

STEM

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ENJOY. SCIENCE TECHNOLOGY ENGINEERING MATHEMATICS.

DELIVERABLE REPORT

D2.1 REPORT ON EMPLOYMENT LABOUR MARKET TRENDS IN EU

M20, DECEMBER 2017





PROJECT DETAILS

| | |
|-----------------|---|
| PROJECT ACRONYM | STEM4YOU(th) |
| PROJECT TITLE | Promotion of STEM education by key scientific challenges and their impact on our life and career perspectives |
| GRANT AGREEMENT | 710577 |
| START DATE | 1 May 2016 |
| THEME | SWAFS |

DELIVERABLE DETAILS

| | |
|----------------------------------|---|
| WORK PACKAGE NO. AND TITLE | Economic and societal dimension of science and technology |
| WORK PACKAGE LEADER | Open Evidence (OE) |
| DELIVERABLE NO. and TITLE | D2.1 Report on employment labour market trends in EU |
| PARTNER IN CHARGE OF DELIVERABLE | OE |
| NATURE OF DELIVERABLE AS PER DOW | R=Report |
| DISSEMINATION LEVEL AS PER DOW | PU=Public |

REPORT DETAILS

| | |
|--------------------------------------|--|
| VERSION | 2.0 |
| DATE | 31 December 2017 |
| MAIN AUTHOR'S NAME AND EMAIL ADDRESS | Pietro Tornese (ptornese@open-evidence.com) Francisco Lupiañez-Villanueva |
| CONTRIBUTING AUTHORS | JSI IRSA EF |



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STATUS (choose one and delete the
rest)

Revised in line with the Review Meeting
comments



TABLE OF CONTENTS

| | |
|---|-----------|
| TABLE OF CONTENTS | 4 |
| LIST OF FIGURES | 6 |
| LIST OF TABLES | 7 |
| LIST OF ABBREVIATIONS | 8 |
| EXECUTIVE SUMMARY | 10 |
| 1 INTRODUCTION | 13 |
| 2 METHODOLOGY | 14 |
| 2.1 BACKGROUND: ON MIXED METHODS | 14 |
| 2.2 OVERALL DESIGN AND RELATIONS WITH OTHER WPs | 15 |
| 2.3 SPECIFIC METHODS | 17 |
| 2.3.1 SYSTEMATIC LITERATURE REVIEW | 17 |
| 2.3.2 DATA ANALYSIS | 19 |
| 2.3.3 CURRICULA ANALYSIS | 25 |
| 2.3.4 IN-DEPTH INTERVIEWS | 27 |
| 2.3.5 VALIDATION WORKSHOP | 31 |
| 3 THE EU LABOUR MARKET FOR STEM SKILLS | 37 |
| 3.1 DEMAND FOR STEM SKILLS | 37 |
| 3.1.1 SIZE AND COMPOSITION OF THE STEM INDUSTRY | 37 |
| 3.1.2 CURRENT STEM EMPLOYMENT | 40 |
| 3.1.3 FUTURE STEM EMPLOYMENT | 47 |
| 3.2 SUPPLY OF STEM SKILLS | 55 |
| 3.2.1 STEM STUDENT BODY | 55 |
| 3.2.2 STEM GRADUATIONS | 59 |
| 4 FACTORS AFFECTING THE STEM SUPPLY | 63 |
| 4.1 ECONOMIC FACTORS | 63 |
| 4.2 SOCIAL AND CULTURAL FACTORS | 64 |
| 4.3 INSTITUTIONAL FACTORS | 65 |
| 4.4 INTERVENTIONS TO ENCOURAGE STEM UPTAKE | 66 |
| 5 CONCLUSIONS | 69 |
| REFERENCES | 71 |



APPENDIX

87

INTERVIEW GUIDELINES

87



List of figures

| | |
|---|----|
| Figure 1 Evolution of STEM labour market supply and demand, 2016-2025 | 33 |
| Figure 2 Shortage of supply scenarios..... | 33 |
| Figure 3 Surplus of supply scenarios | 34 |
| Figure 4 Equilibrium between supply and demand scenarios..... | 34 |
| Figure 1 Size of the STEM industry, as % of the active population (2015)..... | 37 |
| Figure 2 Employed in STEM sectors in the EU-28 as % of active population, 2006 to 2015 | 38 |
| Figure 3 STEM industry (STEM and non-STEM skills) by age group, 2015..... | 39 |
| Figure 4 STEM industry (STEM and non-STEM skills) by gender, 2015 | 40 |
| Figure 5 STEM Employment in the EU by occupation, 2015..... | 42 |
| Figure 6 STEM Employment as % of total employment, 2015..... | 43 |
| Figure 7 STEM Employment in the EU, 2011-2015 comparison..... | 47 |
| Figure 8 STEM job openings in the EU, 2015-2025 | 48 |
| Figure 9 Future STEM employment growth (in %) across the EU in 2015-2025 | 49 |
| Figure 10 STEM students as % of total students in the EU, 2014..... | 55 |
| Figure 11 STEM students as % of student body in the EU by gender, 2014 | 56 |
| Figure 12 Distribution of STEM tertiary graduates by field and gender, EU, 2014..... | 56 |
| Figure 13 Proportion of female students in STEM fields, EU, 2014 | 57 |
| Figure 14 STEM students as % of total students in the EU, breakdown by field of study, 2014 | 58 |
| Figure 15 STEM graduates in the EU, 2003-2012..... | 60 |
| Figure 16 Graduations in STEM fields as % of all graduations, EU-28 and US, 2003-2012 | 60 |
| Figure 17 STEM graduates as % of total graduates, breakdown by field of study, 2014. | 61 |
| Figure 18 Average Annual Growth Rate (AAGR) in the share of STEM graduates in the EU, 2008-2012..... | 62 |
| Figure 19 Average Annual Growth Rate (AAGR) in the share of STEM graduates, selected MS, 2008-2012 | 62 |



List of tables

| | |
|--|----|
| Table 1 Methodological overview - How well is the EU prepared to meet future STEM skills requirements? | 16 |
| Table 2 Database overview | 18 |
| Table 3 STEM fields of study | 20 |
| Table 4 STEM fields of study, ISCED-F 2013 and ISCED 2011 correspondence table..... | 21 |
| Table 5 Comparison of STEM occupation definitions | 22 |
| Table 6 STEM occupations, three- and four-digit ISCO-08 classifications | 23 |
| Table 7 QS – ISCED correspondence table | 25 |
| Table 8 Top 5 Universities by STEM field, global..... | 26 |
| Table 9 STEM Interview guidelines..... | 29 |
| Table 10 STEM Occupations | 41 |
| Table 11 STEM Employment as % of total employment, 2015 – Country ranking | 44 |
| Table 12 Future STEM employment growth (in %) across the EU in 2015-2025..... | 50 |



List of abbreviations

AAGR: Annual Growth Rate
ASPIRES: Accelerating Strategies for Practical Innovation and Research in Economic Strengthening
AU: Austria
BE: Belgium
BG: Bulgaria
BIM: Building Information Modeling
CAO: Chief Analytics Officer
CEDEFOP: European Centre for the Development of Vocational Training
CZ: Czech Republic
CY: Cyprus
DE: Germany
DK: Denmark
EE: Estonia
EL: Greece
ES: Spain
FI: Finland
FR: France
GVCs: Global value chains
HR: Croatia
HRST: Human resources in science and technology
HU: Hungary
IE: Ireland
ICT: Information and communications technology
ILO: International Labour Organization
IoT: Internet of Things
IRR: Internal Rate of Return
ISCED: The International Standard Classification of Education
ISCO: International Standard Classification of Education
IT: Italy
KET: Key Enabling Technologies
LT: Lithuania
LU: Luxembourg
LV: Latvia
MRE: Marine renewable energy
MT: Malta
NL: Netherlands
NPV: Net Present Value
PL: Poland
PT: Portugal
RO: Romania
SCCT: Social cognitive career theory
SOC: Standard Occupational Classification
SE: Sweden
SI: Slovenia
SK: Slovakia



UK: United Kingdom



EXECUTIVE SUMMARY

The broad STEM industry (comprehensive of STEM and non-STEM skills) employed about one-third of the EU active population in 2015. Around 76.5 million people in the EU-28 aged from 15 to 74 were employed in science and technology. The proportion of employees differed greatly among Member States. Luxembourg and Denmark reported the highest proportions, whereas Romania and Greece reported the lowest shares. The size of the STEM industry has increased in the last ten years, and women accounted for about half of the industry. In 2015, only a quarter of the workers in the STEM industry was younger than 34 years old.

In 2015, the labour market for STEM skills accounted for 9% of the total employment in the EU. The figure includes 7.8 million among science and engineering (S&E) technicians, construction supervisors, power plant operators, process control technicians, ship and aircraft controllers ("S&E associate professionals"); 6.7 million among physicists, mathematicians, life science professionals and engineers ("S&E professionals"); 3.7 million among software developers, database professionals ("ICT professionals"); and 1.7 million ICT technicians.

During the period 2011-2015, STEM employment in the EU has increased by 5%. Sectors with the highest STEM employment in the EU include Business Services, Manufacturing, Real Estate, Construction, and ICT services.

This expansion is forecast to continue over the next decade. In the period 2015-2025, there will be around 8.2 million STEM jobs openings in the EU. STEM professionals will probably be more sought after than STEM associate professionals. Future growth in STEM employment is likely to be unevenly distributed across EU Member States. Austria, Sweden, Slovenia, and Malta will enjoy a growth of S&E professionals. In Finland, France, Germany, Hungary, Italy, Luxembourg, Portugal, employment of S&E and ICT professionals is likely to increase. At the same time, Germany and Hungary are expected to have a drop in employment of associate professionals, and so are Bulgaria, Lithuania and Romania. Employment will increase to at least a certain extent across all STEM occupations in Denmark, Spain, Czech Republic, Ireland and Luxembourg.

The outlook for the future STEM industry in the EU as a whole is complex. The skills profiles of STEM workers will need to adapt on the developments and trends of the industries they work for. In addition to industry-specific trends, a number of cross-sectoral factors could further shape the demand for STEM workers. Such trends include automation, the Big Data trend, cloud computing, Internet of Things (IoT), new production processes (Industry 4.0), a growing demand for interoperability, standardization, and new threats from cybercrime and cyberterrorism. Finally, many of the STEM job openings in 2025 will be a consequence of replacement demand.



STEM students in the EU account for 27% of all tertiary education students. There were 5.3 million STEM students in 2014, of which 69% were male and 31% were female. Germany, the most populous Member State, had the largest relative STEM population (33% of all students) followed by Greece (28%), Romania (28%), Finland (28%) and the UK (26%).

STEM programs are consistently less popular among women. Nowhere in the EU are STEM programs attended by more than one-fifth of the female student population. They are relatively more attractive in Germany (19% of female students enrolled in a STEM program). In Italy, France, Belgium, Denmark, Croatia, Luxembourg, Cyprus, and Malta, less than 10% of female students are enrolled in a STEM program.

Engineering accounts for almost half of the STEM student population. Across the EU, 46% of all STEM students (2 million) study engineering, with male students representing 81% of the student body. The second most common field of STEM education (around 750 thousand students) is computing. In this field, 83% of the students are male.

Women are the majority in Life Science programs. The third largest field of STEM study is life science, which include environmental science, biology and biochemistry (577 thousand), accounting for 13% of all STEM students. Women account for two-thirds of the students (63%). In physics, chemistry, and earth science, female students are 41% of all students. Finally, in manufacturing and processing programs (food processing engineering; textiles, clothes, footwear, leather engineering; Mining and extraction engineering; Materials engineering), women account for nearly half of the student body (48%).

Approximately 900 thousand students graduated in STEM tertiary education in the EU in 2012. Women account for 32%. Graduations from STEM programs account for 19% of all graduations. Germany has the largest number and share of STEM graduates (around 155 thousand and 28%). Sweden (24%), Greece (23%), Finland (23%), Romania (22%) and Malta (21%) have the next largest shares of STEM graduates. Between 2008 and 2012, the proportion of STEM graduates in the EU plateaued. It grew in Slovenia and Romania, and fell in Spain and Czech Republic.

The literature identifies a number of economic, social and cultural factors to explain why students choose a particular field of study. Economic returns to STEM education exceed those to humanities. STEM graduates have a lower unemployment risk than others. The choice to pursue STEM studies is not only governed by expected economic returns, but also by cultural norms and expectations. Social factors to enter STEM programs specifically include influence from family, high school teachers, and friends; success in math and science at school; and interest in the career.



The way in which science is taught in schools also has an impact on students' attitude towards STEM and on their choice of study fields. There is a debate on whether STEM teaching should be organised in distinct subject areas or as a single, interdisciplinary program during later school years. Another factor that determines student interest in STEM is the quality of teaching, and the role of teachers in transferring STEM knowledge. To students, science is boring, over-prescriptive, and irrelevant to life outside school.

Gender segregation persists across STEM fields. The lack of role models, discouragement from the media, gender differences in cognitive skills, and unpleasant experiences related to gender-bias in the classroom have all been cited as reasons to explain why women tend not to pursue a career in STEM field. Gender stereotypes emerge early on and develop throughout adolescence. Parents and educators tend to see girls as less qualified in math, which is perceived masculine, and to consider STEM subjects as less important for girls than for boys. The education system, teachers, and peers tend to reinforce these stereotypes, giving support to gendered choices with regard to studies and career prospects. Women may also perceive the university environments of male-intensive fields of study, such as engineering, as unpleasant.



1 INTRODUCTION

The aim of this report is to provide an overview of the labour market for STEM skills in the European Union. The present document represents deliverable D2.1 of the STEM4YOUTH project funded under H2020. It summarizes and presents the result of Task T2.1 “Analysis of Supply and Demand Side of STEM”. Chapter 2 provides an overview of the overall approach and the methodology used throughout the study. Chapter 3.1 presents the findings regarding the demand for STEM skills in the EU. In particular, the size of the STEM industry, the current and future STEM employment have been analysed, through primary and secondary data. Chapter 3.2 considers the supply of STEM skills, and the participation in STEM programs. Chapter 4 investigates the factors behind the choice of a STEM study field and the supply of STEM skills, and interventions to encourage the uptake. Finally, conclusions are presented in chapter 5, followed by a reference list and by the guidelines used during interviews.



2 Methodology

This chapter presents the overall logical framework for WP2, along with a detailed description of the different methods used throughout the realization of this deliverable, and the relation with the other WPs.

2.1 Background: on mixed methods

Qualitative research has been the object of a long and controversial debate (Bryman, 2006; Dezin & Lincoln, 2005) possibly due to the difficulty to establish its own distinctively peculiar “language” and “truths”. While quantitative research has become the language of research because of its success, it has been difficult to establish an independent qualitative language of research with its own developed concepts about the “trinity of truth”: reliability, validity, and generalisation. Whereas the more radical supporters of the qualitative approach argue that the assessment of the quality of qualitative data should transcend conventional standards (i.e. reliability, validity, generalisation), several scholars hold that external confirmation of qualitative findings through well designed purposive sampling checking and methods/sources triangulation can enhance the credibility and validity of qualitative research (Bryman, 2006; Denzin & Lincoln, 2005; Miles & Huberman, 1994; Seale & Silverman, 1997). While pure qualitative approaches are still pursued, since the 1990s a new consensus emerged about the complementary relationship between qualitative and quantitative perspectives that recognizes the different utilities of each for a researcher.

Studies that combine both qualitative and quantitative methods are becoming more and more common (Brannen, 1992; Bryman, 1988, 2004; Bryman, 2006; Creswell, 2007; Creswell, 2003; Tashakkori & Teddlie, 2003). In this sense, we end up with three distinct approaches to research: quantitative; qualitative; and what is variously called multi-methods (Brannen, 1992), multi-strategy (Bryman, 2004), mixed methods (Creswell, 2003; Tashakkori & Teddlie, 2003).

Our research design, data gathering, and analysis are based on a **mixed methods approach** where we triangulate different methods/instruments and sources. As suggested in the editorial (Veltri et al., 2014) to the special issue that the journal “Innovation: The European Journal of Social Science Research” has recently developed on the topic, qualitative and mixed methods research can contribute to “evidence-based” policy in a number of ways depending on the purpose for which the research is launched. Green et al (1989) through a systematic review, later replicated and fully confirmed by Bryman (2006), identified five justifications used by scholars combining quantitative and qualitative methods and sources in mixed approaches:



1. **Triangulation:** convergence, corroboration, correspondence of results from different methods. In triangulation the emphasis is placed on seeking corroboration between quantitative and qualitative data.
2. **Complementarity:** re-elaboration, enhancement, illustration, clarification of the results from one kind of source/method with the results from another kind of source/method;
3. **Development:** using the results from one method to inform the other method (i.e. typically qualitative research such as focus groups conducted as preparatory of quantitative surveys)
4. **Initiation:** seeking the discovery of paradox and contradiction, new perspectives, the recasting of questions or results from one method with questions or results from the other method;
5. **Expansion:** extending the breadth and range of enquiry by using different methods for different inquiry components

2.2 Overall design and relations with other WPs

In his review Bryman (2006) found that **triangulation and complementarity** are the main justifications used by scholars adopting mixed methods approaches. Triangulation and complementarity are also the main reasons why we used different methods and sources in this WP2. More in detail, we have translated WP2 tasks and objectives as envisaged in the proposal into the following overarching research question:

How well is the EU prepared to meet future STEM skills requirements?

This provided us with a starting point for the operationalisation of our tasks. In turn, we have specified our research question into the following four sub-questions:

- *RQ1: What is the extent and nature of the EU labour market for STEM skills?*
- *RQ2: Which factors affect the EU supply of STEM skills?*
- *RQ3: To what extent do innovative practices prepare students with STEM skills? What are the main initiatives to foster STEM skills in the EU?*
- *RQ4: How is the EU market demand for STEM skills likely to evolve in the future, and which STEM skills will likely be most in demand?*

Findings for the first two sub-questions (RQ1 and RQ2) are reported in Deliverable D2.1 “Report on employment labour market trends in EU”, while findings for third and the fourth sub-questions (RQ3 and RQ4) are reported in Deliverable D2.2 “STEM qualification and job profiles report”.

Each of the four sub-questions was answered through a mixed-methods approach, following the principles of triangulation and complementarity. The following five methods were used during the work:



- A systematic **literature review**, to set an overall background;
- Quantitative **data analysis** from official statistics (such as Eurostat) to describe and summarize trends in the EU labour market for STEM skills;
- A **curricula analysis** to describe innovative initiatives as well as key features of leading STEM departments;
- In-depth **interviews** to employers, to understand demand-side barriers;
- A **validation workshop**, to understand supply-side barriers and to develop recommendations.

Each method was used to target one or more research sub-questions. The following figure sketches the methodologies that were used in each sub-question.

