employer differentiation between different 'types' of graduates, with employers placing a higher premium on graduates from the traditional prestigious universities. This could explain why so many UK STEM graduates end up in relatively low-paid service sector jobs with limited opportunities to deploy their STEM knowledge and skills. There is some evidence that the notion of 'employability' has a much wider meaning than a list of skills to be included in curricula. Findings suggest that employers place value on a wider range of dispositions and abilities, including graduates' values, social awareness and generic intellectuality — dispositions that can be nurtured within higher education and further developed in the workplace. In that sense simplistic employer surveys aimed to spur policy focus on the provision of STEM skills can distort labour market intelligence about the real issues at stake.

The above mentioned dynamics in STEM labour markets play a role in reported job vacancies parallel to unemployment among recent STEM graduates. Increasing the supply of STEM graduates will therefore most likely not alleviate current shortages, as there are major disconnects in the matching processes which will also need to be taken into account in forward looking policy making.

Further research is needed to analyse labour market transition pathways for STEM graduates, including the large number of STEM graduates that end up in labour markets that are characterised as non-STEM. Such research would also provide insights into questions such as the relative scope of unemployment of recent STEM graduates also from a mobility perspective, and could also provide evidence of the relative STEM intensity and how that is evolving in sectors which traditionally have been defined as non-STEM intensive.

9.2.1. Limitations of supply-side policies and dealing with unmet demand

There is some evidence that the massive expansion of higher education means labour market outcomes increasingly depend not only on having a degree in study fields that are in high demand in the labour market, but also that employment opportunities are increasingly defined by which university that has awarded the degree. These trends illustrate the limitations of supply side policies. If STEM graduates are to be a catalyst for job-rich growth and innovation outside the high-tech sector, and in particular in SMEs, supply side policies need to be complemented by measures to further develop the absorptive capacity in firms, understood as their ability to make productive use of and further develop recent graduates.

In many EU countries, public sector cuts have led to an increasing number of STEM graduates needing to find employment in SMEs and also outside high-tech sectors. However, both the case studies and the literature review suggest that university career and guidance provision only to a limited extent focus on SMEs as an employment destination. There are different ways that supply and demand side policies can be better balanced. Experiences from Denmark show that supply and demand side policies can go hand in hand.

The policy initiative ‘*Videnpilot Ordningen*⁵³ (the knowledge pilot scheme) targeted SMEs that had not previously hired a tertiary graduate. Through that scheme recent unemployed graduates could work in an SME on a specific jointly formulated innovation project for 9-12 months. Salaries would be partially funded by the Ministry of Higher Education and Research. An impact evaluation of the programme showed that the scheme led to regular employment of the graduates in the majority of cases, and it had a substantial effect on the absorptive capacity and innovation performance of the participating companies. The scheme is now integrated in a multi-strand innovation programme. Similar models could be considered more broadly across Member States to improve matching processes between SMEs in STEM-intensive sectors and STEM graduates, and to enable that more STEM graduates find employment in those sectors and jobs where STEM skills are most in demand. Digital platforms operated by sector bodies or SME organisations could enable efficiency in matching processes and spur mobility, also cross border mobility

9.2.2. Evidence about future supply and demand for STEM skills

At the EU level, CEDEFOP projects employment in STEM occupations to increase 12.1% by 2025, while overall employment in all other professions taken together (excluding STEM employment) is only expected to increase by 3.8% in the EU. Patterns in future STEM demand are projected to vary between Member States, and employment demand in other professional and associate professional and technician occupations (excluding STEM occupations) is projected to increase by 18.0% by 2025 thereby outpacing growth in STEM employment.

Data-driven methods to capture emerging skills trends within STEM-intensive sectors, value chains and occupations, combined with a mix of quantitative and qualitative methods to forecast the demand for specific STEM profiles, can form a foundation for building better labour market intelligence at a more granular level in order to inform policy making in the field of STEM.

9.2.3. Uncertainties and disruptive factors affecting future STEM demand

Quantitative and qualitative forecasts about future skills demands in technology-intensive occupations should be interpreted with caution, as a number of trends can have disruptive impact qualitatively and quantitatively. A range of factors may influence the future of work including convergence of key enabling technologies, a growing data intensity due to embedded sensor and chips, more advanced levels of automation, and changes in patterns of sourcing jobs and skills enabled by digitalisation. All these factors can profoundly change the future of work, and it could lead to a demand for STEM professionals with more transdisciplinary and hybrid skills profiles. STEM skills in combination with e-skills are the foundation for a digital economy in Europe, and constitute the core skills in strategies to reposition advanced manufacturing, as STEM skills are a key foundation for KETs (key enabling technologies). In addition, STEM skills are often associated with higher order analytical skills and the ability to process complex data. Technological convergence, growing data intensity, and the speed of obsolescence of new technological innovations are increasing the importance of innovation management. Traditional linear models of R&D are being replaced by new models of innovation. These rely on open and collaborative innovation and user- and market-led innovation to overcome uncertainties in volatile markets, to reduce the risks of market failure, and to strengthen customer relations and brand value.

In the USA these developments have led to a considerable debate about whether future engineering studies should be STEM- or STEAM-based, the latter denoting that arts and creativity should be integrated in engineering and technical education.

Developments in cloud computing and 3D prints could further accelerate the transformation of labour markets and it could change how matching of skills supply and demand occurs today within national labour markets. This could result jobs and skills, also in the field of

⁵³ <http://ufm.dk/forskning-og-innovation/tilskud-til-forskning-og-innovation/find-danske-tilskudsprogrammer/programmer-under-innovationsfonden/videnpiloter-under-afvikling>

STEM, becoming debundled and sourced as tasks that STEM professionals can bid on via digital platforms such as Upwork, regardless physical location. The impact of these platforms could medium term be that they will alleviate location based supply and demand mismatches. It is in no way certain how these new ways of mediating jobs and skills will play out. They could lead to rich eco-systems of digitally enabled high-skilled STEM entrepreneurs, or to a deterioration of working conditions as access to the global STEM talent base is exponentially increased.

