BEYOND 4.0

Understanding future skills and enriching the skills debate

Deliverable 6.1 – 3rd report

Final version

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Document description

This 3rd report of the Deliverable 6.1 builds on the framework for future skills and the skills categorisation developed in the 1st and 2nd reports of the Deliverable 6.1. The report focuses on empirical results of the Beyond 4.0 project on the topic of skills within the digital transformation. It draws from the range of empirical data collected during the qualitative research undertaken in Work Packages 4 and 8 of the BEYOND 4.0 project by identifying illustrative examples exemplifying the impact of digitalisation on the five categories of the aforementioned skills categorisation, presents and discusses the findings along the lines of skills demand and skills supply-sides issues, and accordingly, presents a number of recommendations for policymakers.

Keywords: skills, digital transformation, future of work, skills demand, skills supply, skills debate, interacting skills

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Content

Executive Summary

The digital transformation of the economy yields great opportunities but also presents challenges for European societies. Like previous phases of technological change, digitalisation is characterised by new skill requirements for employees, managers and job-seekers. At the same time, new ways must be found to teach these in-demand skills. This report aims to provide insights into what skills are needed in the digital age. Based on the skill categorisation presented in the earlier Deliverable 6.1, empirical results of the BEYOND 4.0 project have now been evaluated regarding skill demands (see Section 4). In a further step, findings on the supply side are presented. To understand the skill gaps of the workforce, the skill requirements from companies are then compared with existing skills provided by the education and training systems (see Section 5). This analysis aims to understand better future skills needs (mainly at the level of regional ecosystems) and how education and training systems can adapt to cope with the skills requirements arising from the digital age.

Methodological approach and data sources

The report is based on a general skills framework, which covers skills demand and supply and serves as a basis to compare demand and supply sides to identify future skill imbalances arising from the digitalisation of work. To further examine the skills demands of the digital age, a categorisation of skills was developed in earlier reports of Deliverable 6.1. The categorisation includes newly emerging skills and skills that are becoming increasingly important in light of digital transformation. The categorisation distinguishes between four transversal skill categories: digital skills on the one hand and personal, social and methodological skills (taken together, also described as non-digital skills) on the other. In addition to these transversal skill categories, job-specific skills related to concrete working tasks play a critical role. This final report of deliverable 6.1 draws from the range of empirical data collected during the qualitative research undertaken in Work Packages 4 and 8 of the BEYOND 4.0 project by identifying illustrative examples exemplifying the impact of digitalisation on the five aforementioned skill categories.

The empirical analysis considered in this report covers six countries and eight regions: Germany (Dortmund and Duisburg), Finland (Salo and Oulu), the UK (the West Midlands), Bulgaria (Sofia), Spain (The Basque Region) and The Netherlands (Noord-Brabant). In all regions, the views of various experts, including stakeholder groups such as employment agencies, representatives from government and the public sector, universities, research and other educational institutions, established companies as well as start-ups, were gathered to explore the implications for skills resulting from the impact of digitalisation on work. In this way, in-depth insights about the demand for skills, resulting from the digital transformation, were sought from company representatives (both managers and employees) and other key stakeholders. These insights reveal how well (or otherwise) the supply side is responding to the demand for skills and how companies and other stakeholders are dealing with any identifiable shortcomings in the responsiveness of education and training systems.

Skills Demand

Regarding the individual skill categories, findings drawn from the empirical material confirmed the need for digital skills, current and newly emerging job-specific skills, and non-digital transversal skills. To summarise, the experts consulted during our research identified the following key issues:

- ***Digital skills*** are of high importance in all of the regional ecosystems and countries considered, where the demand for digital skills is increasing for jobs at all skill and/or qualification levels. In many cases, the skill requirements are barely being met, so the demand for digital skills often outweighs the supply of workers who already possessing these skills. However, as suggested in the BEYOND 4.0 skill categorisation, a distinction needs to be made between basic, moderate and advanced levels of digital skills. It became apparent that, while basic digital skills are a prerequisite for virtually all occupations or qualification levels, advanced digital skills are required primarily by highly qualified workers in ICT-heavy professions and companies that have adopted emerging technologies such as automation, AI and sophisticated data analytics.