Table 1 Methodological overview - How well is the EU prepared to meet future STEM skills requirements?

| | Desk research | | | Field research | | |
|--|-------------------|---------------|--------------------|---------------------|---------------------|------|
| | Systematic review | Data analysis | Curricula analysis | In-depth interviews | Validation workshop | |
| <i>RQ1: What is the extent and nature of the EU labour market for STEM skills?</i> | | ✓ | | ✓ | | D2.1 |
| <i>RQ2: Which factors affect the EU supply of STEM skills?</i> | ✓ | | | | | |
| <i>RQ3: To what extent do innovative practices prepare students with STEM skills? What are the main initiatives to foster STEM skills in the EU?</i> | ✓ | | ✓ | | ✓ | D2.2 |
| <i>RQ4: How is the EU market demand for STEM skills likely to evolve in the future, and which STEM skills will likely be most in demand?</i> | ✓ | ✓ | | ✓ | ✓ | |

WP2 is a self-standing work package. However, it is set to contribute to the work of the project, especially with regards to WP3, WP5, WP6, and WP9. More in detail, findings from RQ2 inform the development of methodologies and educational tools (T3.3), while findings from the literature review used to answer to RQ3 benefits from synergies with and is strictly related to the analysis of methodologies and tools (T3.1). The supply and demand analysis conducted for RQ1, and the forecast in the context of RQ4, feed into the development of the content, tools and learning methodology (WP5), and are set to be included in the OLCMS (WP6). Finally, the findings presented in D2.1 and D2.2



contribute to the overall communication of the project, and are contained in the diffusion material developed and shared in the context of WP9.

In the remainder of this chapter, each of the five methods used is described in detail, with particular regard to information collection, processing and analysis.

2.3 Specific methods

2.3.1 Systematic literature review

Our systematic literature review has been aimed at answering the following research sub-questions:

- *RQ2: Which factors affect the EU supply of STEM skills?*
- *RQ3: To what extent do innovative practices prepare students with STEM skills? What are the main initiatives to foster STEM skills in the EU?*
- *RQ4: How is the EU market demand for STEM skills likely to evolve in the future, and which STEM skills will likely be most in demand?*

The review also contributed setting a background for our research, and screened the body literature existing on the matter, by combining studies on supply and demand and studies specifically focused on other aspects concerning STEM, such as gender studies or program evaluations. In this literature review, a structured approach to find and choose the relevant articles was applied. This selection had to be not too broad, so as to have manageable number of papers, and not too restricted, so as to include all the existing relevant evidence. If the review was exclusively focused on a European context, too few results would have been obtained and an important part of the literature would have been missed out accordingly. Therefore, we included evidence from third countries.

The selection of the relevant articles followed three steps:

1. Setting up the scope, the search string, and the inclusion criteria;
2. Creating the database, identifying studies;
3. Selecting the studies to be included in the review.

We defined the scope of the review using the PICOC model: Population, Intervention, Comparison, Outcomes, Context. The population of the study is the EU, where applicable. Interventions are initiatives to encourage the uptake of STEM disciplines, whereas Comparison is not applicable in this case. Outcomes are different variables, such as enrolments, graduations, or dropouts; subjects; Context is STEM skills. However, for the systematic review we broadened the scope in order to have a richer insight of the literature. After several calibrations, the following search string was used with Boolean operators:



*(STEM OR (science AND technology AND engineering AND (mathematics OR maths)))
AND (skills OR competencies OR supply OR degree OR graduate OR university OR
school OR college OR (higher AND education) OR learning OR curricula OR student)
AND (jobs OR (job AND placement) OR employment OR career OR demand OR
workplace OR labour OR labor).*

We introduced some variations in the search string to check how this modified our results. For example, if we did not include the words “school” or “university”, relevant papers disappeared. On the other hand, if we only used the most relevant words such as “skills”, “supply”, “demand” or “higher education”, the number of results increased dramatically and most of the papers deviated notably from the objective of this study. Therefore, we concluded that the previous search string was the most suitable.

Our inclusion criteria were documents written in English and no older than 2000. Using these criteria and the search string, we conducted the search in October 2016 in five electronic databases: EconLit (ProQuest XML), Emerald Management Xtra 111, IDEAS – RePEc (Research Papers in Economics), ISI Web of Science, and Scopus. The following table provides an overview of the data sources.

Table 2 Database overview

| Source | Description |
|---|--|
| EconLit (ProQuest XML) | It is a bibliographic database published by the American Economic Association. It offers access to bibliographic information and abstracts of journal articles, monographs, dissertations, working papers and reviews of documents published in specialized economics and business journals. It covers topics such as accounting, economic policy, labour, marketing economic theory, etc. |
| Scopus | Scopus is the largest abstract and citation database of peer-reviewed literature: scientific journals, books and conference proceedings. It delivers a comprehensive overview of the world's research output in the fields of science, technology, medicine, social sciences, and arts and humanities. |
| ISI Web of Science | It provides access to the world's leading citation database, with multidisciplinary information from over 12,000 high impact journals and over 160,000 conference proceedings from around the world. |
| IDEAS – RePEc (Research Papers in Economics) | It is the largest bibliographic database dedicated to Economics and available freely on the Internet. It includes over 1,700,000 items of research. About 1500 institutions contribute their bibliographic data directly to this database. |



Emerald Management Xtra 111

Emerald is a global publisher linking research and practice to the benefit of society. The company manages a portfolio of over 295 journals and over 2,500 books and book series volumes. The database gives access to some of these documents.

The search provided 2183 results. A preliminary screening of the results revealed that many articles were not relevant and the number went down to 824. In order to narrow the number of articles, the most relevant among them were selected through the screening of the abstracts. This restriction was aimed at finding papers closely related to STEM to create the final database. After introducing these restrictions, the following step was to check that articles were not repeated within the and among databases. The number of papers decreased to 287.

In the analysis, it became soon clear that the literature provides little systematic evidence on demand and supply of STEM-skilled professionals. Therefore, we validated this list through the integration with **reference and manual desk research on grey literature, administrative sources, policy documents and reports**, to maximize the results. Such literature was screened at the national, EU, and international levels through conventional Internet search engine capabilities.

2.3.2 Data analysis

Our data analysis targeted the following two sub-questions:

- *RQ1: What is the extent and nature of the EU labour market for STEM skills?*
- *RQ4: How is the EU market demand for STEM skills likely to evolve in the future, and which STEM skills will likely be most in demand?*

Official statistics (OECD, Eurostat, Cedefop) were consulted and analysed to portrait the main features of the EU labour market for STEM skills, in terms of supply (meant as education) and demand (meant as employment), as well as the forecast of demand for STEM skills up to 2025.

2.3.2.1 Supply

The present study defines the supply of STEM skills in terms of education level and field, in line with international standards, and subject to data availability. According to the OECD Canberra Manual (OECD, 1995), whose recommendations are followed on the Eurostat domain, human resources “devoted to science and technology” (HRST) are people who either

- have successfully completed a tertiary level of education;
- do not formally qualify as above, but are employed in occupations where such qualifications are normally required.



Levels and fields of education are here defined according to the European Classification of Fields of Education and Training¹, adapted from International Standard Classification of Education (ISCED). Developed by UNESCO in the 1970s, ISCED is the reference international standard for organising education by level and field. It forms part of the UN International Family of Economic and Social Classifications². With respect to levels of education, a tertiary education corresponds to: Short-cycle tertiary education (ISCED 5); Bachelor's or equivalent level (ISCED 6); Master's or equivalent level (ISCED 7); or Doctoral or equivalent level (ISCED 8).

With respect to fields of education, where possible, a narrow definition has been applied in the present study. The following two-digit codes are considered here as **STEM fields**:

4. Life science (EF42)
5. Physical science (EF44)
6. Mathematics and statistics (EF46)
7. Computing (EF48)
8. Engineering and engineering trades (EF52)
9. Manufacturing and processing (EF54)

Other fields, such as Architecture and Building (EF58) or Health (EF72) are sometimes included in STEM studies using broader definitions (e.g. EU Skills Panorama, 2014). The following table shows all STEM fields of study here considered at a three-digit level of detail.

Table 3 STEM fields of study

| ISCED category (2-digit) | ISCED category (3-digit) | Code | ISCED Name |
|--|---|-------|---|
| Science, mathematics and computing (EF4) | Life science (EF42) | EF421 | Biology and biochemistry |
| | | EF422 | Environmental science |
| | Physical science (EF44) | EF440 | Physical sciences (broad programmes) |
| | | EF441 | Physics |
| | | EF442 | Chemistry |
| | | EF443 | Earth science |
| | Mathematics and statistics (EF46) | EF461 | Mathematics |
| | | EF462 | Statistics |
| Engineering, manufacturing | Computing (EF48) | EF481 | Computer science |
| | | EF482 | Computer use |
| | Engineering and engineering trades (EF52) | EF520 | Engineering and engineering trades (broad programmes) |
| | | EF521 | Mechanics and metal work |

¹ Europa - RAMON - Classification Detail List. Available at http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=CL_FIELD99&StrLanguageCode=EN&IntPckKey=&StrLayoutCode=HIERARCHIC (retrieved 31 October 2016).

² United Nations Statistics Division - Classifications Registry. Available at <http://unstats.un.org/unsd/class/family/default.asp> (retrieved 31 October 2016).



| | | | |
|------------------------------|--|--------------|---|
| and construction (EF5) | Manufacturing and processing (EF54) | EF522 | Electricity and energy |
| | | EF523 | Electronics and automation |
| | | EF524 | Chemical and process |
| | | EF525 | Motor vehicles, ships and aircraft |
| | | EF540 | Manufacturing and processing (broad programmes) |
| | | EF541 | Food processing |
| | | EF542 | Textiles, clothes, footwear, leather |
| | | EF543 | Materials (wood, paper, plastic, glass) |
| | | EF544 | Mining and extraction |

The reference classification framework used here is ISCED-2011. It is worth noting that a more recent classification framework, namely ISCED-F 2013, has been published. However, to date ISCED-F 2013 has not been implemented in EU data collection by Eurostat³ and therefore does not apply to the present study. The following table shows the correspondence between the two frameworks (UNESCO, 2014).

Table 4 STEM fields of study, ISCED-F 2013 and ISCED 2011 correspondence table

| ISCED-F 2013 | ISCED 1997 (and 2011) Fields of Education |
|--|--|
| 051 Biological and related sciences | 42 Life sciences minus other allied sciences |
| 052 Environment | Part of 42 Life sciences (other allied sciences), part of 62 Agriculture, forestry and fishery (natural parks, wildlife) |
| 053 Physical sciences | 44 Physical science |
| 054 Mathematics and statistics | 46 Mathematics and statistics |
| 061 Information and Communication Technologies | 48 Computing |
| 071 Engineering and engineering trades | 52 Engineering and engineering trades (plus most of 85 Environmental protection) |
| 072 Manufacturing and processing | 54 Manufacturing and processing |

Source: UNESCO Institute for Statistics, 2014

2.3.2.2 Demand

To define STEM jobs, this study uses the current International Standard Classification of Occupations (ISCO-08) as its main reference. One of the International Labour Organization (ILO) classification structures for organizing information on jobs⁴, ISCO-08 forms part of the UN International Family of Economic and Social Classifications⁵. A different classification used in the literature to define STEM jobs (Koonce et al., 2011) is the US Standard Occupational Classification (SOC-10), whose national variations are used

³ International Standard Classification of Education (ISCED) - Statistics Explained. Available at [http://ec.europa.eu/eurostat/statistics-explained/index.php/International_Standard_Classification_of_Education_\(ISCED\)](http://ec.europa.eu/eurostat/statistics-explained/index.php/International_Standard_Classification_of_Education_(ISCED)) (retrieved 31 October 2016).

⁴ International Labour Organization (ILO). International Standard Classification of Occupations (ISCO), Summary of Major Groups. Available at <http://www.ilo.org/public/english/bureau/stat/isco/isco88/publ4.htm> (retrieved 31 October 2016).

⁵ United Nations Statistics Division - Classifications Registry. Available at <http://unstats.un.org/unsd/class/family/default.asp> (retrieved 31 October 2016).



in countries such as Spain⁶ and the United Kingdom⁷. Although the ISCO-08 differs from the SOC-10, both systems classify occupations based on the type of work performed, and crosswalks between the two have been performed⁸.

The ISCO-08 system defines the broad group of **professionals** as "*occupations whose main tasks require a high level of professional knowledge and experience*" such as "*increasing the existing stock of knowledge, applying scientific and artistic concepts and theories to the solution of problems, and teaching about the foregoing in a systematic manner*" (ISCO-08 major group 2). The group of **technicians and associate professionals** includes "*occupations whose main tasks require technical knowledge and experience*" such as "*carrying out technical work connected with the application of concepts and operational methods in the above-mentioned fields, and in teaching at certain educational levels*" (ISCO-08 major group 3).

Within these two broad groups, two-digit and three-digit codes increase the level of detail in occupations. Earlier EU-level work (OECD, 1995; Goos et al., 2013; EU Skills Panorama, 2014; European Commission, 2015) agree in defining STEM occupations as including some or all of the following categories: Science and Engineering Professionals (ISCO-08-21); Health Professionals (ISCO-08-22); Information and Communications Technology Professionals (ISCO-08-25); Science and Engineering Associate Professionals (ISCO-08-31); Health Associate Professionals (ISCO-08-32); Information and Communications Technicians (ISCO-08-35). The following table offers a comparison of three-digit categorizations of STEM occupations as used in the past and in the current study.

Table 5 Comparison of STEM occupation definitions

| Cod e | ISCO-08 Name | EC 2015 | EU Skills Panora ma 2014 | OECD 1995 | Goos et al. 2013 | Current study |
|-------|---|---------|--------------------------|-----------|------------------|---------------|
| 211 | Physical and Earth Science Professionals | | | | | |
| 212 | Mathematicians, Actuaries and Statisticians | | | | | |
| 213 | Life Science Professionals | | | | | |
| 214 | Engineering Professionals (excluding Electrotechnology) | | | | | |
| 215 | Electrotechnology Engineers | | | | | |
| 216 | Architects, Planners, Surveyors and Designers | | | | | |
| 221 | Medical Doctors | | | | | |

⁶ INEbase _ Clasificaciones _ Clasificación Nacional de Ocupaciones 1994. Available at <http://www.ine.es/clasifi/cnoh.htm> (retrieved 31 October 2016).

⁷ Standard occupational classification (SOC) - Office for National Statistics. Available at <https://www.ons.gov.uk/methodology/classificationsandstandards/standardoccupationalclassification/soc> (retrieved 31 October 2016).

⁸ Crosswalks between the 2010 SOC and systems used by other Federal and international statistical agencies. Available at <http://www.bls.gov/soc/soccrosswalks.htm> (retrieved 31 October 2016).



| | | | | | | |
|-----|--|--|--|--|--|--|
| 222 | Nursing and Midwifery Professionals | | | | | |
| 223 | Traditional and Complementary Medicine Professionals | | | | | |
| 224 | Paramedical Practitioners | | | | | |
| 225 | Veterinarians | | | | | |
| 226 | Other Health Professionals | | | | | |
| 251 | Software and Applications Developers and Analysts | | | | | |
| 252 | Database and Network Professionals | | | | | |
| 311 | Physical and Engineering Science Technicians | | | | | |
| 312 | Mining, Manufacturing and Construction Supervisors | | | | | |
| 313 | Process Control Technicians | | | | | |
| 314 | Life Science Technicians and Related Associate Professionals | | | | | |
| 315 | Ship and Aircraft Controllers and Technicians | | | | | |
| 321 | Medical and Pharmaceutical Technicians | | | | | |
| 322 | Nursing and Midwifery Associate Professionals | | | | | |
| 323 | Traditional and Complementary Medicine Associate Professionals | | | | | |
| 324 | Veterinary Technicians and Assistants | | | | | |
| 325 | Other Health Associate Professionals | | | | | |
| 351 | ICT Operations and User Support Technicians | | | | | |
| 352 | Telecommunications and Broadcasting Technicians | | | | | |

As the groups of health professionals and associate professionals fall beyond the scope of the current study, they are therefore excluded from the analysis. For this study, the following four two-digit ISCO-08 categories define **STEM occupations**:

- 21 Science and Engineering Professionals
- 25 Information and Communications Technology Professionals
- 31 Science and Engineering Associate Professionals
- 35 Information and Communications Technicians

The table below lists all occupations, at a four-digit ISCO-08 level, included in the present study. As most databases disaggregate at the two-digit level, it is not always possible to apply narrower definitions of STEM – as an example, the presence of architects (ISCO-08-216) could be up for debate – and therefore some non-STEM occupations may be included in the analysis.

Table 6 STEM occupations, three- and four-digit ISCO-08 classifications

| ISCO name (3-digit) | Code | ISCO name (4-digit) |
|--|------|---|
| 21 Science and Engineering Professionals | | |
| 211 Physical and Earth Science Professionals | 2111 | Physicists and Astronomers |
| | 2112 | Meteorologists |
| | 2113 | Chemists |
| | 2114 | Geologists and Geophysicists |
| 212 Mathematicians, Actuaries and Statisticians | 2120 | Mathematicians, Actuaries and Statisticians |
| 213 Life Science Professionals | 2131 | Biologists, Botanists, Zoologists and Related Professionals |
| | 2132 | Farming, Forestry and Fisheries Advisers |
| | 2133 | Environmental Protection Professionals |
| 214 Engineering Professionals | 2141 | Industrial and Production Engineers |
| | 2142 | Civil Engineers |
| | 2143 | Environmental Engineers |



| | | |
|---|------|--|
| (excluding Electrotechnology) | 2144 | Mechanical Engineers |
| | 2145 | Chemical Engineers |
| | 2146 | Mining Engineers, Metallurgists and Related Professionals |
| | 2149 | Engineering Professionals Not Elsewhere Classified |
| 215 Electrotechnology Engineers | 2151 | Electrical Engineers |
| | 2152 | Electronics Engineers |
| | 2153 | Telecommunications Engineers |
| 216 Architects, Planners, Surveyors and Designers | 2161 | Building Architects |
| | 2162 | Landscape Architects |
| | 2163 | Product and Garment Designers |
| | 2164 | Town and Traffic Planners |
| | 2165 | Cartographers and Surveyors |
| | 2166 | Graphic and Multimedia Designers |
| 25 Information and Communications Technology Professionals | | |
| 251 Software and Applications Developers and Analysts | 2511 | Systems Analysts |
| | 2512 | Software Developers |
| | 2513 | Web and Multimedia Developers |
| | 2514 | Applications Programmers |
| | 2519 | Software and Applications Developers and Analysts Not Elsewhere Classified |
| 252 Database and Network Professionals | 2521 | Database Designers and Administrators |
| | 2522 | Systems Administrators |
| | 2523 | Computer Network Professionals |
| | 2529 | Database and Network Professionals Not Elsewhere Classified |
| 31 Science and Engineering Associate Professionals | | |
| 311 Physical and Engineering Science Technicians | 3111 | Chemical and Physical Science Technicians |
| | 3112 | Civil Engineering Technicians |
| | 3113 | Electrical Engineering Technicians |
| | 3114 | Electronics Engineering Technicians |
| | 3115 | Mechanical Engineering Technicians |
| | 3116 | Chemical Engineering Technicians |
| | 3117 | Mining and Metallurgical Technicians |
| | 3118 | Draughtspersons |
| | 3119 | Physical and Engineering Science Technicians Not Elsewhere Classified |
| 312 Mining, Manufacturing and Construction Supervisors | 3121 | Mining Supervisors |
| | 3122 | Manufacturing Supervisors |
| | 3123 | Construction Supervisors |
| 313 Process Control Technicians | 3131 | Power Production Plant Operators |
| | 3132 | Incinerator and Water Treatment Plant Operators |
| | 3133 | Chemical Processing Plant Controllers |
| | 3134 | Petroleum and Natural Gas Refining Plant Operators |
| | 3135 | Metal Production Process Controllers |
| | 3139 | Process Control Technicians Not Elsewhere Classified |
| 314 Life Science Technicians and Related Associate Professionals | 3141 | Life Science Technicians (excluding Medical) |
| | 3142 | Agricultural Technicians |
| | 3143 | Forestry Technicians |
| 315 Ship and Aircraft Controllers and Technicians | 3151 | Ships' Engineers |
| | 3152 | Ships' Deck Officers and Pilots |
| | 3153 | Aircraft Pilots and Related Associate Professionals |
| | 3154 | Air Traffic Controllers |
| | 3155 | Air Traffic Safety Electronics Technicians |
| 35 Information and Communications Technicians | | |
| 351 ICT Operations and User Support Technicians | 3511 | Information and Communications Technology Operations Technicians |
| | 3512 | Information and Communications Technology User Support Technicians |
| | 3513 | Computer Network and Systems Technicians |



| | | |
|--|-------------|--|
| | 3514 | Web Technicians |
| 352 Telecommunications and Broadcasting Technicians | 3521 | Broadcasting and Audiovisual Technicians |
| | 3522 | Telecommunications Engineering Technicians |

2.3.3 Curricula analysis

Our curricula analysis targeted the following research sub-question:

- *RQ3: To what extent do innovative practices prepare students with STEM skills? What are the main initiatives to foster STEM skills in the EU?*

As part of T2.3, we performed an analysis of curricula and course requirements from the world's leading STEM departments. To do so, the latest QS World University Ranking⁹ has been used as a benchmark. QS ranks universities by academic discipline organized into 5 faculties and 42 subjects. Faculties include Engineering & Technology, Life Sciences & Medicine, Natural Sciences, Arts & Humanities, and Social Sciences & Management. We identified the first three faculties as STEM-related. Taken together, they contain 21 subjects, of which 12 correspond to STEM subjects as defined by the ISCED codes chosen above. The following table shows a correspondence between the two categorizations.

