



European
Commission

Policy Brief

Mind the Science and Technology Skills Gap

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'The human capital is the most precious of all the capitals'³

Summary

This policy brief shows new evidence on the causes of the S&T skills gap in European regions. It highlights that the S&T skills gap is mainly due to shortages of capabilities that are crucial to support the innovation and growth of firms and the other actors of the regional system, including university and government. From these findings, ad hoc policy implications upon the development of innovation capabilities and skills for the European Research Strategy and Innovation agenda are proposed and future research issues identified.

Introduction

One of the challenges Europe is confronted with in its aim of emerging from the crisis and renewing its economy to ensure sustainable levels of growth and employment over time, is to adapt the skills of its people. In a fast-changing world with the transition towards a knowledge-based economy, workers need to adapt their skills, be flexible and innovative. By 2020, 20% more jobs will require higher level

skills⁴ and reforms are urgent to match this demand and guarantee European industry competitiveness in the years to come. Paradoxically, at a time of record levels of unemployment, particularly affecting its youth, Europe is already showing signs of skills shortages, particularly technical and high level skills⁵. In this context, there is no surprise that

¹ The authors acknowledge comments from Pietro Moncada-Paterno-Castello and Sandro Montresor regarding previous versions of the Policy Brief.

The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

² This Policy Brief is based on Maria Del Sorbo's PhD thesis titled: 'Competencies and capabilities: minding the Science and Technology gap in the Campania region. The role of universities and firms' association'(2010); also in: 'A gap in competencies or in capabilities? The role of regional universities in developing scientific and technological skills in Campania' in co-authorship with Prof. Nick von Tunzelmann submitted paper to Environment and Planning A (2013)

³ Marshall, 1890, 1922

⁴ European Commission, 2012

⁵ Average of youth unemployment in Europe (2013) is 23%, and 56% and 62% in Spain and Greece respectively. At the same time, there are more than two million vacancies. Chief Executives of some of Europe's biggest manufacturers have warned about the current and prospective lack of engineers in Europe (article in *Financial Times* 'Alarm over skills shortage in Europe', 26 May 2013). Quotes from Commissioner Vassiliou's opening speech at the 5th European University-Business Forum, 4 June 2013

the problem of skill mismatch in Europe⁶ has drawn the attention of policy-makers, as reflected in the Europe 2020 strategy for growth and jobs⁷ and relevant initiatives, such as the 'New Skills for New Jobs' flagship.

The role of human capital as a key production factor that contributes to the development of new ideas leading to improved or new products, services and/or processes is widely recognised in economic and business literature⁸. However, and as it happens with other intangible assets contributing to business innovation (R&D, design or organisational know-how), the empirical evidence, helping to quantify the impact of human-related investments, such as training in company performance and value, is still scanty⁹.

In the analysis of human capital and skills as intangible assets contributing to innovation and to company performance, three issues make the task particularly difficult: first, the concepts and definitions used to analyse human capital and skills in the context of innovation are not sufficiently developed and precise; second, there is no suitable and standardised methodology; third, the lack of fit data for analysis. One shortcoming, for example, is that human capital is generally measured and tested through the level of formal education, obviating the important role of on-the-job training and other types of informal skills upgrade and learning, including firm-specific training through which specific skills are re-shaped in order to prepare employees to perform new tasks required by their innovation activities.

In this policy brief we look at the issue of skill mismatch, focusing on the skills shortages and skill gaps most likely affecting firms operating in technology and research intensive sectors: the science, technology, engineering and mathematics (STEM) related skills. For this purpose, we first present in section 2 a novel analytical framework to analyse STEM-related

skills by disentangling the concepts of competencies and capabilities and by establishing a bidirectional model where university and firm are considered to interact with each other in supplying and demanding geographically-located competencies and capabilities. Then, we present in section 3 a practical implementation of such analytical framework to study STEM skill gaps in a concrete region which provides empirical evidence on the important role that firms, interacting with local universities, can play in addressing the problem. From these contributions, we raise in section 4 some relevant policy questions and propose further research avenues to support policy-making in this area.

Disentangling competencies and capabilities and their supply and demand

Depending on the nature of the innovation project and the stage of the innovation cycle (from basic research to market launch), leading innovative firms must find the most suitable blend of skills and capabilities, some existing already in the firm and others new to the firm¹⁰. For example, scientific, technological, engineering and design skills may be combined differently according to the type of innovation such as product, process and/or organisation.