- ***Personal skills***, such as adaptability and self-organisation, while always necessary to a more or lesser extent, are also gaining importance because of the digital transformation. The empirical findings make it clear that the world of work is becoming even more fast-paced due to digitalisation. Employees must constantly familiarise themselves with new digital tools, programmes and systems. As a result, the need for workers to engage in lifelong learning is more important than ever.

- Empirical findings show that the demand for ***social skills***, such as teamwork-related skills and communication skills, has also risen sharply. This rise in demand for social skills is connected to an increasing exchange between different professional groups, who may all be involved in using the same technologies, tend to have different communication cultures. The findings suggest that due to changing organisational structures, more interdisciplinary project-based work is being done in teams, so more advanced communication skills are needed, especially in more highly skilled occupations such as those working in jobs at the 'digital frontier'.

- ***Methodological skills*** are also gaining importance in the course of digitalisation. The empirical examples illustrate that methodological skills, such as critical thinking, problem-solving, and creativity, are essential in the digital age. In addition, basic skills such as language proficiency, numeracy and literacy are also in demand for less skilled jobs at lower qualification levels, as these skills are the foundational prerequisites for the formation of digital skills, and lifelong learning in general.

- While job-specific skills are not considered as relevant for the digital transformation in literature, the empirical results from the different regions in WP4 and WP8 confirm that **job-specific skills** will remain important in digital transformation. Against the backdrop of a changing world of work, experts emphasised that knowledge of job-specific processes was crucial, making it vital that workers continually update their job-specific skills to keep abreast of technological change in their respective fields.

One of the most important findings of the empirical evaluations on skill demands is that it is not only individual skill categories that are in high demand. Rather, combinations of different skill categories are often needed in the labour market - whereby these are primarily combinations of digital skills and another non-digital skill category, so to speak, demand for *"digital skills plus X"* skills. While not a term used in the existing literature, this report refers to these as *interacting skills*. In this sense, different combinations of the various skill categories interact in order for workers to perform the individual tasks within their jobs. Furthermore, as new digital technologies permeate a rising number of jobs and tasks, combining digital skills with job-specific skills is becoming increasingly important. In addition to digital and job-specific skills, the report provides examples from the empirical evidence highlighting the importance of other skill combinations. Namely, digital and methodological skills, digital and social skills, and digital and personal skills. The research confirms the value of looking at the interaction of skill categories, rather than merely focusing on single categories of skill. By shifting from a siloed approach, provides additional insights about the impact of digitalisation on work.

Skills Supply

With regard to the supply side, and thus in relation to the question of how skills can be developed, initially it became apparent that national policies on digital skills existed in all countries featured in the empirical analysis. Concerning digital skills in particular, however, it becomes clear that national educational and training systems are reacting too slowly to meet the emerging skills needs of companies. At this point, the empirical findings show that it is often internal company training measures, as opposed to the formal education and training system in the respective country, that equip employees and managers with the skills necessary for digitalisation. At the same time, training that adopts a more holistic approach to impart the essential interacting skills is, to date, also mainly provided in-house by companies. This was more evident in larger companies, because they are more able to dedicate more resources to training than smaller companies. Among others, methods such as work-based learning or project-based training are being used by larger companies to address skills gaps related to interacting skills. While such in-house teaching of skills is considered important for digital transformation, it may threaten an inclusive approach to growth. This is because an in-house approach risks excluding disadvantaged labour market groups such as the long-term unemployed and new immigrants. To a lesser extent, it may also mean that workers who are not employed in large companies may not be afforded the same opportunities to develop their skills as their counterparts who are employed in large companies. Therefore, it is essential that training measures that impart the necessary interaction of skills also occur outside of companies.