Table 7 QS – ISCED correspondence table

| Faculty (QS) | Subject (QS) | Code (ISCED) | Current study |
|--------------------------|--|--------------|---------------|
| Engineering & Technology | Chemical engineering | 52 | |
| | Civil & structural engineering | 58 | |
| | Computer Science & Information Systems | 48 | |
| | Electrical & electronic engineering | 52 | |
| | Mechanical, aeronautical & manufacturing engineering | 52 | |
| | Mineral & Mining Engineering | 54 | |
| Life Sciences & Medicine | Agriculture & Forestry | 62 | |
| | Biological Sciences | 42 | |
| | Dentistry | 72 | |
| | Medicine | 72 | |
| | Nursing | 72 | |

⁹ QS World University Rankings by Subject 2016 – Top Universities. Available at <http://www.topuniversities.com/subject-rankings/2016> (retrieved 15 December 2016).



| | | | |
|------------------|-------------------------|----|--|
| | Pharmacy & Pharmacology | 72 | |
| | Psychology | 31 | |
| | Veterinary Science | 64 | |
| Natural Sciences | Chemistry | 44 | |
| | Earth & Marine Sciences | 44 | |
| | Environmental Sciences | 42 | |
| | Geography | 31 | |
| | Materials Sciences | 54 | |
| | Mathematics | 46 | |
| | Physics & Astronomy | 44 | |

For each the 12 resulting subjects, we have analysed and explored degree requirements, curricula, and study plans of undergraduate STEM courses at the five highest ranking universities, with a focus on the recurring ones:

- Massachusetts Institute of Technology (MIT) (12 times in the top-5)
- Stanford University (11)
- University of Cambridge (9)
- University of California, Berkeley (UCB) (8)
- University of Oxford (5)
- Imperial College London (2)

Our objective was to keep a global perspective in order to spot elements of excellence, or degree features that could be exemplar for all European universities to be prepared to meet future STEM skill requirements. The following table lists the world's top five universities by STEM subject.

Table 8 Top 5 Universities by STEM field, global

| STEM subject (QS) | Rank | | | | |
|----------------------|---|--|---|-------------------------|--|
| | 1 | 2 | 3 | 4 | 5 |
| Biological Sciences | Harvard University | University of Cambridge | Massachusetts Institute of Technology (MIT) | University of Oxford | Stanford University |
| Chemical engineering | Massachusetts Institute of Technology (MIT) | Stanford University | University of California, Berkeley (UCB) | University of Cambridge | National University of Singapore (NUS) |
| Chemistry | Massachusetts Institute of Technology (MIT) | University of California, Berkeley (UCB) | University of Cambridge | Harvard University | Stanford University |



| | | | | | |
|---|--|---|---|---|--|
| Computer Science & Information Systems | Massachusetts Institute of Technology (MIT) | Stanford University | University of Oxford | Harvard University | Carnegie Mellon University |
| Earth & Marine Sciences | ETH Zurich - Swiss Federal Institute of Technology | Harvard University | University of California, Berkeley (UCB) | Massachusetts Institute of Technology (MIT) | University of Oxford |
| Electrical & electronic engineering | Massachusetts Institute of Technology (MIT) | Stanford University | University of Cambridge | University of California, Berkeley (UCB) | University of California, Los Angeles (UCLA) |
| Environmental Sciences | University of California, Berkeley (UCB) | Stanford University | Massachusetts Institute of Technology (MIT) | Wageningen University | Harvard University |
| Materials Sciences | Massachusetts Institute of Technology (MIT) | Stanford University | Imperial College London | University of California, Berkeley (UCB) | University of Cambridge |
| Mathematics | University of Cambridge | Harvard University | Massachusetts Institute of Technology (MIT) | Stanford University | University of Oxford |
| Mechanical, aeronautical & manufacturing engineering | Massachusetts Institute of Technology (MIT) | Stanford University | University of Cambridge | University of California, Berkeley (UCB) | Imperial College London |
| Mineral & Mining Engineering | Colorado School of Mines | Massachusetts Institute of Technology (MIT) | Stanford University | University of Cambridge | University of Oxford |
| Physics & Astronomy | Massachusetts Institute of Technology (MIT) | Harvard University | Stanford University | University of Cambridge | University of California, Berkeley (UCB) |

Due to the diversity in the composition of curricula and the requirements across countries and outside the EU-28, as well as the difference in educational systems, findings from the analysis are descriptive and limited. However, following a complementarity and triangulation approach, we then integrated the findings with a scoping review of key innovative practices and initiatives in STEM in Europe, both within and outside universities. Findings from the curricula analysis are specifically set to influence and contribute to the work of WP3 and WP5.

2.3.4 In-depth interviews

Our interviews aimed at answering the following research sub-questions:

- *RQ1: What is the extent and nature of the EU labour market for STEM skills?*



- *RQ4: How is the EU market demand for STEM skills likely to evolve in the future, and which STEM skills will likely be most in demand?*

In-depth interviewing is a powerful research technique. It consists of conducting intensive individual interviews with a small number of participants to explore their take on a given topic. They are used to provide context, and corroborate the evidence gathered from other sources, offering a more complete picture. Their main advantage is that they provide much more detailed insights than what would be available through surveys or other data collection methods. They also provide a more comfortable environment in which to collect data, as opposed to filling out surveys.

Our process consisted in the following steps: planning, developing instruments, collecting data, and analysing. While planning, we have identified our target group in **employers from small and large STEM-intensive enterprises**. More specifically, we specified respondents to be senior executives:

- In small and medium-sized companies, this tended to be the managing director, CEO or chairman;
- in larger firms, it was the HR director or equivalent.

A purposive sampling inspired by the principle of representation guided the selection of companies: firms had to be representative of different typological and characterising elements (class size, industry sectors, geography). We conducted a total of **11 in-depth individual interviews**. Our goal, as pointed before, was to better understand the current and future demand for STEM skills. Therefore, we selected only sectors where the demand for STEM skills is strong and likely to be affected by change, as we were informed by the literature review. The following sectors were identified:

- Automotive
- Biotechnology
- Business Services
- Computer Programming, Data Processing (2)
- Cosmetics
- Electrical/Electronic Manufacturing (2)
- Food Manufacturing
- Research and Development (R&D)

In terms of size, respondents worked in firms of different categories:

- Micro (3)
- Small (4)
- Medium (2)
- Large (2)



Finally, we selected countries according to the findings of our data analysis, trying to capture different contexts with different STEM skills supply and demand. Our final selection included the following EU Member States:

- Poland (1), where the share of STEM graduates is low, and the number of STEM jobs is one of the lowest, especially among ICT associate professionals;
- Spain (4), a country with a decreasing share of STEM graduates, and with high and increasing employment in ICT;
- Greece (2), where the share of STEM students is the second highest in the EU-28, and which ranks at the bottom quartile in STEM employment;
- Slovenia (4), a country with the highest growth in STEM graduates, and a high and rising number of STEM professionals working in science and engineering (S&E).

Once we defined the target group and planned, we elaborated **detailed interview guidelines**. These were rules that guided the administration and execution of the interviews, to ensure consistency between interviews, and increase reliability of findings. However, they only served as prime guidance for the interviewers. The interview was semi-structured, therefore it allowed for additional information to be taken on board, depending on how it evolved. **Guidelines** meant to address the interview were arranged around the following topics:

- STEM skills
- Recruitment Practices
- Apprenticeships
- Links with schools and universities
- Future STEM demand

The following table displays the questions centered around each of the topics mentioned above.

Table 9: STEM Interview guidelines

| Theme | Question |
|------------------------------|---|
| I: ABOUT YOUR COMPANY | <ul style="list-style-type: none"> • Do you currently employ people with STEM-related degrees and qualifications in your company? What are their main roles (e.g. managers, technicians, professionals)? |
| II: SKILLS | <ul style="list-style-type: none"> • The demand for people with STEM qualifications is closely linked to the skills that they bring to the workplace. Employers typically welcome capabilities in active learning, critical thinking, complex and creative problem-solving, all of which correlate closely with STEM qualification based skills. To what extent are these skills important to your company? • What other skills and attributes are important to your company? |



| | |
|------------------------------------|---|
| | <ul style="list-style-type: none"> As a whole, do you consider the skills of your workforce adequate? Do your employees lack certain skills (e.g. IT literacy, numeracy, foreign language skills)? Do you provide remedial training? |
| III: RECRUITMENT | <ul style="list-style-type: none"> What do you look for when you are hiring new staff (e.g. attitudes, past experience, degree subject, university name, foreign language skills...)? Do you actively seek for people with STEM degrees? Which STEM subjects do you find more important for your company? Is there any particular degree that suits your company better? Have you encountered difficulties in recruiting STEM-skilled? If so, which problems do you encounter? (E.g. shortage of supply, lack of workplace experience, non-relevant degree, wrong attitude, lack of interpersonal skills...) |
| IV: APPRENTICESHIPS | <ul style="list-style-type: none"> Is your company involved in apprenticeships programs? How does it work? What kind of training do you provide? (e.g. basic, advanced...) (If yes) Despite the current economic pressures, do you plan to maintain or increase investments in training over the coming year? What do you think are the main barriers to overcome in order to promote the success of these programs (e.g. more guidance on how to make work experience worthwhile, less onerous requirements, reduce bureaucracy around government financing, etc.)? |
| V: SCHOOLS AND UNIVERSITIES | <p>Higher education institutions</p> <ul style="list-style-type: none"> Strengthening links between universities and business has the potential to enhance economic growth. Businesses look to higher education to develop people with the right knowledge and skills to meet their future needs. Has your company developed links of some type with universities (e.g. for internships, graduate programs, R&D partnerships)? Are you looking to grow these ties with universities in the future? Do you provide some kind of specific projects or resources to help students understand the practical relevance of their courses? <p>Schools</p> <ul style="list-style-type: none"> What happens in schools is equally important for the future of our economy and society. Has your company built links with secondary schools or further education colleges in the past 3 years? What kind of programs or collaborations do you share (e.g. career advice, work experience for pupils, curriculum development)? |
| VI: FUTURE DEMAND | <ul style="list-style-type: none"> Over the next 3 to 5 years, do you expect to hire more (or less) staff with higher-level skills? As reported by the literature, while employers are confident there will be enough people available to fill their low-skilled vacancies, the same is not true for the demand of high-skilled employees. How confident are you in being able to recruit high-skilled employees in the future? Government can help tackle future STEM skills supply shortages, for example by promoting science and maths in schools. Which actions do you think the government should take to encourage the study of STEM disciplines? (e.g. more apprenticeships, financial incentives, closer ties with business...) |



| | |
|----------------------------|---|
| | <ul style="list-style-type: none"> • <i>Is there anything else we should discuss regarding the topics we have addressed at this point?</i> |
| Concluding question | <ul style="list-style-type: none"> • <i>Of all the things we have discussed today, what would you say are the most important issues you would like to express about the future demand for STEM skills?</i> |

Once interviews were set up, we explained the purpose, the duration, and the selection criteria to the respondents. We then conducted the interview, after which we summarized the key data, fact-checked information where necessary, and conducted a **thematic content analysis**. This type of analysis, very common in qualitative research, emphasizes analysing patterns – or themes – within data. It provides a flexible method and allows for researchers with various methodological backgrounds to engage in it. It encompassed the following steps: first, getting familiar with the interview transcripts, by reading and re-reading them; second, by labelling the whole text; third, by searching for patterns, or themes, with broader meaning; fourth, by reviewing such themes to ensure they fit the information; fifth, by naming themes; sixth, by writing a consistent, organized narrative that included quotes from the interviewees. The nature of in-depth interviews and the small sample do not allow for generalised conclusions or external validity. Nonetheless, this method was consistently applied, and themes spurring from the analysis were reported on in a likewise fashion, forming the respective sections of D2.1 and D2.2 related to the specific sub-questions.

2.3.5 Validation Workshop

Our validation workshop targeted the following research sub-questions:

- *RQ3: To what extent do innovative practices prepare students with STEM skills? What are the main initiatives to foster STEM skills in the EU?*
- *RQ4: How is the EU market demand for STEM skills likely to evolve in the future, and which STEM skills will likely be most in demand?*

As envisaged in the project proposal, a workshop was performed in the context of T2.2 “Development and validation of the scenarios and trends”. The discussion focused on scenarios for the STEM labour market built with the input from T2.1 “Analysis of Supply and Demand Side of STEM”. The workshop had the aim to validate and expand the information presented in D2.1, and to provide relevant input for the present deliverable as well as to the other project WPs.

The workshop took place on 1 December at the JSI premises (Ljubljana, Slovenia), during the STEM plenary meeting. The participants included members of the Consortium as well as external stakeholders from NGOs, private companies, and higher education. Overall, there were 23 representatives of universities, research institutes, NGOs and the private



sector. This diverse audience provided different points of views which enriched the discussion. First, the main conclusions from the analysis of the STEM supply and demand (T2.1) were exposed in order to contextualise the discussion and to provide information on the current situation of the STEM labour market as well as on some estimations. This was followed by the presentation of the scenarios.

Scenario building helps to predict and shape the innovation process by stimulating different perspectives or images on the future of a certain area in order to allow better predictions for evolution. To develop the scenarios, we used **trend analysis** techniques, according to which the scenarios reflect the type of future to which the trends may lead. Instrumental for the scenario definition we used both **state of play**, establishing the baseline of the foresight, and **gap analysis**, comparing the scenarios against the state of play to identify what is lacking for making desirable elements of the scenarios happen and for avoiding undesirable ones. The process of scenario building was based on the following steps:

- identification of the main trends,
- classification of trends,
- organization of trends,
- deriving concerted scenarios,
- communication of the scenarios.

In the present case, the scenarios were assumed to take place in ten years' time and depended on **the evolution of two key variables: supply and demand of the STEM labour market**. In the period spanning from 2016 to 2025, both variables might fluctuate several times, but, in sum, they can increase, decrease or remain the same. The combination of these possibilities generates nine different scenarios, which are represented in the figure below. For instance, the scenario in the top-left corner represents the situation in which both demand and supply increase. On the other hand, in the bottom-centre scenario, supply decreases while demand stays the same.



Figure 1 Evolution of STEM labour market supply and demand, 2016-2025

| | | Demand (+/-) | | |
|--------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| | | $S \uparrow D \uparrow$ | $S \uparrow D =$ | $S \uparrow D \downarrow$ |
| Supply (+/-) | $S = D \uparrow$ | $S = D \uparrow$ | $S = D =$ | $S = D \downarrow$ |
| | $S \downarrow D \uparrow$ | $S \downarrow D \uparrow$ | $S \downarrow D =$ | $S \downarrow D \downarrow$ |
| | $S \downarrow D \downarrow$ | $S \downarrow D \downarrow$ | $S \downarrow D \downarrow$ | $S \downarrow D \downarrow$ |

It is important to note that the current scenario is assumed to be an equilibrium between supply and demand. Therefore, in the latter case there would be a shortage of supply respect to demand, this is, the number of employees with STEM skills would not be enough to cover the demand from the employers. This situation would also occur if demand increases while supply remains unchanged, and if demand rises and supply falls.

Figure 2 Shortage of supply scenarios

| | | Demand (+/-) | | |
|--------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| | | $S \uparrow D \uparrow$ | $S \uparrow D =$ | $S \uparrow D \downarrow$ |
| Supply (+/-) | $S = D \uparrow$ | $S = D \uparrow$ | $S = D =$ | $S = D \downarrow$ |
| | $S \downarrow D \uparrow$ | $S \downarrow D \uparrow$ | $S \downarrow D =$ | $S \downarrow D \downarrow$ |
| | $S \downarrow D \downarrow$ | $S \downarrow D \downarrow$ | $S \downarrow D \downarrow$ | $S \downarrow D \downarrow$ |

The following figure shows the opposite situation, when there is a surplus of supply respect to demand. Here, there are more people with STEM skills that are willing to work than job vacancies suited to them.



Figure 3 Surplus of supply scenarios

| | | Demand (+/-) | |
|--------------|-----------------|--------------|-----------------|
| Supply (+/-) | | $S \leq D =$ | $S \leq D \leq$ |
| | $S = D \leq$ | $S = D =$ | $S = D \leq$ |
| | $S \leq D \leq$ | $S \leq D =$ | $S \leq D \leq$ |

Finally, the other three scenarios imply a maintenance of the current equilibrium, provided that demand and supply rise at the same rate (top-left) or decline by the same amount (bottom-right).

Figure 4 Equilibrium between supply and demand scenarios

| | | Demand (+/-) | |
|--------------|-----------------|--------------|-----------------|
| Supply (+/-) | | $S \leq D =$ | $S \leq D \leq$ |
| | $S = D \leq$ | $S = D =$ | $S = D \leq$ |
| | $S \leq D \leq$ | $S \leq D =$ | $S \leq D \leq$ |

All these scenarios are possible. However, as is seen in D2.1, the market analysis provides some insight about which of them is more feasible. According to CEDEFOP data, employment in STEM would grow by 8.2 million jobs in ten years (2016-2025). Therefore, demand will be assumed to grow and, thus, scenarios are reduced to three. In all of them demand rises, but the behaviour of supply varies. In the first scenario, STEM supply either falls, stays the same, or increases but less than demand. As a consequence, there is a **shortage** of STEM supply, meaning that there are more STEM jobs than graduates. In the second scenario, supply keeps pace with demand and, thus, the **equilibrium** is maintained. In this, the number of STEM jobs matches that of STEM graduates. In the last



scenario, the growth of STEM supply surpasses that of demand, creating a situation of **surplus** of STEM supply, in which there are more STEM graduates than jobs.

The interactive workshop hosted relevant stakeholders who discussed the scenarios developed. Small group discussions were held to be effective in ensuring in-depth analysis and high value contributions, such as well develop recommendations and inspiring cases. The stakeholders were engaged in interactive activities to achieve a consensus among participants in the prioritization of the scenarios and thus to identify the most promising ones according to the project requirements.