As labour markets are very often characterised by imperfect information¹¹ and high search costs, finding employees who match their needs to carry on successful innovative projects is not an easy task for firms. One critical element is the ability of the education system, including vocational education and training systems, to respond to this demand by imparting to graduates the necessary knowledge and skills. But also crucial is that firms play their part by investing adequate resources in specific training to accomplish the alignment of employee skills (both existing and new ones) to the type of innovation they pursue. In this context, the analysis of skills shortages and gaps for innovation requires going beyond a simple scheme of supply (from the education system) and demand (from companies) and to look at interactions between the different actors: firms, universities, governments, and gatekeepers¹², such as firms associations¹³.

⁶ Research on the issue of skill mismatch in Europe is being carried out by CEDEFOP. For an overview, see Briefing Note: 'Skill mismatch in Europe', June 2010

⁷ The EU has called upon Member States to 'promote productivity and employability through an adequate supply of knowledge and skills to match current and future demand in the labour market' and to improve the performance of education and training systems at all levels 'to ensure the acquisition of the key competencies that every individual needs for success in a knowledge-based economy'. Guidelines 8 and 9 of Europe 2020 Integrated guidelines for the economic and employment policies of the Member States, COM(2010) 193 of 27.04.2010

⁸ Bayo-Moriones *et al.*, 2008; Becker, 1994; Beugelsdijk *et al.*, 2006; Boothby *et al.*, 2010; Cabello-Medina *et al.*, 2011; Côté, 2001; Demarest, 1997; Du *et al.*, 2007; Leonardbarton, 1992

⁹ Ciriaci, 2011a, b; Ciriaci and Hervas, 2012

¹⁰ Lawson and Samson, 2001

¹¹ Acemoglu, 1997

¹² Gatekeepers are tasked with facilitating the relationships between the bridging activities of firms and universities

¹³ Lambert, 2003

This is what the so-called Capabilities and Competencies Framework (CCF) for STEM skills gaps attempts to do. In this analytical framework, capabilities and competencies are disentangled (see box 1 and table 1). At the most basic level, competencies mainly relate to enhancement of resources, while capabilities to enhancement of functions. In this sense, competencies could be seen as an output of formal education whilst capabilities would be shaped through wide and deep relationships nurtured mainly by the enhancement of services, learning by doing, specific non-transferable skills, knowledge development accumulated within the organisation, realised activities, and a supply/demand-driven approach. At this point through the dialogue between university and firm, mutual needs are identified and satisfied only thanks to shared solutions¹⁴. In this framework, formal and vocational education contributes to the competencies and capabilities building throughout training and the upgrading of company skills. To give an example, when hiring new staff an enhancement of resources is achieved, i.e. competencies; while investment in training produces an enhancement of services, i.e. capability-building, because of the knowledge accumulation developed within the firm's environment¹⁵.

Box 1 A Capabilities and Competencies Framework (CCF) for STEM skills gaps

The concept of 'capabilities' in this framework is based on Amartya Sen's definition of consumer capabilities¹⁶. Here the definition is extended to include producer and supplier capabilities. Following Sen's taxonomy, producer capabilities would be constituted by the set of production resources which comes bundled with its own specific set of characteristics (so-called 'functionings'). In a dynamic perspective, the capabilities must evolve to respond to continuously changing consumer/producer needs. In the context of human capital and skills, competencies include the pre-set attributes and skills of individuals recruited by the firm, while capabilities are the result of the adaptive learning process of these individuals acquired as workers of the firm.

¹⁴ Malerba, 1992; von Tunzelmann, 2009, 2010; von Tunzelmann and Del Sorbo, 2013

¹⁵ For example, the International Union for Quaternary Science (INQUA) in 2013 created a scheme for the skills enhancement of its member scientists. This scheme aims at supporting scientists with insufficiently developed networks by bridging networking, exchanging information, training and connecting people in order to stimulate new international focus groups or projects. See <http://www.inqua.org/formsSkills.html>.

¹⁶ Sen, 1990, 1997; Sen, 1999

The table below attempts to differentiate the specific characteristics of capabilities from those of competencies in relation to various dimensions. The distinctions in the first half of the table can be deemed as 'essential', with the first six regarded as 'static', while rows 7 and 8 relate more to dynamic competencies and capabilities. The remaining rows, from 9 onwards can be thought of as 'associated attributes'.