It was reassuring, however, to find current examples from Finland and the Basque Country where different stakeholder groups are working together in a region to co-develop and deliver relevant interacting future skills training. These approaches come close to the envisaged concept of a well-functioning regional skills ecosystem, where it is possible to be more responsive to skills demand issues at the regional level when the relevant stakeholders work together to co-design initiatives that meet the skill needs of regionally-significant sectors.

Recommendations

Based on the findings of this final version of Deliverable 6.1, it is recommended that the concept of a regional skills ecosystem should be reviewed concerning the possibilities of systematic and far-reaching implementation of interacting skill categories. There are also examples of reforms in the education system (e.g. Finland) and a shift in emphasis towards project-, problem- and work-based learning and training that should be considered by the EU and member countries. Furthermore, the systematic implementation of interacting skills in companies, the provision of transferable interacting skills in the regions, and the consideration of interacting skills in the respective education and training systems are recommended.

List of abbreviations

AI – Artificial Intelligence

CEDEFOP – European Centre for the Development of Vocational Training

COVID-19 – Coronavirus Disease

D - Deliverable

DigComp – European Digital Competence Framework for Citizens

EPSC – European Political Strategy Centre

ESSA – European Sector Steel Alliance

ETHAZI - "Etekin Handiko Zikloak": High performance training cycles in the Basque Country

EU-LFS – EU Labour Force Survey

EWCS – European Working Conditions Survey

FE – Further Education

HE – Higher Education

ICT - Information and communications technology

ILO – International Labour Organization

IoT – Internet of Things

ISCO – International Standard Classification of Occupations

IT – Information technology

IVET – Initial Vocational and Educational Training

NACE – Statistical Classification of Economic Activities in the European Community

NHS – (UK) National Health Service

NUTS – Nomenclature of Territorial Units for Statistics

OECD – Organisation for Economic Co-operation and Development

OEM – Original Equipment Manufacturer

PES – Productive, Expandable and Social (Green's PES concept of skills)

PIAAC – Programme for the International Assessment of Adult Competencies

UK – United Kingdom

VET – Vocational Education and Training

WP – Work Package

List of figures

List of tables

1. Introduction

The debate about the future of work has shifted away from the 'death of jobs' scenario to acknowledging that tasks will change within existing jobs along with job destruction and creation (Warhurst et al., 2019, p. 32). So, as new technologies are introduced into workplaces, workers will need new combinations of skills to perform these tasks. Understanding these skills is essential so that, at the very least, appropriate education and training provisions can be designed and delivered (Warhurst et al., 2019, p. 32). To this end, digitalisation has been identified as one of the critical drivers of changes in skills requirements. It has been established that current and future jobs will require new and/or more advanced digital skills.

As highlighted in the BEYOND 4.0 concept paper (D2.1), any understanding of the future of work needs to examine the impact of the new digital technology on skills and how the supply and demand for skills, mainly digital and specialist IT skills, are changing. Indeed, the European Commission believes that ***'the future of work is all about skills'*** (EPSC, 2016, p. 7)**.**

The OECD, for example, has identified two main aspects where increasing the use of digital technologies at work is increasing the demand for new skills, including: *specialist digital skills* to programme, develop applications and manage networks and *generic digital skills* to use such technologies for professional purposes (OECD, 2016c). Change resulting from digitalisation means a rising demand for workers who can code, develop applications, manage networks and analyse Big Data(OECD, 2016b). However, digitalisation also calls for all workers to have a relatively high minimum level of digital skills, even those workers in lower-skilled jobs. For example, this is the case for blue-collar workers in factories that are entirely automated or waiting staff in restaurants taking orders on tablets (such as iPads) (OECD, 2016b).