Participants were divided in smaller groups in order to discuss in deep each of the three scenarios, to allow for a dynamic discussion, and to ensure that everybody could contribute. A group was created for each of the three scenarios. Groups were requested to **identify the challenges** that the scenario posed **to universities, the private sector, and the government**, stylizing a high-level SWOT. **SWOT analysis** is a diagnostic tool that analyses the strengths and weaknesses of a given option and assesses the future opportunities and threats to it. This type of analysis is most likely to draw on documentary (e.g. previous studies, etc.), statistical sources of data and interviews with key informants. This technique can be used, applying the principle of inter-subjective objectivity, to fill in qualitatively but treat quantitatively cost-benefit or cost-effectiveness templates. According to the principle of inter-subjective objectivity, if a large enough number of individuals with some relevant expertise are asked to provide their subjective judgment (but using evidence provided by the evaluators) on an evaluation question, by averaging their aggregate answer, one moves away from subjectivity and somehow approaches objectivity, especially if the respondents have the right expertise/experience. In this case, the SWOT analysis was instrumental to the scenario validation and therefore focused on the Opportunities and Threats.

The **Delphi survey** is a structured group interaction process involving a sample of experts in which participants, unlike expert panels, are kept separate in order to avoid bias. Delphi survey is used to obtain independent expert-based and non-biased opinions on a technical or very specific issue. In a similar fashion, participants were individually asked to **suggest recommendations** for the respective stakeholders to help them face the challenges. In this case, time and space constraints suggested to move away from anonymity and towards a face-to-face interaction. Furthermore, experience shows that participants welcome an extra round to discuss results in a general meeting. Therefore, participants had about twenty minutes to debate. Later, the key findings were collected and presented in front of the whole audience.





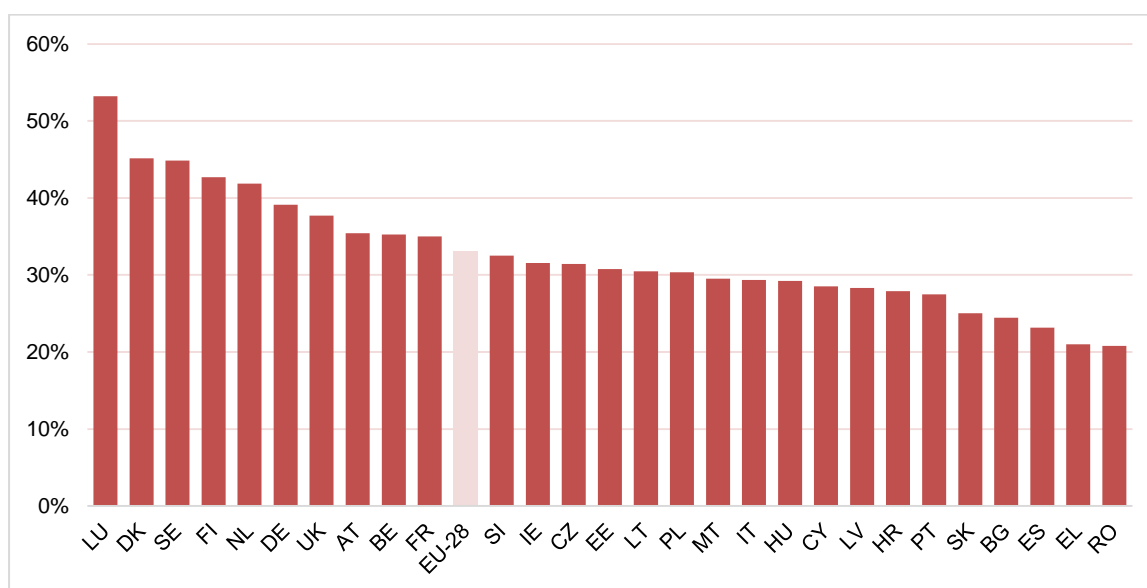
3 The EU labour market for STEM skills

3.1 Demand for STEM skills

3.1.1 Size and composition of the STEM industry

In 2015, the STEM industry employed about one-third of the EU active population aged 25 to 64 (33.1%), according to the Eurostat HRST database. Around 76.5 million people in the EU-28 aged from 15 to 74 were employed in science and technology. The figure includes STEM professionals, as well as non-STEM professionals, who work in STEM industry. However, the proportion of employees differed greatly among Member States. Luxembourg (53.2%) and Denmark (45.2%) reported the highest proportions, whereas Romania (20.8%) and Greece (21.0%) reported the lowest shares. It is worth noting that the Eurostat HRST database does not exclude Architecture and Building (EF58) from the computation.

Figure 5 Size of the STEM industry, as % of the active population (2015)



Source: Authors' elaboration on Eurostat data (lfsi_emp_a; hrst_st_nocc).

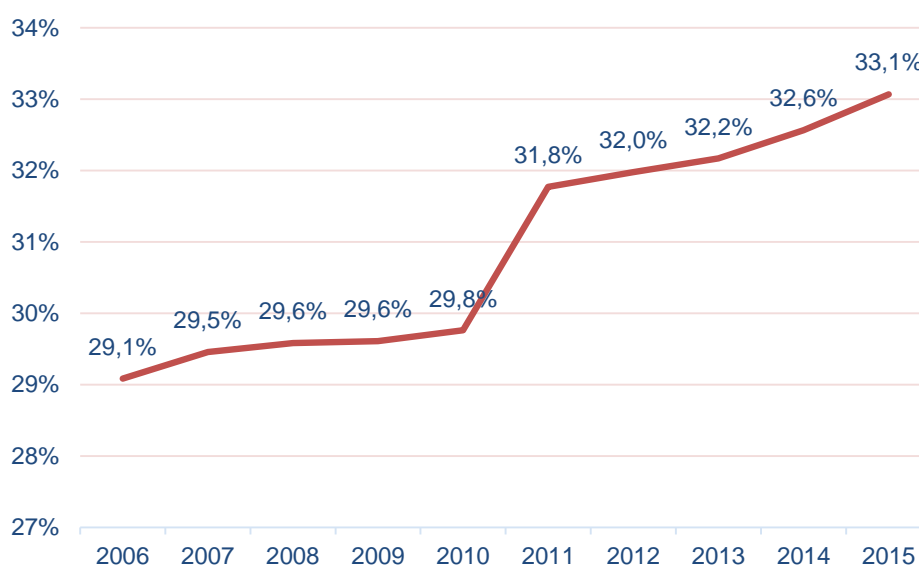
The active population, also known as labour force, workforce, or “economically active population”, is the fraction of a population that includes the employed (employees and self-employed) and the unemployed, but not the economically inactive such as pre-school and school children, students, or the retired¹⁰. The size of the STEM industry has increased for the last ten years, with a more marked increase between 2010 and 2011

¹⁰ Glossary_Labour force - Statistics Explained. Available at http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Labour_force (retrieved 31 October 2016).



as shown in the figure below. The latter could be explained with more people from the non-STEM industry exiting the active population – e.g. discouraged workers – as a consequence of the economic crisis that hit in those years.

Figure 6 Employed in STEM sectors in the EU-28 as % of active population, 2006 to 2015

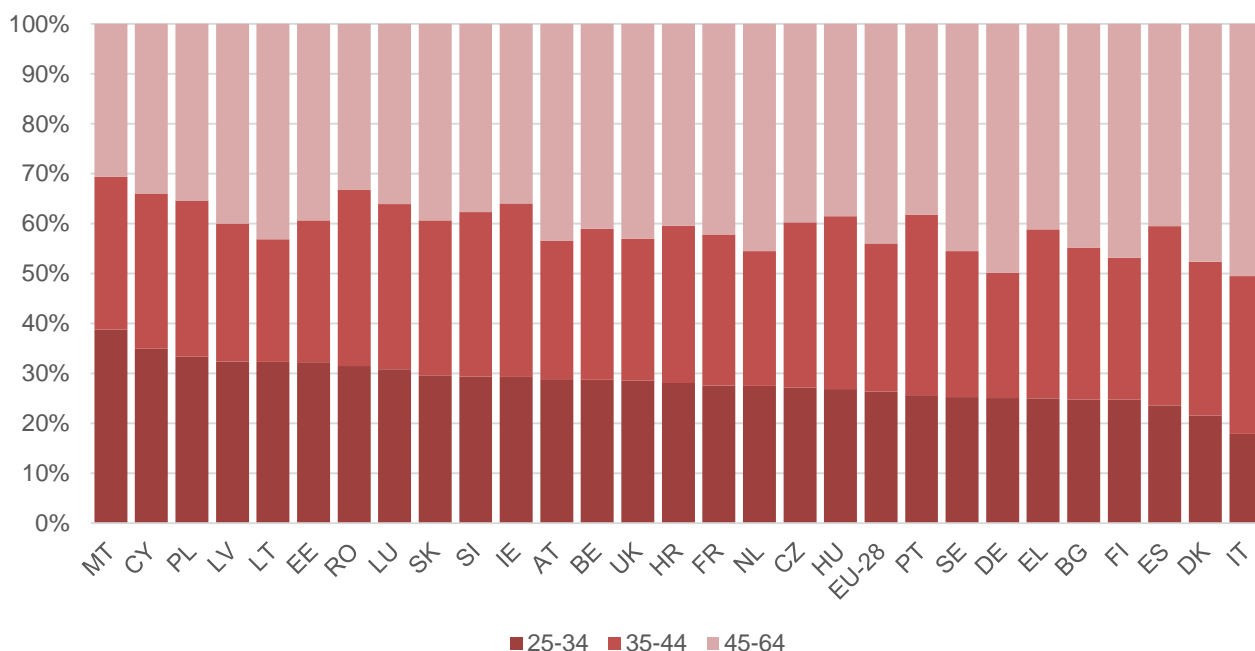


Note: Missing data for Croatia in 2006 and 2007. Source: Authors' elaboration on Eurostat data (lfsi_emp_a; hrst_st_nocc)

In 2015, only a quarter of the workers in the STEM industry (26.7%) was younger than 34 years old. With regards to the age composition of STEM sectors in EU-28, on average the 55 to 64 age group is the largest (43.9%), followed by the 45 to 54 bracket (29.7%). However, the age composition of STEM employment also differs across EU. In Poland, Malta and Cyprus, more than one in three STEM employees is younger than 34 years old. In Germany and Italy, around half of the STEM workforce is older than 55 years old. In Malta and Cyprus there are more STEM workers aged 25-34 than aged 55 to 64. Elsewhere else, the 55 to 64 age group is larger than the 25 to 34 bracket.



Figure 7 STEM industry (STEM and non-STEM skills) by age group, 2015

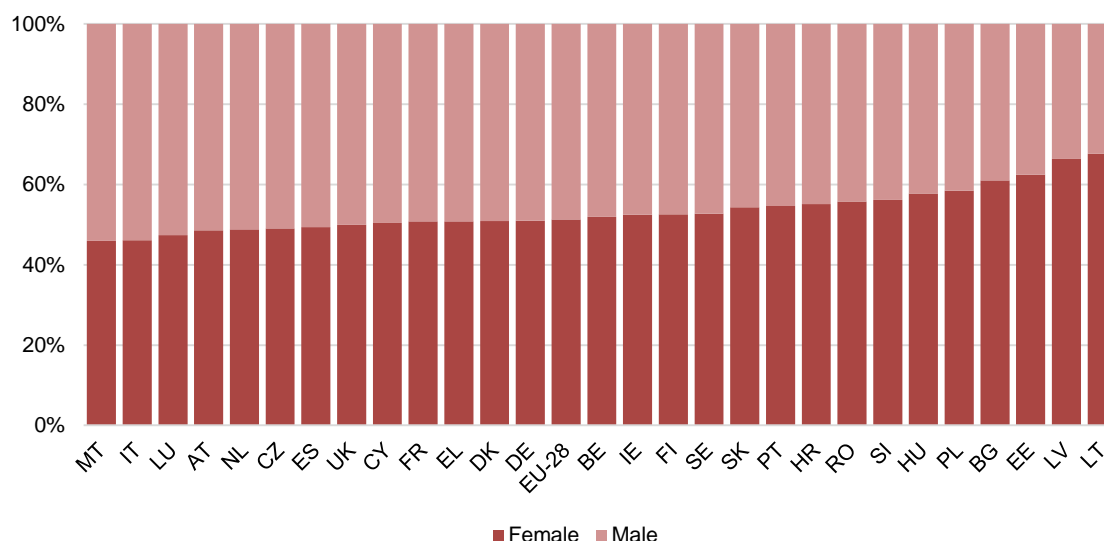


Source: Authors' elaboration on Eurostat data (hrst_st_nfieage)

Women accounted for about half (51.3%) of the overall workforce, including STEM and non-STEM skills, in STEM sectors in the EU in 2015. The figures differ on a national level, reflecting broader country trends. The Baltic region has the largest share, with women accounting for more than two-thirds of the total workforce in Lithuania (67.7%), and slightly less so in Latvia (66.4%) and Estonia (62.5%). Conversely, Malta (46.0%) and Italy (46.1%) report the lowest shares. Figures are unsurprisingly consistent with overall country data: in 2015, Lithuania, Latvia and Estonia held the first, second and fourth highest percentages of women in the active population (at 51.0%, 50.2% and 48.7% respectively), whereas Italy (42.6%) and Malta (38.0%) ranked at the bottom in this regard.



Figure 8 STEM industry (STEM and non-STEM skills) by gender, 2015



Source: Authors' elaboration on Eurostat data (hrst_st_ncat)

3.1.2 Current STEM Employment

As briefly introduced before, STEM employment is here defined as the sum of employment in the following four statistical categories: Science and engineering (S&E) professionals; ICT professionals; S&E associate professionals; ICT associate professionals. The table below provides details on each of the four categories considered.



Table 10 STEM Occupations

| | |
|--|---|
| <p>S&E Professionals</p> <p>Workers in this occupation conduct research, improve or develop concepts, theories and operational methods, or apply scientific knowledge relating to fields such as physics, astronomy, meteorology, chemistry, geophysics, geology, biology, ecology, medicine, mathematics, architecture, engineering, design and technology. Occupations in this group include, for example, physicists, astronomers, chemists, mathematicians, actuaries and statisticians, botanists, zoologists, civil engineers, and building architects.</p> | <p>S&E Associate Professionals</p> <p>Workers in this occupation supervise and control technical and operational aspects of mining, manufacturing, construction and other engineering operations, and operate technical equipment (including power plants, aircrafts and ships). Other professionals are involved in studying the technological aspects of products and processes. In this group include, for example, physical and engineering science technicians, mining, manufacturing and construction supervisors, process control technicians, life science technicians or ship and aircraft controllers and technicians.</p> |
| <p>ICT Professionals</p> <p>Workers in this occupation conduct research, plan, design, provide advice and improve information technology systems, hardware, software and related concepts for specific applications; develop associated documentation including principles, policies and procedures; design, develop, control, maintain and support databases and other information systems to ensure optimal performance and data integrity and security.</p> | <p>ICT Associate Professionals</p> <p>Workers in this occupation support the design, development, installation, operation, testing, and problem-solving of hardware and software. They comprise a wide set of sub-occupations that range from network system technicians to telecommunications engineering technicians. Due to the wide penetration of information and communications technologies across the economy, they work across a wide range of sectors including ICT, manufacturing, telecommunications and service sectors.</p> |

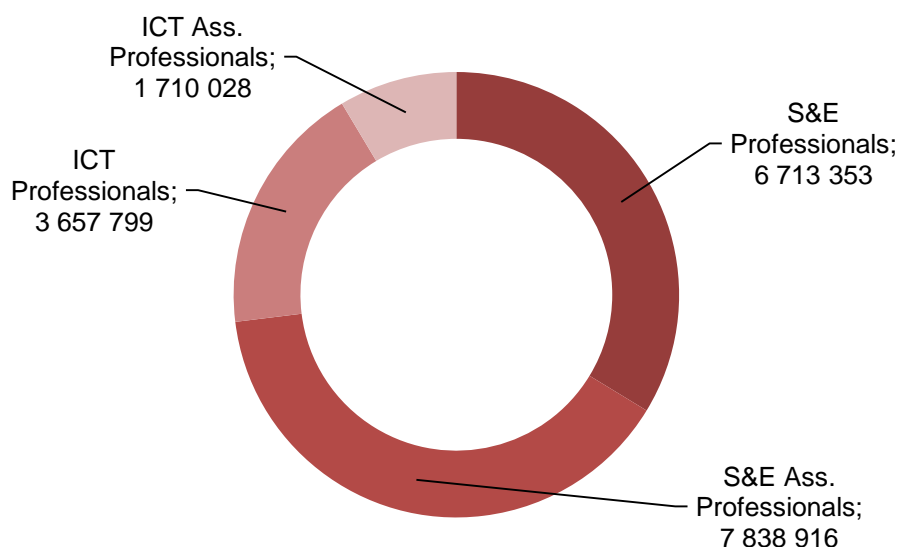
Source: CEDEFOP, EU Skills Panorama.

Available at <http://skillspanorama.cedefop.europa.eu/en> (retrieved 31 October 2016).

In 2015, STEM employment accounted for 9.0% of the total employment in the EU. The total employment in the four STEM occupations reached 19,920,096 according to data from the European Centre for the Development of Vocational Training (CEDEFOP). The figure includes around 7.8 million science and engineering (S&E) associate professionals (including physical and engineering science technicians, construction supervisors, power plant operators, process control technicians, ship and aircraft controllers, about 39.4% of total STEM occupations), followed by around 6.7 million S&E professionals (including physicists, mathematicians, life science professionals and engineers about 33.7% of total STEM occupations), around 3.7 million ICT professionals (including software developers and database professionals, 18.4% of total STEM occupations), and around 1.7 million ICT technicians (about 8.6% of total STEM occupations).