9.2.4. Steering STEM skills

The lack of commonly agreed statistical definitions on STEM within the EU and the lack of data at a sufficiently granular level limit the decision base in policy making. Furthermore, using the umbrella term STEM is not necessarily helpful in discussions about supply and demand of science, technology, engineering and maths graduates. Different fields within STEM tend to be highly specialised, each with its own properties and core subjects. The implications are that one STEM field can most likely not replace another. The literature review furthermore shows that employer demand tends to be for highly specialised employees, limiting the opportunities for educational substitution even within a field such as engineering. From a graduate perspective STEM represents far too broad a field to guide choice of study and labour market orientation.

A deeper understanding of how matching dynamics play out and how they impact career destinations and career opportunities for STEM graduates requires much better data, including longitudinal data, and more research on labour market transition pathways for STEM graduates from the perspectives of graduates and employers. Such an effort should include a focus on recruitment and selection mechanisms, including how ‘employability’ and professional identity are defined and shaped by graduates as well as by employers.

Evidence from employer surveys and analyses of vacancies are often contradictory. Job vacancies tend to be very specific when it comes to technical skills requirements, whereas employer surveys and interviews regarding STEM graduates tend to stress the important of transversal skills such as communication, problem solving, and team cooperation, and personal characteristics such as flexibility and ability to thrive in concurrent change. These are skills and abilities that employers typically refer to as ‘employability skills’. Numerous studies have been published on STEM graduates and their lack of ‘employability skills’ However, many of these studies are based on limited survey data, and for the higher education sector to take action more research is needed to understand the relative premium put to ‘employability skills’, and what they mean in practice in labour markets for new STEM graduates.

Vacancy data indicate that many STEM vacancies are for highly specialised posts which would be hard for any higher education graduate to without substantial work experience. Data indicate that:

- Employers may be expecting too much (in terms of ready units of labour).
- More needs to be done to support innovations in STEM curriculum and pedagogics so that graduates have more opportunities to work on authentic and complex challenges or through partnerships with companies are exposed to cases and tasks that are embedded in the learning environment.
- Real-time labour market data through data mining offer new opportunities for public and private providers and individuals to create a dynamic, efficient and timely continuing training response to fast changing occupations and skills such as in STEM fields.

To inform the dialogue between higher education and industry, more knowledge is needed regarding the labour market induction of STEM graduates and how the transition can be facilitated through strong partnerships. There is a need for examples of how such good practice partnerships have reached some level of scale and what the critical processes and steps have been.

9.3. Policy pointers

Six study findings should in particular be considered in any future action to promote STEM:

1. The *umbrella term STEM* is not a useful category for understanding the supply and demand dynamics in science, technology, engineering and mathematics as it tends to imply a high level of substitution between different education fields and occupations, which is not necessarily possible in practice. Furthermore, there is a lack of agreed statistical definitions within countries and across the EU of what constitute STEM study fields, STEM occupations, and STEM sectors. There is also a *lack of sufficiently granular data on STEM vacancy rates and STEM mobility*. For some countries, there is a lack of data on STEM graduates and STEM labour markets. These data gaps mean there is often a lack of adequate data to inform policy making reliably.
2. The analysis has also focused on the debates and criticism about *STEM graduates' employability* and how this is shaped. In a wider policy context, the narrative on graduate employability mirrors shifting interplays between universities, the labour market, and HE policies. Demands to the higher education sector are being reshaped with a stronger focus on the economic value of higher education graduates and parallel to the expansion of higher education provision - also in the field of STEM. In that changing landscape, a question emerges as to *whose responsibility it is to enable a smooth transition* into the labour market and to productive and relevant employment for STEM graduates. What is the balance of responsibility between the government, employers, or individual graduates themselves? A fundamental question for policy making.
3. An increase in the supply of STEM graduates will not necessarily meet demand because *a large number of STEM graduates end up in non-core STEM jobs*. There is a lack of good evidence about the underlying factors that shape graduates' labour market transition and employment opportunities and whether it is out of choice or necessity that STEM graduates end up in jobs in non-core STEM sectors.
4. The growth of the higher education sector, cuts in the public sector and limited growth in recruitment in "traditional" graduate employers in many EU countries have led to a situation in which graduates increasingly will need to *orientate themselves towards SMEs*. While this could be positive from an innovation perspective, there is some evidence that SMEs in traditional sectors of the economy have difficulties in *absorbing and making productive use* of the increasing number of higher education graduates and their knowledge and skills. This can result in under-employment. This development illustrates that alongside "supply-side" skills policies, efforts also need to be directed at stimulating *absorptive capacity and skills use* across the economy.
5. Job vacancy data suggest that employers in several EU countries *may have overly high expectations of graduates*. Although higher education institutions can work with industry in many ways to ensure that graduates are prepared for a dynamic labour market, graduates cannot be expected to be highly specialised and have the full range of skills necessary for a particular post to allow them to be fully productive from day one. Furthermore, how "employability skills" are understood seems to depend upon such issues as size of company and sector, as well as work organisation and management practices, which makes it even more complex to ensure a match.
6. The *mobility of high-skilled STEM graduates* from within the EU increased during the crisis, but there is evidence that STEM graduates from other EU countries are at greater risk of ending up as under-employed or under precarious working conditions. Furthermore, outside the ICT sector employers seem hesitant to recruit graduates from other countries within or outside the EU.

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