The Capabilities and Competencies Framework (CCF) for STEM skills gaps is set on a supply-supply/demand-demand model which highlights the importance of interactions between the different actors and, more particularly, between the firms and universities (see Box 2). The matching of supply and demand skills, from both universities and firms, would be easier if each part manages to develop and exchange a clearer vision of how competencies and capabilities are combined. This framework considers not only the flow of students and graduates between university and firms, through internships for instance, but also the exchange of professors and professionals in performing tasks. This results in employing academic knowledge into participating firms, providing specific firm-competency courses to the university.

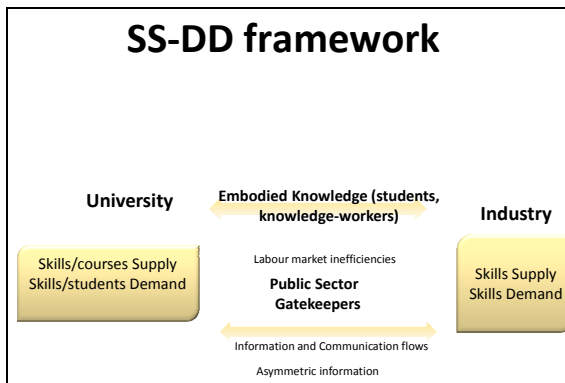
Through established relationships, the university and the firm can exchange their knowledge flows to explore and exploit new business/research opportunities. Knowledge flows, in order to work, need the support of suitable communication flows to gather the relevant information and detect asymmetric ones. The proposed competencies and capabilities approach attempts to assist the knowledge/skills production of universities and firms and their linkages, which play a crucial role in skills alignment.

Table 1 Characteristics of competencies versus capabilities

	Competencies	Capabilities
1. Function	Enhancement of resources	Enhancement of services
2. Stocks	Human and R&D capital stocks	Knowledge stocks
3. Chain position	Inputs related	Outputs related
4. Product area	Specific, focused	General, adaptable
5. Supply/demand	Supply driven	Demand and supply driven
6. Stage	Potential	Realised
7. Development	Acquired and hired	Accumulated within
8. Learning	Learning by searching	Learning by doing
9. Asymmetries	Of information	Of knowledge
10. Skills	Generic, transferable	Specific, non-transferable
11. Breadth	Relatedly simple	Relatedly complex
12. Depth	Cognitive complex	Cognitive simple
13. Reasoning	Logic	Nous
14. Time location	<i>A priori</i>	<i>A posteriori</i>
15. Appropriation	Appropriate	Appropriable
16. Spread	Diffusion by information	Diffusion by demonstration

Source: von Tunzelmann, from multiple secondary sources (see text in von Tunzelmann, 2009)

Box 2 A Supply-Supply/Demand-Demand Approach



The above SS-DD framework graph shows the bidirectional relationship between University and Industry, in which both sides supply and demand skills. On the one hand, firms demand generic skills from universities: graduates and professors who provide new business/research ideas (knowledge workers). At the same time, firms supply for skills through specific training to re-skill/up-skill their employees. On the other hand, universities supply skills through their education activities and demand students and professionals. To complete the picture, the students are willing to attend courses and graduate (they actually demand courses and the supply of skills once graduated); while professionals are willing to transfer pragmatic and tacit knowledge (business cases studies).

In this scenario public sector and gatekeepers play a crucial role in creating those framework conditions in order to support universities, firms, and students in building stable bi-directional relationships. The public sector should provide *ad hoc* measures to facilitate and support the networking and knowledge transfer process, and to remove labour market inefficiencies and asymmetric information. Gatekeepers should provide suitable communication and information channels to assist all the actors involved.

Analysing the stem skills gap at regional level – a case study

An example of how to obtain concrete empirical evidence about the STEM skills gap and how firms react to it is provided by a recent study based on interviews with firms and universities in Campania, an Italian Southern region (see Box 3). In this case study, the Capabilities and Competencies Framework (CCF) for STEM skills gaps presented in the previous chapter, has been applied.

The analysis of skills shortages and gaps at regional level can be very useful as very often it is at the level of the regional innovation system that interactions between industries and universities take place. One fundamental question to answer is: what are the STEM skills required by firms (not just now but also, and more importantly, in the foreseeable future)? In order to answer this question, it is key to take into account not only the specific needs and characteristics of the firm (analysing what strengths and opportunities they have) but also the regional context in which it is located (what strengths and opportunities the region offers)¹⁷.