Figure 9 STEM Employment in the EU by occupation, 2015

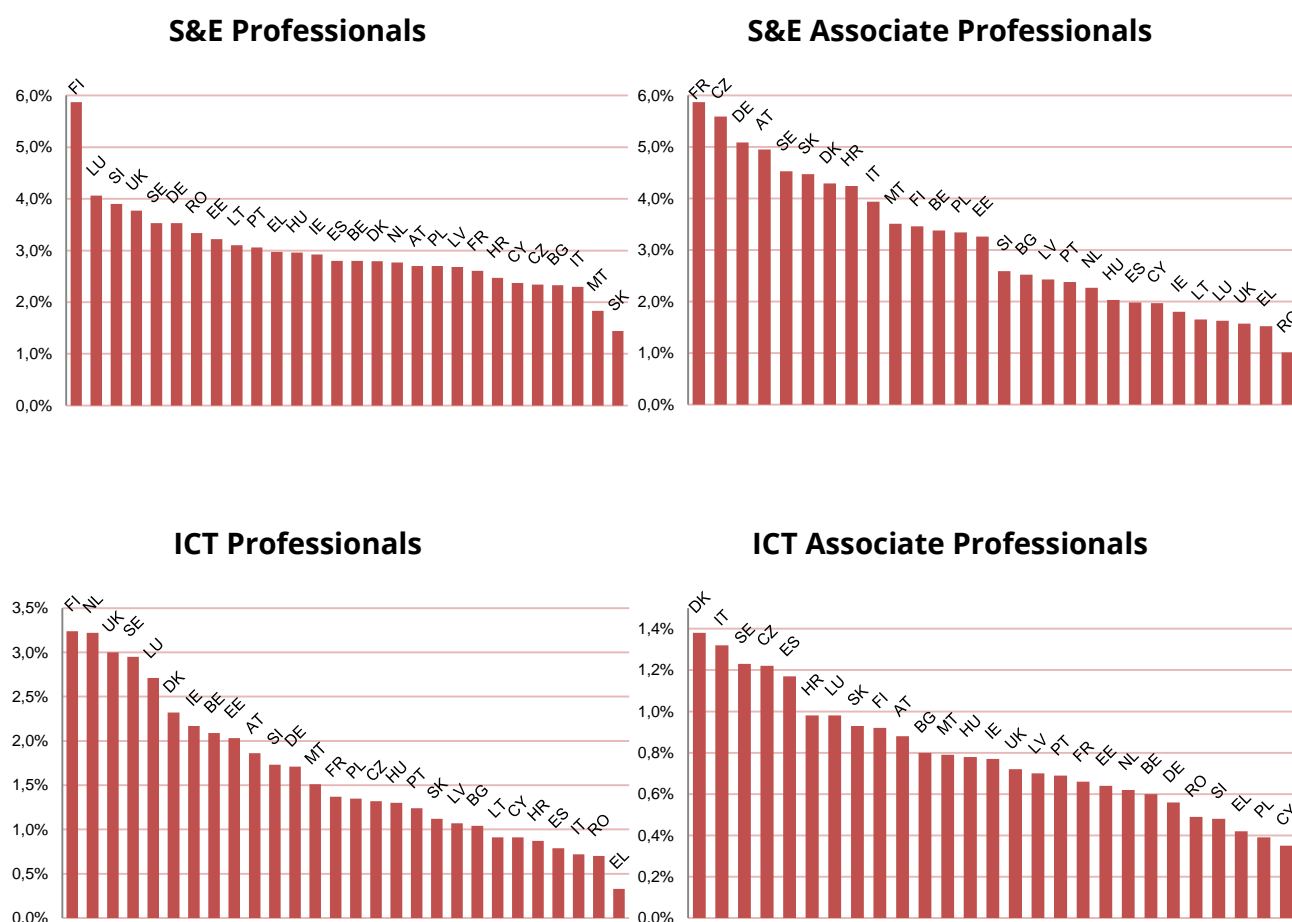


Source: Authors' elaboration on CEDEFOP data

Figures differ greatly among EU Member States. S&E professionals accounted for 3.0% in the total employment in the EU in 2015. However, they amounted to 5.9% and 4.1% of the total employment in Finland and Luxembourg respectively, and only 1.4% and 1.8% in Slovakia and Malta. Similarly, ICT professionals accounted for 1.7% in the total employment in the EU in 2015. However, they amounted to 3.2% of the total employment in Finland and the Netherlands, and only 0.3% and 0.7% in Greece and Romania. S&E associate professionals accounted for 3.6% in the total employment in the EU in 2015; they amounted to 5.9% and 5.6% of the total employment in France and Czech Republic respectively, but only 1.0% and 1.5% in Romania and Greece. ICT associate professionals accounted for 0.8% in the total employment in the EU in 2015. They amounted to 1.4% and 1.3% of the total employment in Denmark and Italy respectively, and 0.4% in Cyprus and Poland.



Figure 10 STEM Employment as % of total employment, 2015



Source: Authors' elaboration on CEDEFOP data

The following figure shows the ranking of EU Member States in terms of STEM employment, by category of STEM occupation. Member States like Finland, United Kingdom and Luxembourg all rank high in the employment of S&E and ICT professionals. Others, including Italy, Czech Republic and Croatia, employ a large share of S&E and ICT associate professionals. In Sweden and Denmark, STEM occupations of all kinds account for higher shares of total employment.



Table 11 STEM Employment as % of total employment, 2015 – Country ranking

| EU MS | S&E Professionals | S&E associate professionals | ICT professionals | ICT associate professionals |
|----------------|-------------------|-----------------------------|-------------------|-----------------------------|
| Austria | 18 | 4 | 10 | 10 |
| Belgium | 15 | 12 | 8 | 21 |
| Bulgaria | 25 | 16 | 21 | 11 |
| Croatia | 22 | 8 | 24 | 6 |
| Cyprus | 23 | 22 | 23 | 27 |
| Czech Republic | 24 | 2 | 16 | 4 |
| Denmark | 16 | 7 | 6 | 1 |
| Estonia | 8 | 14 | 9 | 19 |
| Finland | 1 | 11 | 1 | 9 |
| France | 21 | 1 | 14 | 18 |
| Germany | 6 | 3 | 12 | 22 |
| Greece | 11 | 27 | 28 | 25 |
| Hungary | 12 | 20 | 17 | 13 |
| Ireland | 13 | 23 | 7 | 14 |
| Italy | 26 | 9 | 26 | 2 |
| Latvia | 20 | 17 | 20 | 16 |
| Lithuania | 9 | 24 | 22 | * |
| Luxembourg | 2 | 25 | 5 | 7 |
| Malta | 27 | 10 | 13 | 12 |
| Netherlands | 17 | 19 | 2 | 20 |
| Poland | 19 | 13 | 15 | 26 |
| Portugal | 10 | 18 | 18 | 17 |
| Romania | 7 | 28 | 27 | 23 |
| Slovakia | 28 | 6 | 19 | 8 |
| Slovenia | 3 | 15 | 11 | 24 |
| Spain | 14 | 21 | 25 | 5 |
| Sweden | 5 | 5 | 4 | 3 |
| United Kingdom | 4 | 26 | 3 | 15 |

Source: Authors' elaboration on CEDEFOP data. * Missing observation

3.1.2.1 Recruitment of STEM skills

Sectors with the highest STEM employment in the EU include Business Services and Manufacturing. In 2015, S&E professionals were mostly employed in Business Services (around 2.9 million people), Real Estate (around 2.2 million people) and Manufacturing (around 1.7 million people). ICT professionals were mostly employed in business services (around 2.6 million people), information and communication activities (around 1.9 million people), and manufacturing (around 370,000 people). S&E associate professionals were mostly employed in manufacturing (around 3.2 million people) and construction (around 1.2 million people). ICT associate professionals were mostly



employed in business services (around 1.0 million people) and information and communication activities (around 780,000 people).

Among firms that need STEM skills, employers report difficulty in recruiting. An employer interviewed from a medium-sized Spanish company stated that during the economic crisis they had to fire people and perform a global restructuration to save the company. However, now that the hardest period is over, they are stronger and they are actively hiring new staff again, mostly people with STEM-related degrees. He added that they usually look for recent graduates hiring the best students. Their policy is to have them interning in the company for a while or working on their final degree projects and thus they can already evaluate their competence. They also had many PhD students since they are closely linked to university. The interviewee saw a large number of students every year passing through their premises, which was a good system to assess who was worth hiring. According to this employer, 80% of their current workforce emerged from this source and thanks to their ties with university. In terms of profiles, he specified that they are not closed to a specific type of professional or degree. In fact, according to the interviewee, the idea of super specialization is wrong. A competent workforce must be very ambivalent and able to easily adapt to any sector. The same employer reported to have encountered difficulties in recruiting STEM-skilled professionals not due to a shortage of supply but due to the difficulty of finding the specific profile they looked for. That is why, according to the interviewee, his approach is to select the best among the recent graduates and provide them with the specific training they consider important for the needs of the company. To this employer, the lack of workplace experience was not a problem when hiring young people.

One representative from a large-sized Slovenian company stated that it is very important to establish a model in recruitment. According to the interviewee, they had a successful policy of early recruitment with scholarships which began in high school but who continued to undergraduate, graduate and doctoral studies – assuring their future supply. Several employers indicate that the previous work experience is one of the aspects valued the most among candidates. A representative of a large-sized company reported difficulties in recruiting STEM-skilled professionals, especially in the field of IT where there is full employment. He added that it is easier to find people among recent graduates, but obviously they do not have the experience in the industrial context that they would like to see in an employee. Another representative from a medium-sized Spanish IT company commented on an apparent contradiction in the IT field. On one hand, they wanted people with work experience and with certain knowledge of the market so they do not normally hire graduates. On the other hand, young STEM professionals were leaving Spain to get training in countries more committed to innovation (such as UK and the USA) and it is really difficult that these professionals will return to Spain.



STEM skills alone are not enough – employers seek for diverse skills. The demand for people with STEM qualifications is closely linked to the skills that they bring to the workplace. Most of the employers surveyed particularly seek for capabilities in active learning, critical thinking, complex and creative problem-solving, all of which correlate closely with STEM qualification based skills. About specific requirements in an employee personality, most of the interviewed employers mentioned critical thinking as a key skill. Initiative was also indicated as an important competence for some. In general terms, the majority of interviews expected a solid scientific background to ease adaptation in the different areas. According to a medium-sized Spanish high-tech employer, ideal employees should have reaction skills, a good moral and scientific authority, which gives them the respect of their co-workers and subordinates and the ability to treat with clients. The same employer also mentioned as an important skill, which is not taken into consideration often among STEM professionals: the ability to appreciate culture and humanities. A representative from a large-sized company stated that what they wanted in an employee is the ability to adapt to change, autonomy and critical thinking. As reported by a medium-sized Spanish IT representative, employees should be pragmatic, able to solve technical problems and with a critical spirit. She added that it is important to have people with an open and flexible mind as the market is in constant movement and you must adapt quickly to it.

Future prosperity of the labour market depends developing a skilled, flexible workforce that can drive up productivity and respond rapidly to shifts in global market opportunities (Brennan and Limmer, 2015). Interviewed employers from micro IT companies value diversity in employee skills. On one side, they looked for people with good knowledge of algorithm, programming, processing methodologies and, in general, people mastering technical skills. On the other side, they expected management and leadership skills, which do not always come on a STEM student preparation. The majority of the employers interviewed stated to be satisfied with the skills of their current workforces. An employer from a medium-sized Spanish company pointed that it is not easy to find the right skills and he considered he had the right skilled people because of the strict selection process they were able to perform among students and graduates thanks to their link with universities. Overall, foreign language skills were mentioned as a common lack among the general workforce. This was considered as an issue for some of the employers as they stated knowledge of foreign languages as a very important skill in the globalized market. It is seen as beneficial to the business although not necessarily a recruitment requirement. Three of the interviewees provided remedial training to help their employees improve their proficiency in English. One medium-sized employer from a Spanish company stated that he took for granted that STEM professionals spoke at least English, as it is the language of most of the literature studied in university.

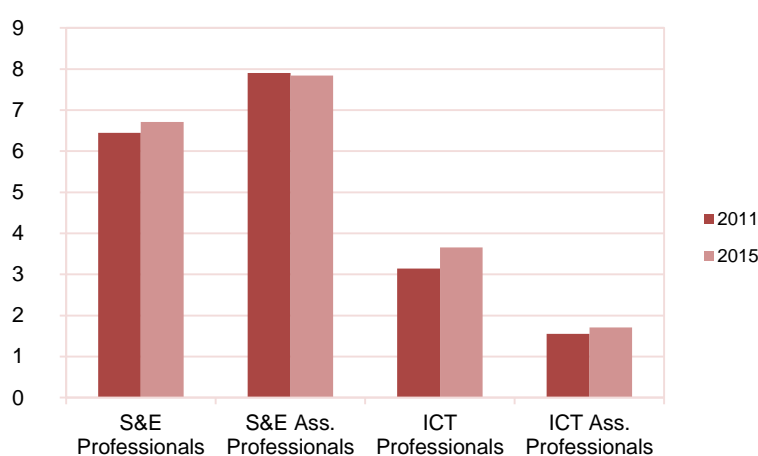


3.1.3 Future STEM Employment

During the period 2011-2015, STEM employment in the EU has increased by 4.6%.

As the figure shows, the change is mostly due to the increase in ICT professionals (+16.4%) and ICT associate professionals (+10.0%). The number of people employed as S&E professionals has increased by 4.1%, whereas employment of S&E associate professionals has slightly decreased (-0.8%) during the period 2011-2015.

Figure 11 STEM Employment in the EU, 2011-2015 comparison

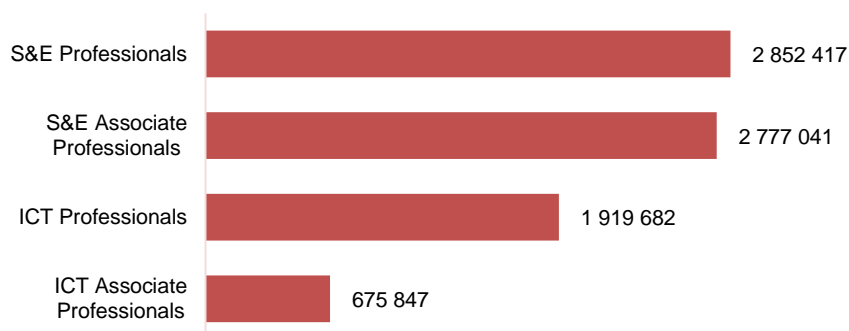


Source: Authors' elaboration on CEDEFOP data

This expansion is forecast to continue over the next decade. In the period 2015-2025, there will be around 8.2 million STEM jobs openings in the EU. The figure, based on CEDEFOP data, amounts to the number of people who will be required to work in one of the four STEM occupations, given projected changes in employment and replacement demands. Each of the four STEM occupations is expected to have a positive employment balance. According to CEDEFOP, by 2025 employment for S&E and ICT professionals is projected to increase by 12.5% and 11.8% respectively, which means around 2.9 and 1.9 million job openings including replacement demands. To a lesser extent, projected change in employment to 2025 for S&E and ICT associate professionals amounts to 1.9% and 5.2% respectively, which translates to around 2.7 and around 0.7 million job openings including replacement demands.



Figure 12 STEM job openings in the EU, 2015-2025



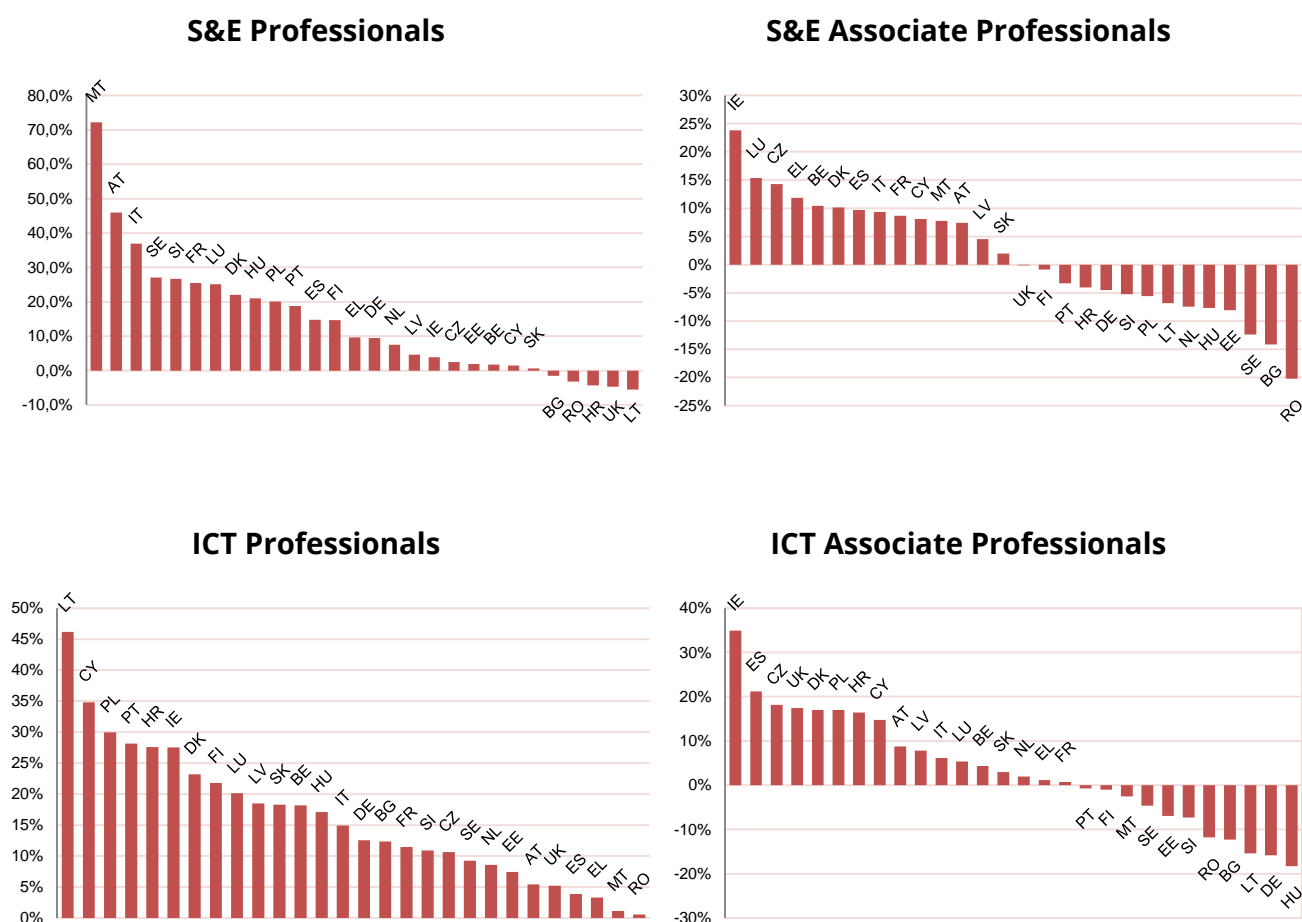
Source: Authors' elaboration on CEDEFOP data

Between 2015 and 2025, STEM professionals will probably be more sought after in the labour market than STEM associate professionals. When looking at the individual occupations, as the following figure shows, two patterns seem to stand out. On the one hand, with regards to STEM professionals, nearly all Member States will enjoy employment growth to at least a certain extent. On the other hand, with regards to STEM associate professionals, employment will decrease in nearly half Member States. Associate professionals might be at risk of replacement due to technological advancement in automation (Chui et al., 2016).

More specifically, employment of S&E professionals is especially likely to increase in Malta (+72.3%), Austria (+45.9%) and Italy (+36.9%), while it is expected to slightly drop in Lithuania (-5.5%), the United Kingdom (-4.7%), and Croatia (-4.4%). Conversely, employment of ICT professionals in Lithuania is particularly expected to increase (+46.2%), and so it will everywhere else across the EU, including Cyprus (+34.8%) and Poland (+30.0%). Romania (+0.6%) and Malta (+1.1%) show a more modest forecast. With regards to Employment of S&E associate professionals, it will especially increase in Ireland (+23.8%), Luxembourg (+15.4%) and Czech Republic (+14.3%), whereas it is expected to drop significantly in Romania (-20.3%), Bulgaria (-14.2%) and Sweden (-12.4%). Similarly, employment of ICT associate professionals is expected to rise in Ireland (+34.9%) and Czech Republic (+18.2%), as well as in Spain (+21.2%), and is expected to drop in Hungary (-18.3%), Germany (-15.8%) and Lithuania (-15.4%).



Figure 13 Future STEM employment growth (in %) across the EU in 2015-2025



Source: Authors' elaboration on CEDEFOP data

Future growth in STEM employment is likely to be unevenly distributed across EU Member States. This is further explained in the following heatmap, in which the percentage change for each STEM occupation is broken down by Member State. In Austria, Sweden, Slovenia, and Malta, for example, employment growth will mostly be a matter of S&E professionals. In Finland, France, Germany, Hungary, Italy, Luxembourg, Portugal, employment of professionals (either ICT or S&E) is likely to increase. At the same time, Germany and Hungary are expected to have a drop in employment of associate professionals, and so are Bulgaria, Lithuania and Romania. Employment will increase to at least a certain extent across all STEM occupations in Denmark, Spain, Czech Republic, Ireland and Luxembourg.



Table 12 Future STEM employment growth (in %) across the EU in 2015-2025

| | S&E Professional s | S&E associate professional s | ICT professional s | ICT associate professional s |
|----------------|--------------------------|---------------------------------------|--------------------------|------------------------------------|
| Austria | 46% | 7% | 5% | 9% |
| Belgium | 2% | 10% | 18% | 4% |
| Bulgaria | -2% | -14% | 12% | -12% |
| Croatia | -4% | -4% | 28% | 16% |
| Cyprus | 1% | 8% | 35% | 15% |
| Czech Republic | 2% | 14% | 11% | 18% |
| Denmark | 22% | 10% | 23% | 17% |
| Estonia | 2% | -8% | 7% | -7% |
| Finland | 15% | -1% | 22% | -1% |
| France | 25% | 9% | 11% | 1% |
| Germany | 9% | -5% | 13% | -16% |
| Greece | 10% | 12% | 3% | 1% |
| Hungary | 21% | -8% | 17% | -18% |
| Ireland | 4% | 24% | 28% | 35% |
| Italy | 37% | 9% | 15% | 6% |
| Latvia | 5% | 5% | 18% | 8% |
| Lithuania | -6% | -7% | 46% | -15% |
| Luxembourg | 25% | 15% | 20% | 5% |
| Malta | 72% | 8% | 1% | -3% |
| Netherlands | 8% | -7% | 9% | 2% |
| Poland | 20% | -6% | 30% | 17% |
| Portugal | 19% | -3% | 28% | -1% |
| Romania | -3% | -20% | 1% | -12% |
| Slovakia | 1% | 2% | 18% | 3% |
| Slovenia | 27% | -5% | 11% | -7% |
| Spain | 15% | 10% | 4% | 21% |
| Sweden | 27% | -12% | 9% | -5% |
| United Kingdom | -5% | 0% | 5% | 17% |

Source: Authors' elaboration on CEDEFOP data

Among interviewed employers, many are confident that they will be constantly hiring STEM skilled professionals in the next 5 years. According to an employer from a medium-sized Spanish company, after the strong impact the Spanish market suffered during the economic crisis a recovery and the market awakening are on sight. As reported by this employer, his company is growing and they will hire more people. He was positive of being able to find and recruit high-skilled employees. There are many professionals currently working in Germany, France, the UK, who left during the economic recession and are moving back to Spain now that they are able to find good



job opportunities there too. This would be good news for the Spanish industry as these professionals have been trained in more advanced markets and they return with additional experience. The same employer believes that the offer of STEM graduates will be enough to cover the needs of the industry, and that perhaps there will be a shortage in some specific disciplines such as informatics engineering, which are in strong demand at the moment. He added that this might be different in other European countries, where a shortage of supply might occur for different reasons - not enough people considering STEM programs in universities, for example, especially in countries where individuals can reach high standards of living anyway, and the alleged extra effort of a STEM degree might not be worth.

A representative from a large-sized Spanish company expected to hire technological profiles, process engineers and IT professionals constantly within the next years. However, he is not confident that the company will be able to find these people. He reported issues regarding this subject in the past. He commented that recently, their company started hiring professionals from Latin America, and they may continue if unable to find in the EU. An employer from a micro-sized Greek company stated that the drawback his company is expected to face regarding the recruit of a high-skilled employee is relocation, as many ideal candidates have usually moved abroad. The head of operations of a medium-sized IT company added that as innovation is constant in their field, they would need to find more people. According to her, the market will be in high demand of STEM skilled profiles. She is confident that they will be able to find these people, maybe not with the specific profile they would like but people able to learn and to fill these needs.

A representative of a small-sized Slovenian company indicated that, in his opinion, the ability of recruitment depended on different factors: payment, location of the workplace, attractiveness of the industry, general public and awareness of the brand/company among others. He also predicted that it will be less difficult to attract talent in the future. Finally, another representative of a large-sized Slovenian company stated that the company will be hiring a lot of professionals in the future, particularly specialists on automatization, production, future developments and project leaders. He was very confident for the future. He added that in the last career fair they host, they had a great response, and a growing interest from female candidates.

Summing up, the outlook for the future STEM industry in the EU as a whole is complex. From the analysis above, corroborated by the literature review, three distinct aspects seem to emerge for STEM workers: multiple industry trajectories, the presence of cross-sectoral trends, and the role of replacements.



3.1.3.1 Trends in the STEM industry

First, **the skills profiles of STEM workers will need to adapt on the developments and trends of the industries they work for.** In the construction sector, rising technologies such as the Building Information Modeling (BIM) integrate planning and landscaping with data analytics, smart homes and the Internet of Things (IoT) while minimising environmental impact. The EU is already investing on sustainable urban development (European Commission, 2013). In the UK, the government has recently made BIM compulsory on all public works. Professionals in the sector will need to adapt and possess expertise on data management and other new skills (UK Government, 2015). Other innovations in the constructing industry, such as geo-location and higher-definition surveying, will likely impact the skills profile for S&E associate professionals such as geology technicians (Agarwal et al., 2016). Employment of STEM technicians in the construction sector is also likely to benefit from the growing demand for environmentally sensitive and energy efficient buildings (Pye and Dobbins, 2015).

In the energy sector, the transition from traditional sources to renewable energy has changed the industry framework and the profile of skills required. Traditionally concentrated, capital-intensive, and often government-led, large energy companies had been relatively stable employers with fair levels of pay. The growth of renewable energy has significantly fragmented industry: a larger proportion of employment is in new companies, and more work is project-based. Fast deployment could lead to shortages in technical occupations such as solar installers and electrical engineers (EC Joint, 2011). On the other hand, concern for climate change is likely to increase employment opportunities. Governments committed to the 2016 Paris Agreement on carbon emissions will increase public sector funding, which in turn is likely to create jobs in deploying, operating and maintaining renewable energy projects (Walt, 2015; IEA, 2016). In addition, climate change impact prevention and mitigation activities grow in many more sectors than before. Demand for specialist operations and development expertise in photovoltaic technology, wind power and energy savings could increase. Engineers and life scientists equipped with data analytics, systems, risk, project management skills would then be needed to support R&D in these fields (Brennan & Limmer, 2015). The emergence of the marine renewable energy (MRE) industry is also creating new skillsets from the combination of many different areas. New STEM occupational profiles, such as the wind turbine service technician, are likely to be formed (Podevin, 2015).



In the automotive industry, electronics contribute 30% of car production costs. This is expected to reach 50% by 2030¹¹. Electronic systems already account for 90% of car innovations and new features (Coulon, 2014). As a consequence, skills for manufacturing and developing electronic parts are expected to increase, at the cost of traditional mechanical engineering skills. In the oil & gas market, the reducing demand for fossil fuels in Europe, together with falling oil prices and the outsourcing of complex refinery infrastructure outside of the EU, might reduce demand for STEM professionals (Lukoil 2013; Fitzgibbon et al., 2015). The biotechnology industry, one of the Key Enabling Technologies (KET) under Horizon 2020, is expected to grow from EUR 28 billion to EUR 50 billion by 2030 (BIO-TIC, 2015). With biotech driving innovation in many sectors - chemicals, food, detergents, paper, textiles, bioenergy, agriculture, healthcare - demand for biotech skills is likely to rise exponentially (EY, 2014).

3.1.3.2 Cross-sectoral trends

In addition to industry-specific trends, **a number of cross-sectoral factors could further shape the demand for STEM workers**. One example is the growing importance of automation. As industry invests in advanced robots, smart homes, virtual personal assistants, and driverless cars, the demand for software and hardware experts by start-ups - as well as by established organizations - is likely to rise (West, 2015). Whereas disruptions such as 3D printing and robotics are expected to cause an overall decline in the demand for jobs, the opposite is true with regards to STEM professionals and technicians, due to the need for high-skilled specialists able to develop and execute advanced production systems (WEF, 2016).

The Big Data trend is creating demand for jobs with data analytical skills, data management and data scaling skills (Morrison, 2016). New jobs, such as data scientist and Chief Analytics Officer (CAO), have already surfaced (Foo, 2013). Likewise, as more and more enterprises and consumers shift to cloud computing, technical knowledge shifts away from users towards cloud providers (IDC, 2014). Companies in the sector will need STEM professionals and technicians equipped with skills including cloud design and management, service integration and management, and cloud data centre building and optimization (Darrow, 2015).

The growing Internet of Things (IoT) is also likely to boost the demand for those STEM professionals and technicians with the capacity to handle diversified systems, and for those with an understanding of architecture, design, standardisation and interoperability. Network management skills are also expected to increase, as well as

¹¹ Automotive electronics costs worldwide 2030Forecast.Available at <https://www.statista.com/statistics/277931/automotive-electronics-cost-as-a-share-of-total-car-cost-worldwide> (retrieved 31 October 2016).



technical knowledge of IoT. (WEF, 2016). Changes in consumer demand towards more customized products and services have resulted in new, technology-intensive and flexible production processes, known as “Industry 4.0” (Bundesministerium für Bildung und Forschung, 2014). Industry 4.0 creates “Smart factories”, where cyber-physical systems interact with IoT and the Internet of Services¹². STEM specialists will need to possess additional software and hardware skills to develop complex human-independent machines able to interact with each other (Schlepper and Koch, 2015).

With the growth in smart devices, and a constant demand for interoperability, standardization activities are likely to increase (European Commission, 2011). Standardizations are already under way in 5G networks, 3D printing, and IoT (IERC, 2015). The effect of a growth in standards and patents on employment is ambiguous: on one hand, it could lead to a larger demand for STEM professionals who work on product specifications; on the other hand, existing STEM professionals might lose their jobs as the standards they are specialized in become obsolete. Smart systems also open a new window of attack for cybercrime and cyberterrorism (Nugent, 2016). Security defences of the interconnected, “smart” infrastructures of the future will have to expand beyond the conventional borders of existing computing systems. As a consequence, the demand for cybersecurity skills is likely to increase, together with business skills to manage trust and risk (Cisco, 2015).

Lastly, the international fragmentation of production is on the rise, with intermediates now accounting for 50% of world trade in manufacturing (OECD, 2015). Globalization has transformed innovation into an international, collaborative activity (WEF, 2015). The number of jobs involved in global value chains (GVCs) has increased in Europe, as did the share of high skilled workers, including STEM professionals. Meeting foreign demand will require relatively high shares of highly-skilled workers (OECD, 2015). In addition, strong communication skills will be increasingly important to lead and work in such international and collaborative environments (McDougall, 2014).

3.1.3.3 Replacement demand

Finally, **many of the STEM job openings in 2025 will be a consequence of replacement demand**. According to CEDEFOP, STEM employment growth will mostly reflect the necessity to fill jobs vacated by those who left the labour market due to retirement, migration, shifts between jobs, or temporary leave (Cedefop, 2016).

¹² Internet of Services - SAP Research - SCN Wiki. Available at <https://wiki.scn.sap.com/wiki/display/Research/Internet+of+Services> (retrieved 31 October 2016).

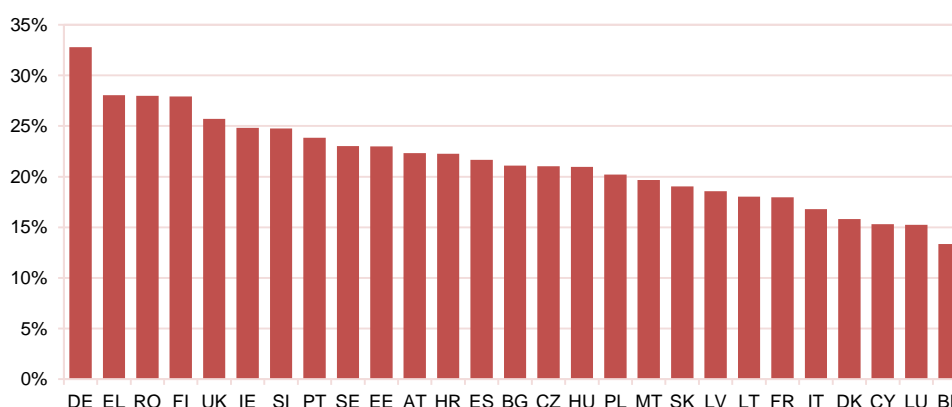


3.2 Supply of STEM skills

3.2.1 STEM student body

In the EU-28 there were 5.3 million STEM students in 2014, of which 68.9% were male (about 3.6 million) and 31.1% were female (about 1.7 million) according to Eurostat data. STEM students account for about 27.2% of all students in tertiary education¹³. Germany, the most populous Member State in the EU, in 2014 had 954,363 students enrolled in a STEM degree, which was the highest number in the EU in 2014. The United Kingdom (604,837 students), France (429,421), Spain (429,114) Poland (355,963) and Italy (305,127) had the next largest STEM population. Germany also had the relative largest of STEM students, corresponding to 32.8% of all students in tertiary education. Greece (28.1%), Romania (28.0%), Finland (27.9%) and the United Kingdom (25.7%) had the next largest STEM student population.

Figure 14 STEM students as % of total students in the EU, 2014



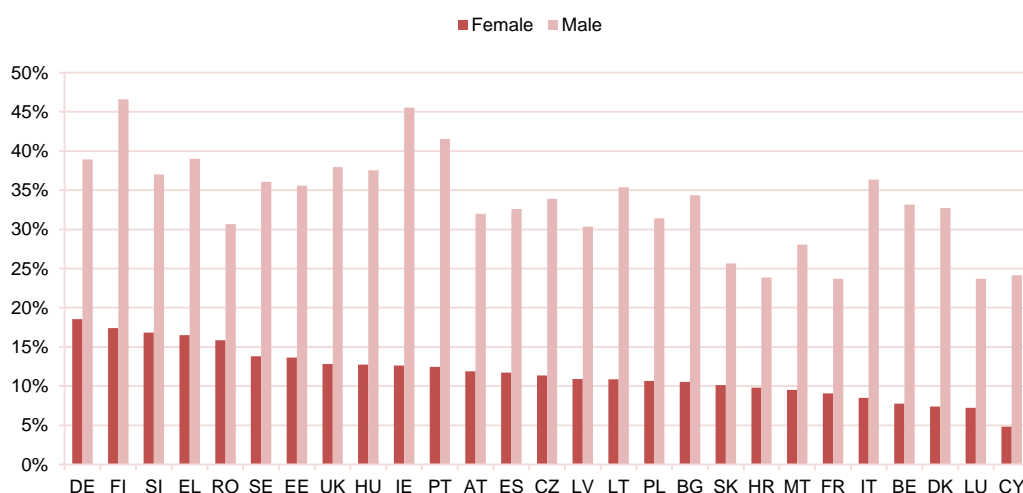
Source: Authors' elaboration on Eurostat data (educ_uoe_enrt).

STEM programs are consistently less popular among women. Nowhere in the EU are STEM programs attended by more than one-fifth of the female student population. They are relatively more attractive in Germany, where around 18.5% of female students are enrolled in a STEM program - while male STEM students account for around 38.9% of all students. In Italy, France, Belgium, Denmark, Croatia, Luxembourg, Cyprus, and Malta, less than 10% of female students are enrolled in a STEM program. Conversely, male STEM students account for more than 40% of the student body in Portugal, Ireland and Finland.

¹³ The EU-28 figure includes Architecture and Building (EF58) students. Two-digit ISCED breakdowns, which are necessary to exclude Architecture field from the computation, do not include the Netherlands, where 3.4 % of the EU-28's tertiary students studied in 2014. The average share of Architecture students on all STEM students for the remaining Member States is about 18%, with a median of 19%.



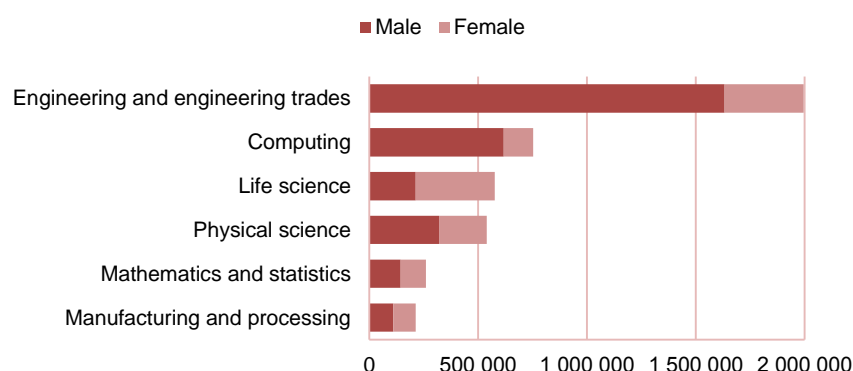
Figure 15 STEM students as % of student body in the EU by gender, 2014



Source: Authors' elaboration on Eurostat data (educ_uoe_enrt).

Engineering accounts for almost half of the STEM student population. Across the EU, almost half (46.0%) of all STEM students, around 2.0 million, were studying engineering and engineering trades, with almost four in five students (81.8%) being male in this field of education. Programs in this field of study include mechanics, energy, electrical engineering, electronics and automation, chemical engineering, ships and aircraft engineering. The second most common field of education (around 750,000 students) was computing, including computer use and computer science programs, which accounted for 17.4% of the STEM student body. In this field, 82.8% of the students were male.

Figure 16 Distribution of STEM tertiary graduates by field and gender, EU, 2014



Source: Authors' elaboration on Eurostat data (educ_uoe_enrt).