Box 3 Methodology and research questions

The methodology was based on the Qualitative Comparative Analysis (QCA) developed by Ragin¹⁸ implementing the tool for small 'n' analysis developed by Cronqvist¹⁹. The QCA is a strategy combining both qualitative (and case-oriented) and quantitative (or variable-oriented) approaches and has been used to unveil the complex causal conditions of the skills mismatch. The QCA recognises the presence and/or absence of a set of causal conditions, generating a significant outcome at social and scientific levels and allowing comparisons between the similarities and differences of 'a limited set of comparable cases'. Thus, it can be seen as a powerful tool able to recognise different patterns leading to an outcome useful for supporting policy advice and for post experimentation/policy intervention.

The research questions were the following:
Does the STEM skills gap in Campania reflect a deficiency in competencies or capabilities? And if so, what? Also, what is the role of universities and firms associations? And additionally: should universities supply more generic/transferable or specific/vocational skills?

The interviewees were general directors and/or those responsible for the education sector in the provincial organisation of Confindustria in Avellino, Benevento, Caserta, Naples and Salerno. The selection of cases utilised snowball techniques and includes STEM university officers and professors (depending on their role), and industry representatives. The firms associations have been chosen as the unit of analysis of the business side because of their representative

¹⁷ Iammarino *et al.*, 2008; Lawson and Lorenz, 1999; Lundvall and Johnson, 1994

¹⁸ Ragin, 2000, 2007; Ragin *et al.*, 1984

¹⁹ Cronqvist, 2009

business role. Thirty-two interviews were held face to face, eight on the business side (collected from the six firms associations) and twenty-four on the University side (Parthenope University of Naples, University of Naples 'Federico II', University of Salerno, Second University of Naples and University of Sannio).

This study looked, on the one side, at the demand of STEM skills in Science and Technology by the firms, and, on the other side, at the supply of STEM skills by the University²⁰. Universities and firms seem to have different cultures, incentives, approaches and scopes. Yet, firms tend to be determined to increase their interactions with universities to grow in terms of innovation, as they believe that enhancements of resources and services coming from universities are auspicious in improving company performances.

The investigation shows that the STEM skills gap is not clearly a deficiency just in competencies (as defined in the analytical framework presented in the previous section), but more so in capabilities and in the links between the two. On one hand, firms do not always know what universities can offer in terms of supporting their innovativeness, so they look at technology transfer as the way to source competencies and capabilities from outside the firm. On the other hand, at times universities and firms may engage in collaborative projects as a way of accessing public funding, rather than as a way to facilitate innovation. Besides, the results show that STEM universities are trying to realise better interactions with industry but that it is still left mostly to the personal relationships of professors (e.g. the dean of the department or head of the technology transfer and/or placement office).

Considering whether universities should provide general and more transferable skills or instead more specific and industrial skills may help to solve the skills gap. At this end, the study shows that firms seek specific/vocational skills (capabilities) to be exploitative in the short-medium term; and generic/transferable skills (competencies) to be explorative in the long-term (ref. box 1 in section 2). Furthermore, the professors argue that they themselves provide both generic and specific skills as part of the education and training offered to students by the Science and Technology faculties.

The Campania case showed that those universities realising planned joint activities and

those having more developed relationships with firms, where each plays an active role, were the ones able to 'mind the skills gap' by raising competencies, capabilities and their interactions. On the other hand, the universities 'not minding the skills gap' were those associated with unilateral relationships with business, either supplying or demanding skills.

Likewise, firms associations have been acting as gatekeepers between universities and firms. Although firms have been trying to increase interactions with the university to grow in terms of innovation, only half of the firms associations managed to mind the S&T skills gap whilst the other half still needs to invest more resources in order to tackle the issue. The need for capabilities becomes evident from the fact that there is almost no trace of bidirectional knowledge flows from business to university and vice versa as there is a relationship based on demand (so named when there is a funding opportunity detected and initiated by one of the two) in order to exploit mutual funding opportunities.

The degree of relationship development between university and firms determines the competencies and capability building in a way in which the more developed and wider the relationship, the higher the presence of capabilities seen as established relationships between the two agents. Therefore, University-Industry (U-I) joint projects tend to be more specialised but variegated, rather than too generic, repetitive or just building marginally upon previous joint U-I realised projects. Therefore, the creation of a bidirectional supply chain of STEM skills between firms and universities, by facilitating regular interactions and supporting the allocation on both sides of appropriate human and economic resources dedicated to this task, would be beneficial in addressing the STEM skills gap in the region. A way forward would be to devise specific policy measures to induce, reinforce and consolidate the required positive interactions for the achievement of U-I joint projects and the development of efficient skill supply chains.