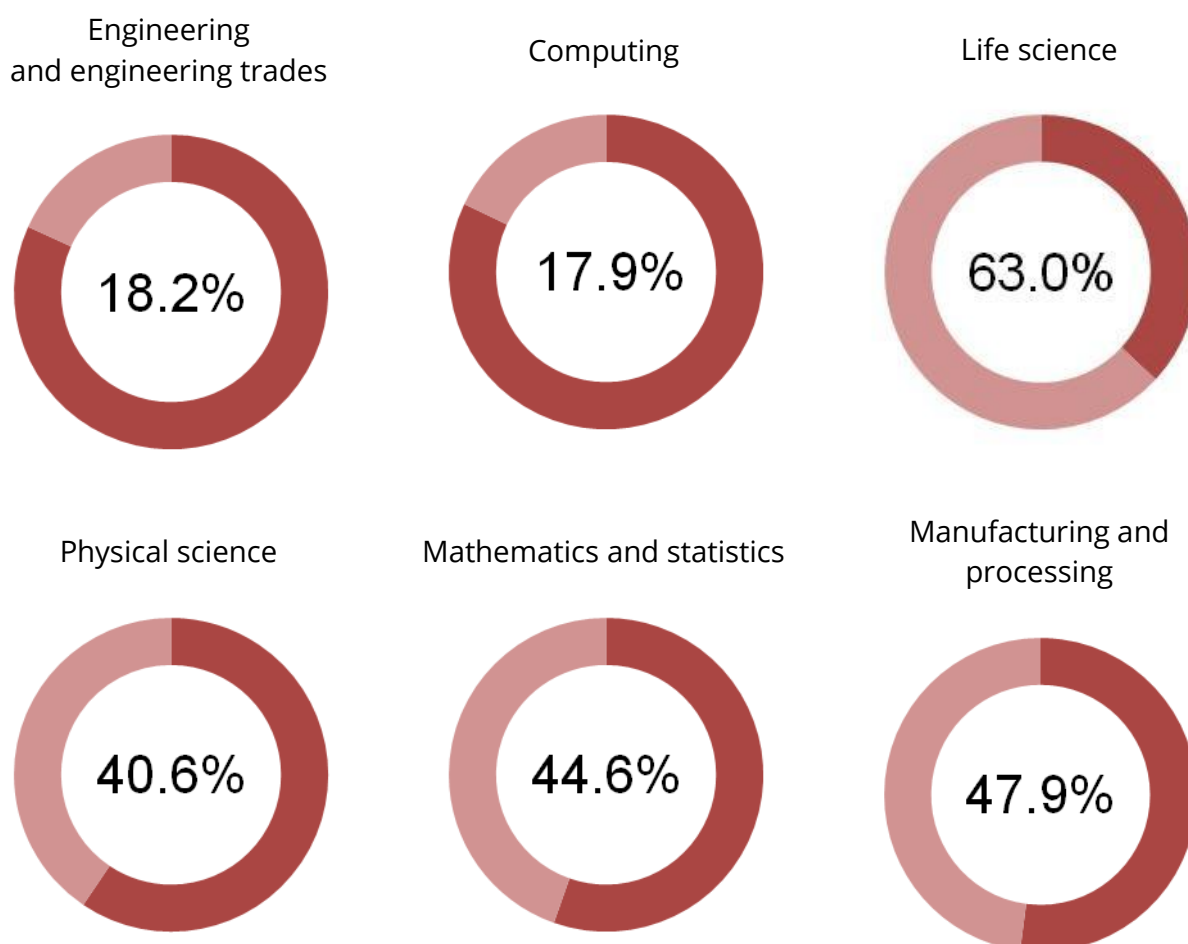
Note: Missing observation for the Netherlands

Women are the majority in Life Science programs. The third largest field of STEM study in 2014 was life science (around 577,000 students), accounting for 13.2 % of all



STEM students. In life science programs, which include environmental science, biology and biochemistry, women accounted for two-thirds of the students (63.0%). In physics, chemistry, and earth science (group of Physical science, around 540,000 students overall) the proportion of female students was 40.6%. Finally, in the manufacturing and processing group (around 212,000 students), women accounted for nearly half of the student body (47.9%). The manufacturing and processing group includes degrees in: food processing engineering; textiles, clothes, footwear, leather engineering; Mining and extraction engineering; Materials engineering (wood, paper, plastic, glass).

Figure 17 Proportion of female students in STEM fields, EU, 2014



Source: Authors' elaboration on Eurostat data (educ_uoe_enrt).

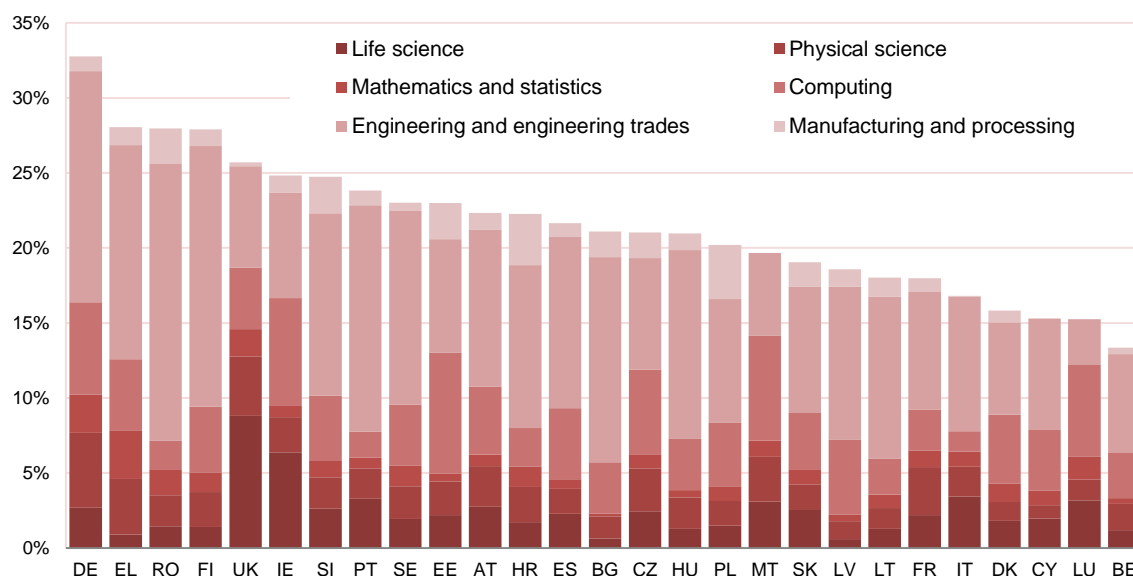
Note: Missing observation for the Netherlands

The STEM student supply across the EU is highly varied. Among the EU Member States, some STEM fields can be spotted in which — compared with all fields of study — a particularly large or small share of students was enrolled in 2014. The share of Life Science students was relatively low in Latvia and Bulgaria, while it was particularly high



in the United Kingdom and Ireland. The share of Physical Science students was relatively low in Cyprus, Latvia, Lithuania, and Denmark, while it was relatively high in the United Kingdom, Germany, and Greece. Similarly, the proportion of students in Mathematics and statistics was particularly high in Germany and Greece and relatively low in Bulgaria and Belgium. The share of Computer Science students was relatively low in Italy and Portugal and relatively high in Estonia and Ireland. The share of engineering students was relatively low in Denmark and Luxembourg and relatively high in Romania and Finland. Finally, the proportion of Manufacturing and processing students was negligible in Italy and the United Kingdom, virtually non-existent in Luxembourg and Malta, and relatively high in Poland and Croatia.

Figure 18 STEM students as % of total students in the EU, breakdown by field of study, 2014



Source: Authors' elaboration on Eurostat data (educ_uoe_enrt).

Note: Missing observation for the Netherlands

Strengthening links between university and business is said to have the potential to enhance economic growth. Employers interviewed for the present study expect higher education institutions to develop people with the right knowledge and skills to meet their future needs. All of the interviewees agreed that close relations with universities are positive to the present and future interests of both parties. Among interviews, 8 stated to have developed direct links with universities such as collaboration in training programs and knowledge sharing. One employer from a medium-sized Spanish company described their relation to the university as "very strong"; his company is involved in research groups, through which university's technology is shared to business and both parties develop publications together. Many of the company's employees are academics. Through the connection with the same university, the same



company frequently receives students to work on their own final degree projects. Although they do not provide direct training, students are guided on their project development and are allowed to use the company's technology to run their tests. Another employer from a micro-sized Spanish IT company stated to have strong links with the university to the point that they directly hire skilled people among students who are about to finish their studies or to work on their final projects.

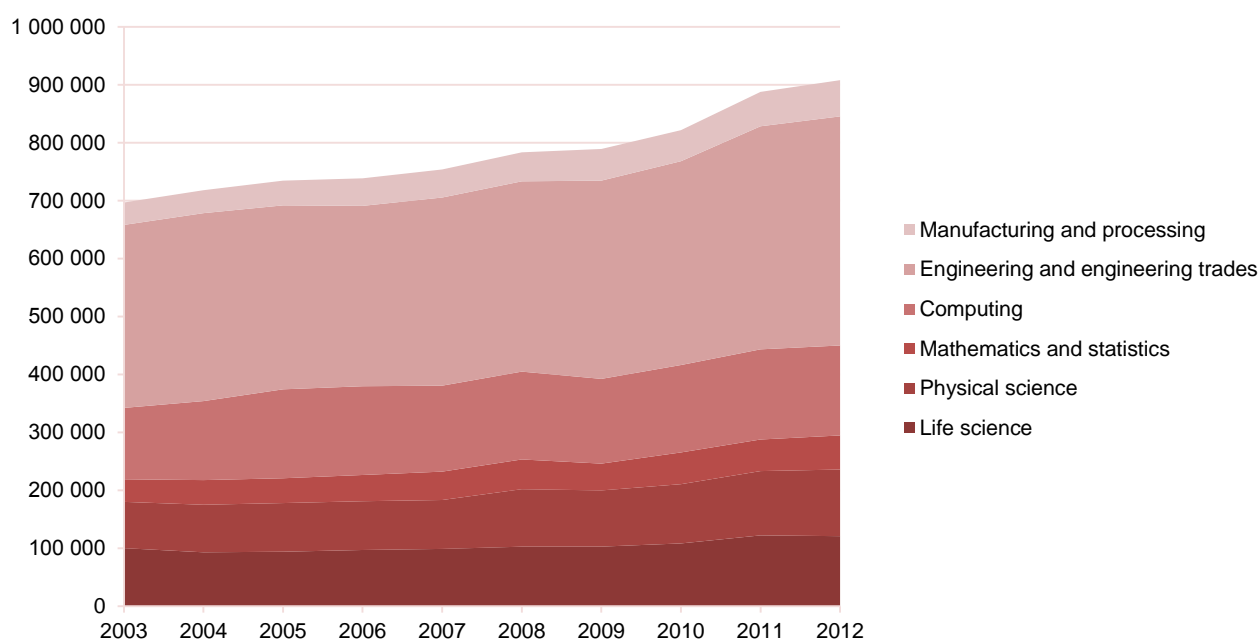
According to employers, **what happens in secondary schools, especially vocational training institutions, is equally important for the future of STEM employment.** One employer reported to have signed collaboration agreements to develop stronger ties with vocational training schools. Although these links are not as strong as those with universities for the moment, he expects to continue working to empower these ties. He considers vocational training of great importance to the future of the industry. In his opinion, there is a shortage of medium-skilled technicians because professional training is not seen as a key area, and the public sector is not providing enough resources to this type of schools. The interviewed expressed a concern regarding the idea that our society has on this subject, which is causing students to consider non-vocational high school as the only path to access a good job. In order to promote this type of school, they have vocational training students participating in training programs as well. They also provide formation and support to these centres. Regarding the same topic, an employer of a micro-sized Slovenian company stated that he had some experience working with these centres in the past. However, he does not plan to continue the collaborations in the future as in his opinion, secondary school students do not have the proper experience to perform research work. Another employer, from a micro-sized Spanish IT company expressed his interest in establishing ties with vocational training centres as he considered that the people these centres are training may be of importance in the future.

3.2.2 STEM graduations

Approximately 900,000 students graduated in STEM programs from tertiary education institutes in the EU-28 in 2012. Women (about 283,000) accounted for 31.5%, while men (about 616,840) accounted for 68.5%. Among all STEM graduates, about 395,000 graduated in Engineering programs (43.6%) which were the most popular STEM field of study. Computing (around 155,000 graduates) and Life Science (around 120,000 graduates) were the next most popular STEM fields. The number of STEM graduates has been on a constant rise from 2003 to 2012.



Figure 19 STEM graduates in the EU, 2003-2012

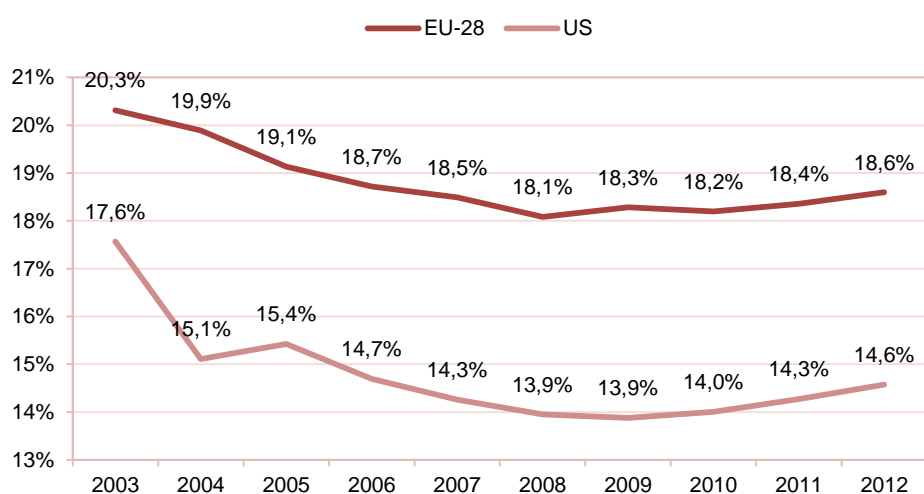


Source: Authors' elaboration on Eurostat data (educ_grad5).

Note: Missing observation for Croatia in 2011.

In 2012, graduations from STEM programs accounted for 18.6% of all graduations. The figure is lower than that of 2003, when 20.3% of new graduates were from a STEM program. However, it is on a steady rise since 2008. The proportion of STEM graduations is also constantly higher than that of the U.S., where graduations from STEM programs were 14.6% of all graduations in 2012.

Figure 20 Graduations in STEM fields as % of all graduations, EU-28 and US, 2003-2012



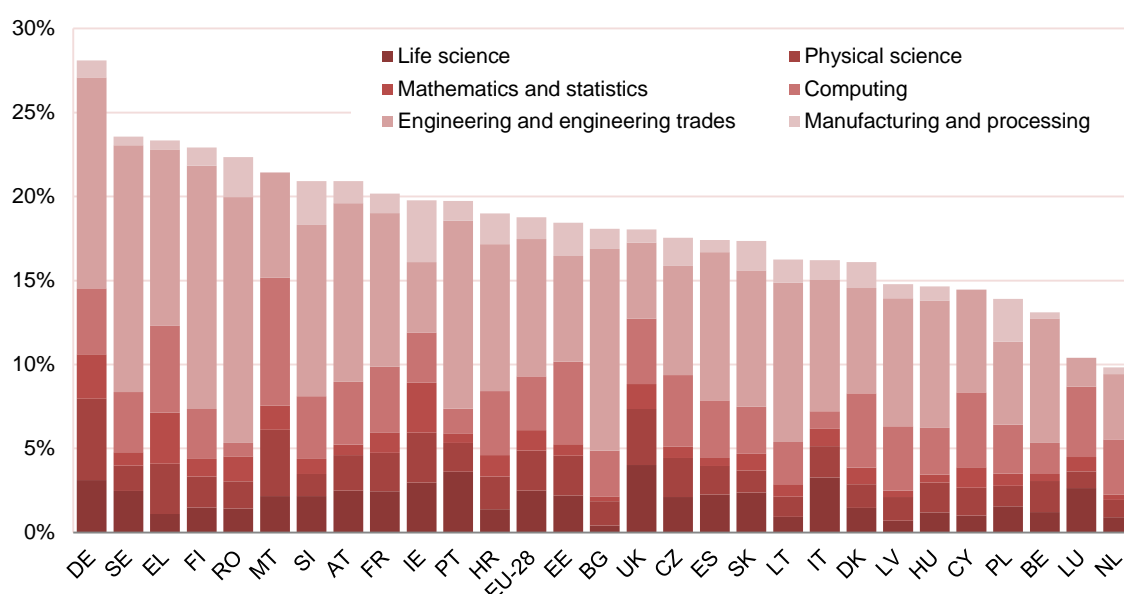


Source: Authors' elaboration on Eurostat data (educ_grad5).

Note: Missing observation for Croatia in 2011.

In 2012, Germany had the largest number of STEM graduates (around 155,000). In absolute terms, Germany is followed by the United Kingdom and France (around 141,000 – but the latter's observation dates to the year 2011) way ahead of Poland (around 89,000), Spain (around 68,000) and Italy (around 62,000). The number of STEM graduates in the United Kingdom and France might, at least to some extent, be affected by the shorter average course length in the two countries¹⁴. In relative terms, Germany also has the largest proportion of STEM graduates among graduates from all fields of study (28.1%). However, here Germany is followed by Sweden (23.6%), Greece (23.3%), Finland (22.9%), Romania (22.3%) and Malta (21.4%).

Figure 21 STEM graduates as % of total graduates, breakdown by field of study, 2014



Source: Authors' elaboration on Eurostat data (educ_grad5).

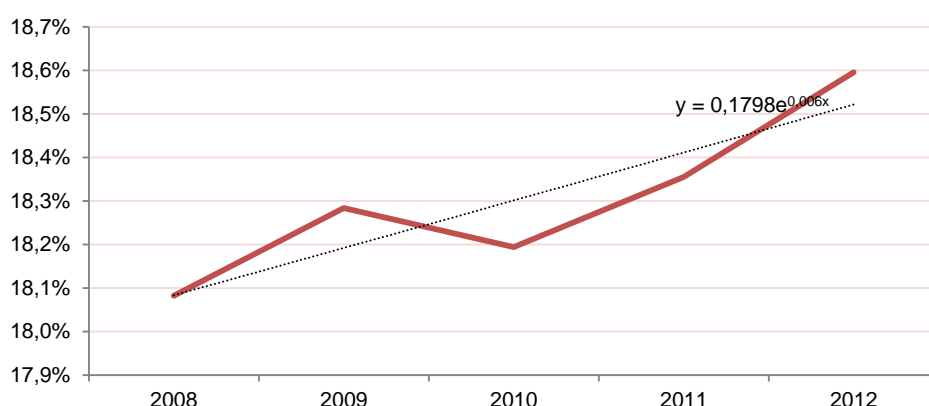
Note: observation for France dates to 2011

Between 2008 and 2012, the proportion of STEM graduates in the EU plateaued. An analysis of the Average Annual Growth Rate (AAGR) in the 2008 to 2012 period shows a negligible EU-wide growth for the share of STEM graduates among all graduates (+0.7%), as shown by the trend chart below.

¹⁴ Tertiary education statistics - Statistics Explained. Available at http://ec.europa.eu/eurostat/statistics-explained/index.php/Tertiary_education_statistics (retrieved 31 October 2016).



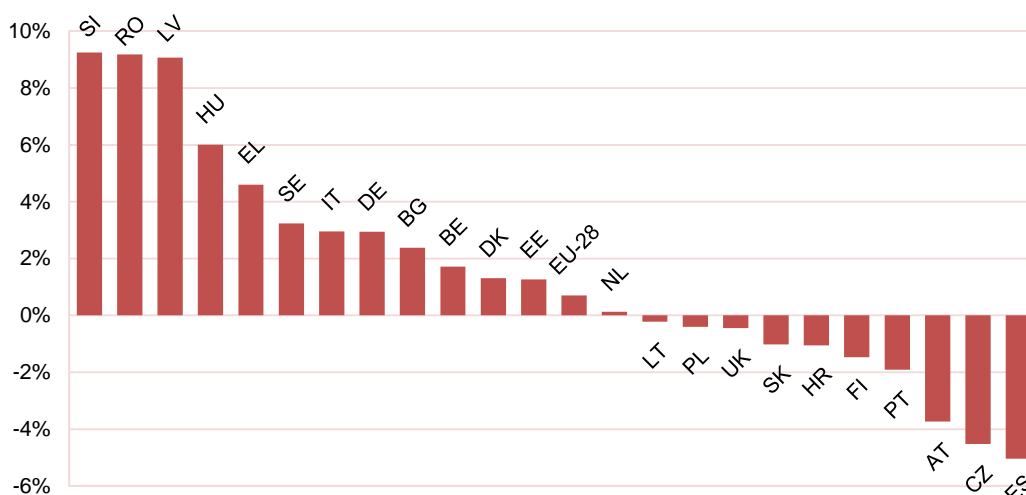
Figure 22 Average Annual Growth Rate (AAGR) in the share of STEM graduates in the EU, 2008-2012



Source: Authors' elaboration on Eurostat data (educ_grad5). Note: the equation has the form $y=b*e^{g*x}$ where $g=0.006$ is the growth rate.