Finally, the evidence shows that the Campania region has several robust and wealthy industry sectors on which firms could boost their investments and concentrate on the development of specific skills for innovation: agro-food, Information and Communication Technology (ICT), engineering and aerospace. In this respect, ad hoc skills that support measures adapted to the region's strengths would be very beneficial. Some examples already exist in the region, such as the joint educational programme in rail engineering co-developed by the

²⁰ Certainly, there are other agents in the labour market, such as the public sector demand of skills, and the education system supply for skills

University Federico II of Naples and firms. This could be taken as an example of good practice to be shared with other lagging regions in the context of the regional innovation smart specialisation strategies (RIS3) process.

Conclusions – how policies can help firms to address the stem skills gap?

In order to effectively address the challenge of increasing the STEM skills gap to boost the future competitiveness of the European industry, a better understanding of the skills involved (competencies versus capabilities) and of the role played by the key actors (firms and universities) is needed. This forms the main argument of this policy brief which offers **a novel analytical framework** that could support firms, universities and policy-makers in properly identifying and supplying the specific skills required for developing and exploiting the growth and jobs potential of the more promising high knowledge intensive sectors (such as the eco industry, and the ICT and healthcare sectors) where significant skills shortages are generally reported in Europe²¹.

In the context of national and regional innovation systems, policies can play an important role in supporting the required stable relationships between firms and universities, as well as with other relevant actors (such as governments, industrial and labour associations). Beyond a better design of programmes to support University-Industry projects, exploiting the competencies and capabilities analytical framework would help policymakers to put in place adequate incentives for each group of actors to assign the necessary human and financial resources to play their roles in the supply of innovation skills. In performing such a role, **industry and universities should be encouraged to establish regular interactions in a truly bidirectional supply chain of STEM skills.**

When considering the design of support measures to the specific contribution of firms in addressing the innovation skills gap, policymakers still need more information and empirical evidence about the main drivers and barriers of firms' training activities. First, a shared definition of skills and capabilities is needed in order to deal with data classification. Second, the measurement of human capital and skills is still very challenging since the level of

education and/or qualification only seizes some features of human capital without identifying certain types of skills. In fact, this may be the cause of the mismatch between qualifications and jobs. **In order to conduct focused analyses on skills and capabilities ad-hoc surveys should be carried out.**

One source of company data to be further exploited is the Community Innovation Survey (CIS). Previous research on CIS data (2006 edition) carried out by the Joint Research Centre of the European Commission showed the positive impact of firms' training activities on its innovation performance (measured in terms of share of innovative sales)²². **The 2010 CIS edition**, expected to be released in the second half of 2013, **includes data related to skills and creativity** from which it may be possible to identify the skills accumulated within the firm, or obtained as external sources. This can bring insights on: a) the type of skills that impact on innovative sales, such as engineering/applied sciences or design, multimedia and so forth; b) what are the skills nurturing innovation in terms of product and process, and/or in terms of marketing and organisation innovation; c) what are the most successful techniques in order to develop new ideas and enhance creativity. **On the basis of improved knowledge of what skills are relevant for firms' innovation, specific support to the firm's concrete training activities could be envisaged.**

Finally, and in a broader policy context, establishing an open dialogue platform within the government, with the participation of industry and university representatives, may support the decision-making process. At national level, the ministers responsible for science policy may be encouraged to interact with the ministries of industry and employment to increase awareness of the profound changes occurring in organisations and firms in order to create synergies and avoid duplication. In the EU context, where **education and employment policies** remain largely the competence of Member States, additional measures to **strengthen coordination** and promote possible co-regulation on specific educational aspects (such as vocational and continuous company training for innovation) should be considered.

²¹ Commission, 2013, p. 9

²² See Ciriaci, 2011b

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Abstract

This policy brief shows new evidence on the causes of the S&T skills gap in European regions. It highlights that the S&T skills gap is mainly due to shortages of capabilities that are crucial to support the innovation and growth of firms and the other actors of the regional system, including university and government. From these findings, ad hoc policy implications upon the development of innovation capabilities and skills for the European Research Strategy and Innovation agenda are proposed and future research issues identified.

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