Between 2008 and 2012, the share of STEM graduates grew in Slovenia and Romania, fell in Spain and Czech Republic. The analysis repeated in a sub-sample of 23 EU Member States - those for whom data had been consistently reported in the 5-years interval – shows that on average, there was a significant growth in the proportion of STEM graduates in Slovenia (+9.2%), Romania (+9.0%) and Latvia (+9.1%). The share of STEM graduates increased in several Member States, including Hungary (+6.0%), Greece (+4.6%), Sweden (+3.2%) and Italy (+3.0%). At the other end of the list, Spain (-5.0%) and Czech Republic (-4.5%) show the largest drop in the proportion of STEM graduates. Negative growth results in other Member States as well, including Austria (-3.7%), Portugal (-1.9%) and Finland (-1.5%)

Figure 23 Average Annual Growth Rate (AAGR) in the share of STEM graduates, selected MS, 2008-2012



Source: Authors' elaboration on Eurostat data (educ_grad5).



4 Factors affecting the STEM supply

The literature identifies a number of economic, social, cultural, and institutional factors to explain why students choose a particular field of study.

4.1 Economic factors

There is an abundant literature on the **economic returns to education**, starting from the work of Becker (1964) and Mincer (1974). One branch of studies investigates returns by field of study. Differentials in productivity of individuals are not only explained by the level, but also by the nature of human capital (Dickson and Harmon, 2011). Many sources of heterogeneity exist, such as race (Handerson et al., 2011) or nationality (Park, 2011). A second branch of literature computes returns - in terms of “what an individual gets out of a specific education” - through indicators such as the Internal Rate of Return (IRR) or Net Present Value (NPV). A growing number of country-level studies focuses on EU Member States, such as Germany (Kim and Kim 2003; Grave and Goerlitz 2012), France (Goudard and Giret 2010), Italy (Buonanno and Pozzoli 2009), Greece (Livanos and Pouliakas 2008), Ireland (Kelly et al., 2010), Slovenia (Bartolj et al. 2012) Czech Republic (Munich et al., 2005) and the UK (Blackaby et al., 1999; Blundell et al., 2000; Bratti and Mancini, 2003; O’Leary and Sloane, 2005; Walker and Zhu, 2011; Chevalier, 2011). A common finding is that returns to STEM fields exceed those to education, and humanities. Among EU-level studies, Reimer et al. (2008) find that STEM graduates have a lower unemployment risk than others.

The relative importance given to intrinsic, extrinsic rewards of a job - including social, altruistic rewards, power, money, and prestige - vary by gender (Hakim 1991; Beutel and Marini 1995; Johnson 2001; Konrad et al. 2000). While expected earnings are an essential component in the selection of a field of study, women are less influenced (Montmarquette, Cannings, and Mahseredjian 2002). Women value the non monetary aspects of jobs— security, flexibility—more than wages (Currie 1997; Zafar 2009). They might also see the work environments of otherwise desirable jobs as hostile for women (DiTomaso 1989; Heilman et al. 2004).

The more students graduate from university, the greater the differences in labour market opportunities for graduates from different fields. Prospective students take several of decisions with little information when they choose their field of study: they evaluate their dropout risk (costs), assess job opportunities (gains) and the future impact of technology. STEM fields are typically considered harder and with higher dropout rates (De Paola and Gioia 2012; Montmarquette 2001; Leppel 2001). Risk-averse students are more likely to enrol in either humanities or engineering, rather than in social sciences. In particular, apter students will apply to engineering, where dropout rates are more



elevated but so also are wages and job opportunities, whereas the less apt will gravitate towards humanities to be sure to finish (De Paola and Gioia 2012).

4.2 Social and cultural factors

The choice to pursue STEM studies is not only governed by expected economic returns, but also by **cultural norms and expectations** (Coleman, 1988). Social cognitive career theory (SCCT) hypothesizes that the choice of study is a function of the dynamic interplay between self-efficacy beliefs and environmental conditions (Lent et al., 1994). Beliefs determine whether a person will pursue an action, how much effort he or she will give to the pursuit, what are the chances of persistence in the face of obstacles and what will be the performance (Bandura, 1986). Someone with an interest in a particular career is unlikely to pursue that path if barriers to entry or advancement are perceived (Lent et al., 1996). Barriers include, for example, confidence in success, or chances to get student funding. Social factors to enter STEM programs specifically include influence from family, high school teachers, and friends; success in math and science at school; and interest in the career (Seymour and Hewitt, 1997). Parents are often unaware of the STEM labour market conditions (Jenkins and Pell, 2006). Those students who choose STEM programs based on personal interest are found more likely to complete than those who did so because of family influence (Seymour and Hewitt, 1997). With regards to engineering, students who do not drop out do so because they identify engineering with their sense of self, (Matusovich et al., 2010). Interest in STEM fields appears to decrease with development and the attainment of higher standards of living (Osborne et al., 2003). The ASPIRES project uses the concept of science capital to understand how pupils' aspirations are shaped. According to this project, most students like science but do not aspire to go on science careers. Science capital correlates with the level of interest, knowledge, and understanding of science, all of which depends on the environment. Increasing science capital can make a high-schooler more interested towards STEM so as to consider a future STEM career. It also hints that the most important factors that influence the pupils' aspirations lay outside the classroom. Accordingly, it is important to increase science capital although it is a complicated task that requires structural social changes. The alleged drop in popularity of STEM fields could be due to the growing opaqueness of modern technologies and the rise of the environmentalist movement (Winckler and Fieder, 2006).

As mentioned earlier in the report, **gender segregation** persists across STEM fields (Caprile et al., 2012). The lack of role models, discouragement from the media, gender differences in cognitive skills, and unpleasant experiences related to gender-bias in the classroom have all been cited as reasons to explain why women tend not to pursue a career in STEM field (Larki, 2014). The failure to effectively explain gender segregation has led researchers to focus on the childhood experience and "gender-essentialism" as



the explanation for the gap in fields of study (Charles and Bradley 2009). Childhood aspirations and evaluations tend to become more realistic as children get older (Ginzberg et al. 1951; Csikszentmihalyi and Schneider 2001; Tracey et al. 2005). Gender stereotypes emerge early on and develop throughout adolescence (Legewie and DiPrete 2014). Parents and educators tend to see girls as less qualified in math, which is perceived masculine, and to consider STEM subjects as less important for girls' (than boys') future path (Correll 2001; Eccles and Jacobs 1986; Eccles, Jacobs, and Harold 1990). Children and adolescents internalize these stereotypes, which in turn shape gender identities, and contribute to gender differentiation in study choice (Eccles et al. 1983; Ridgeway and Correll 2004; Ridgeway 2011). The education system, teachers, and peers tend to reinforce these stereotypes, giving support to gendered choices with regard to studies and career prospects (Sáinz et al., 2012). Early gender segregation hinders women's later study opportunities. Women may also perceive the university environments of male-intensive fields of study, such as engineering, as unpleasant (Ulku-Steiner, Kurtz-Costes, and Kinlaw 2000; Ecklund, Lincoln, and Tansey 2012). Female students succeed in female-intensive environments (Alon and Gelbgiser, 2011). Following the stereotype threat theory, Groups might be aware of stereotypes about women—and women may therefore avoid male-intensive fields, where stereotypes are more likely to emerge (Steele and Aronson 1995; Steele 1997). However, whereas gender is still frequently highlighted as a cause for the discrepancies in the STEM uptake, it is not the main barrier (IET, 2008). A career in science might have little appeal for either boys or girls, while a career in technology might have some appeal for boys. Adolescent girls, although they appreciate the technology, would rather like to have an identity that conveys late-modern post-material values, such as self-realisation, creativity and innovation, working with people and helping others (Schreiner and Svein, 2006).

4.3 Institutional factors

The way in which science is taught in schools also has an impact on students' attitude towards STEM and on their choice of study fields. There is a debate on whether STEM teaching should be organised in distinct subject areas or as a single, interdisciplinary program during later school years. Researchers in favour of interdisciplinary teaching argue that it motivates both teachers and students (St. Clair and Hough, 1992) and that it favours gender and social equality (Langen et al., 2006). Critics of this approach point at the difficulty to isolate the effect of integrated curricula from other variables (Eurydice, 2011). Among other aspects, an inquiry-based, project-centered approach to learning has been linked to greater motivation (Beres, 2011). The existing system is reportedly outdated, and lab-based science teaching should be integrated by out-of-school learning, for example with school trips in science centers, botanic gardens, zoos and science museums (Braund and Reiss, 2006).



Another frequently cited factor (Stephenson, 2000; Gago, 2004; ACME, 2007; Papanastasiou and Papanastasiou, 2004; Pollard et al., 2003; Osborne et al., 2003) that determines student interest in STEM is the quality of teaching, and the role of teachers in transferring STEM knowledge. To students, science is boring (Cerini et al., 2004), over-prescriptive (House of Commons Selected Committee on Science and Technology, 2002), and irrelevant to life outside school (Cleaves, 2005; Fensham, 2006; Lyons, 2006; Lindahl, 2003; Aikenhead, 2004; Reiss, 2004; Campbell and Keegan, 2000). Science is oft-quoted as “boring” because too many of the same topics are repeated over school years (Roberts, 2002; EMTA, 2002; NESTA, 2005), teaching leaves no room for creativity or critical thinking (Fensham, 2004), and there is a perception that whoever succeeds in STEM fields is a “geek” or a “nerd” (ACT2, 2001; Creative Research, 2000).

4.4 Interventions to encourage STEM uptake

Research seems to prove that interest in STEM subjects must be created and enhanced in primary and secondary school. At undergraduate level, interventions are needed to retain student and eschew lack of motivation to pursue a STEM career. Thus, research on the subject stresses interventions that can be done within different scopes and on different level with different targets.

The first step is to raise interest in subject that often are depicted by pupils as abstract and boring. As to this regard, inquiry-based learning, with a strong emphasis on practical experiences, experiments and connections with real world and technological problems is deemed fundamental by all governments’ teaching policies (Kearney 2016) together with a strong emphasis on socio-economic aspects of science. Inquiry-based methods enhance pupils to critically observe and examine facts notice and evaluate consequences also develops transversal skills like working in groups, problem solving, written and verbal expression.

Unsurprisingly, current research reveals also that one of the most important determinants of what students learn is the expertise and pedagogy of the teacher (Ragusa G., 2012). Thus improving skills of teacher and updating their knowledge and competencies is one of the primary concerns of governments’ intervention to rearrange teaching degrees in all European nations (Kearney 2016). Literature stresses also various psychological and behavioural aspect that must be addressed to avoid lack/loss of motivation in pursuing a stem career. Providing pupils with a clear insight of what a STEM career consists of can very helpful to capture their attention and curiosity and shape an interest in stem subjects. This should be done as earlier as possible in learning trajectories, best according to certain authors in the middle school. So STEM can be introduced through experiential learning using hands-on/real-world projects, classroom/lab instruction, speakers, on-campus field trips and workshops in different STEM fields of study (Burwell-Woo C., Lapuz R., Huang T., Rentsch N.P. 2015).



Improving pupils' self confidence and self efficacy at every stage of their career is not less important. This factors should be regularly monitored and reestablished through. The contribution and input of teachers, parents, mentors, counselors and peers. This has a deep impact on the level of self-efficacy and persistence in STEM (Charleston L., Leon R. 2016).

Specifically, at undergraduate and graduate level, significant literature points to the importance of mentoring to ensure individuals' professional success. Individual and small group mentoring is a very effective strategy to boost student's motivation and notably to regularly check their development and retain them in their stem learning trajectories. Graduate students report both psychosocial and instrumental benefits from their mentoring relationships (Wheless A., Blaser B., Litzler E., 2007).

The shaping of STEM identity through involvement in faculty activity seems also to have a remarkable impact on motivation and retaining students (Callahan J., Pyke P., Shadle S., Landrum R.E. 2014).

A considerable amount of surveyed articles also emphasizes the importance of extracurricular activities all along on pupil's path from primary school to universities. STEM extra-curricular activities inherently have a larger effect in increasing the amount of STEM pupils than additional focus in the classroom because they help students develop interests and allow them to gain the experience that is necessary for careers Garg S. (2015). Among extracurricular activities there are summer programs and summer camps that seem particularly fit to enhance and implement the concept of inquiry-based teaching and the connection between theory and its practical and technological applications. Summer programs are known to have many positive outcomes for students, such as bolstered confidence, retention in STEM majors with continuation into science graduate programs and careers, and socialization into the science research culture (Brown C., Russell C., Long H., 2010).

As to secondary school summer programs, learning experiences in informal STEM educational settings, such as camps, provide significant benefits for secondary students such as awareness of STEM subjects and careers along with increasing enthusiasm, self-efficacy, and content knowledge. Informal learning environments can result in increased achievement, self-efficacy, and interest in STEM along with encouraging students to pursue STEM careers. (Nite S.B., Margaret M., Capraro R.M., Morgan J., Peterson C.A., 2015). Participants indicate that most activities positively affected their interest in STEM subjects. Parents and guardians also reported that student subject-matter interest was noticeably enhanced following the camp. Results indicate that inquiry-based but non-mathematical STEM activities were most successful at stimulating interest (Douglas Dillivan K., Dillivan M.N., 2014).



Finally, literature also emphasizes some gender-specific interventions seemingly crucial for future pursuing of STEM career by girls: an early involvement of girls in STEM subjects since the middle school; more focused and intense form of mentoring, use of role models; working with families to promote STEM; focussing on specific groups of girls (Broadley, K., 2015). As to mentoring in particular, a paper of Irvin K., Hiteshue E., Lanzerotti M., Langley D., Martin R., Geselowitz M., Cerny C.L., Paul B., Chattopadhyay B. (2016) examined the result of an intervention where mentorship is provided to the students when they identify and interview leaders whose careers align with the desired career fields of the students. Koch M., Georges A., Gorges T., Fujii R. (2010) examined some structured interactions with IT professionals to encourage girls' IT fluency, interest in mathematics, and exploration of STEM careers. A mixed method, pre-post test design to evaluate the program revealed that even with limited interactions, girls' expectations of success and attitudes about STEM careers were influenced when they interacted with female professionals. Another study examined whether participation in the mentoring program and use of the online platform effects increases in the girls' confidence in their own STEM abilities, their self-assessment of STEM competencies, their self-assessment of knowledge about university studies and jobs in STEM, and their academic elective intentions. The results indicate an improvement of all four variables regarding girls participating in Cyber Mentor, whereas girls from the waiting-list control group did not show any increase. (Greindl T., Schirner S., Stoeger H., Ziegler A., 2013). Also intense contact with certain school where a group of girls is singled out for stem presentation and activities can be have positive outcomes (Gruenbacher D.M., Natarajan B., Pahwa A., Scoglio C., Lewis C., Mugira M., 2007).



5 Conclusions

This report presented an overview of the labour market for STEM skills in the European Union. It is the result of the activities under Task T2.1 “Analysis of Supply and Demand Side of STEM” of WP2 “Economic and societal dimension of science and technology”. A systematic literature review was undertaken to set a background for the research. Evidence was corroborated through further desk research of official statistics, policy reports and grey literature. Finally, a number of in-depth interviews to European employers have been carried out.

With regards to the supply, STEM students in the EU account for 27% of all tertiary education students. Engineering accounts for almost half of the STEM student population. However, STEM programs are consistently less popular among women. Gender segregation persists across STEM fields, and nowhere in the EU are STEM programs attended by more than one-fifth of the female student population. An exception is Life Science, where women are the majority. The literature identifies a number of economic, social and cultural factors to explain why students choose a particular field of study. The way in which science is taught in schools has also an impact on students' attitude towards STEM and on their choice of study fields.

With regards to the demand, employment for STEM skills accounted for 9% of the total employment in the EU. It has grown from previous years, and this expansion is forecast to continue over the next decade. In the period 2015-2025, there will be around 8.2 million STEM jobs openings in the EU. However, future growth in STEM employment is likely to be unevenly distributed across occupations and EU Member States. In general, the outlook for the future STEM industry in the EU as a whole is complex. The skills profiles of STEM workers will need to adapt on the developments and trends of the industries they work for. In addition to industry-specific trends, a number of cross-sectoral factors could further shape the demand for STEM workers. Finally, many of the STEM job openings in 2025 will merely be a consequence of replacement demand.

This report allowed to better understand the actual and future market conditions for STEM skills in the EU. In this sense, it represents an input for the rest of WP2, and for the project as a whole. This report will be presented and validated during a workshop with relevant stakeholders, under T2.2 “Development and validation of the scenarios and trends”. In parallel, further desk research is being carried out under T2.3 “Definition of educational profiles addressing the labor market needs”. Findings from this report will be compiled in the latter, with the aim of identifying educational profiles to meet STEM occupations, in line with projected employment growth on the basis of an objective review of the data gathered this far.





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APPENDIX

Interview guidelines

THEME I: ABOUT YOUR COMPANY

- Do you currently employ people with STEM-related degrees and qualifications in your company? What are their main roles (e.g. managers, technicians, professionals)?

THEME II: SKILLS

- The demand for people with STEM qualifications is closely linked to the skills that they bring to the workplace. Employers typically welcome capabilities in active learning, critical thinking, complex and creative problem-solving, all of which correlate closely with STEM qualification based skills. To what extent are these skills important to your company?
- What other skills and attributes are important to your company?
- As a whole, do you consider the skills of your workforce adequate? Do your employees lack certain skills (e.g. IT literacy, numeracy, foreign language skills)? Do you provide remedial training?

THEME III: RECRUITMENT

- What do you look for when you are hiring new staff (e.g. attitudes, past experience, degree subject, university name, foreign language skills...)? Do you actively seek for people with STEM degrees? Which STEM subjects do you find more important for your company? Is there any particular degree that suits your company better?
- Have you encountered difficulties in recruiting STEM-skilled? If so, which problems do you encounter? (E.g. shortage of supply, lack of workplace experience, non-relevant degree, wrong attitude, lack of interpersonal skills...)

THEME IV: APPRENTICESHIPS

- Is your company involved in apprenticeships programs? How does it work? What kind of training do you provide? (e.g. basic, advanced...)
- (If yes) Despite the current economic pressures, do you plan to maintain or increase investments in training over the coming year? What do you think are the main barriers to overcome in order to promote the success of these programs (e.g. more guidance on how to make work experience worthwhile, less onerous requirements, reduce bureaucracy around government financing, etc.)?

THEME V: SCHOOLS AND UNIVERSITIES



Higher education institutions

- Strengthening links between universities and business has the potential to enhance economic growth. Businesses look to higher education to develop people with the right knowledge and skills to meet their future needs. Has your company developed links of some type with universities (e.g. for internships, graduate programs, R&D partnerships)? Are you looking to grow these ties with universities in the future? Do you provide some kind of specific projects or resources to help students understand the practical relevance of their courses?

Schools

- What happens in schools is equally important for the future of our economy and society. Has your company built links with secondary schools or further education colleges in the past 3 years? What kind of programs or collaborations do you share (e.g. career advice, work experience for pupils, curriculum development)?

THEME VI: FUTURE DEMAND

- Over the next 3 to 5 years, do you expect to hire more (or less) staff with higher-level skills?
- As reported by the literature, while employers are confident there will be enough people available to fill their low-skilled vacancies, the same is not true for the demand of high-skilled employees. How confident are you in being able to recruit high-skilled employees in the future?
- Government can help tackle future STEM skills supply shortages, for example by promoting science and maths in schools. Which actions do you think the government should take to encourage the study of STEM disciplines? (e.g. more apprenticeships, financial incentives, closer ties with business...)
- Is there anything else we should discuss regarding the topics we have addressed at this point?

Concluding question

Of all the things we have discussed today, what would you say are the most important issues you would like to express about the future demand for STEM skills?