Jobs requiring more intensive digital skills also require a range of *digital-complementary skills* to perform new tasks associated with ICT usage, such as technical, professional and other occupation-specific skills, a solid level of information-processing skills (e.g. literacy and numeracy), as well as the ability to communicate, collaborate and share information, give presentations, provide advice, work autonomously, manage, influence and solve problems (OECD, 2016c). In addition, as technology is adopted to automate specific tasks, the value of skills needed for non-automatable tasks, such as social skills, also increases (Autor, 2015; Deming, 2015).

The main premise for the BEYOND4.0 project is that technology, and certainly digital technology, is not deterministic; rather, it is socially negotiated by key social actors at various levels: firms, industry, regional, national and the EU level. This premise opens up the possibility that the EU can use digital technologies, specifically those related to Industrie 4.0, to promote the creation of an inclusive digital economy that provides decent work and decent lives for EU citizens (Warhurst et al., 2019).

This report builds on the overarching conceptual framework for the BEYOND 4.0 project (D2.1, see Warhurst et al., 2019) and, more specifically, two previous iterations (see D6.1, first and second report (Kohlgrüber et al., 2020, 2022)) of this report, by way of gathering insights gained during the empirical research conducted in Work Packages (WP) 4 and 8 of the BEYOND 4.0 project, and then applying these insights to the new skills framework.

Work Package 6 contributes to debate around three of the general strands of work in the BEYOND 4.0 research design. Namely, the strand on digital transformation: regional perspectives and prospects (Strand 2); the strand on understanding future skills: empowering groups (Strand 4); and the strand on company strategies for leading economic performance and social performance (Strand 6) (see D2.1, Warhurst et al., 2019).

- *The aim of the general strand of work on digital transformation:* is to develop regional perspectives and prospects to identify current and future growth-related impacts of digital transformation. Also, to identify policy pointers for how the EU can help support regions and entrepreneurial ecosystems in adapting and changing course. As envisaged in the research design, this paper draws from the qualitative research in WP4 and WP8 to generate new empirical evidence on skills issues connected with inclusive-growth impacts of digital transformation in six regions and selected ecosystems in the EU (Warhurst et al., 2019, p. 7).
- *The aim of the general strand of work on understanding the future skills:* is to provide new insights to understand better the skills needed for future workplaces, including the analysis of the skills actually used in these workplaces, and from these insights, enrich the policy debate on skills. As envisaged in the research design, the primary data generated at the regional and company levels, supplemented by a review of existing literature, was used to compare expected skills demand with the supply side of vocational education and training (VET) systems and training providers to clarify gaps, identify areas for possible improvements, and to provide knowledge for better inclusion of disadvantaged employees and unemployed people (Warhurst et al., 2019, p. 7).
- *The aim of the general strand on company strategies for leading economic and social performance:* is to provide state-of-the-art examples of European approaches to technical transformation, including how stakeholders have responded to these changes. It also aims to understand what elements of an inclusive economic policy are essential for stakeholders, where the analysis shifts from the regional to the company level. The empirical evidence about the economic and technological effects at the company level of technological transformation was considered, to the extent possible, in relation to tasks, skills and competencies (Warhurst et al., 2019, p. 7).

While these empirical results are the main focus of this report, a systematic literature review on skill demands and skills supply was carried out in preparation for this third update of Deliverable 6.1. For example, various publications from CEDEFOP on Future of Work and VET 4.0 were evaluated, as well as those of the European Commission (e.g., cf. Cedefop, 2020a, 2020b; European Commission, 2020; Gonzalez Vazquez et al., 2019). Insights derived from these reports were used to update the current state of the literature since the second version of the Deliverable 6.1 report was finalised. These publications underlined and reinforced the continued importance of skills in the agenda of the European Commission.

Based on literature analysis, a new framework of five skill categories was developed in previous reports of Deliverable 6.1. In this report, this framework serves as a structuring element for empirical results on skills. It makes a distinction between five distinct skill categories: four categories of transversal skills: (digital, personal, social and methodological skills) and the category of job-specific skills, which continues to play a major role in the context of the digital transformation.

Beyond the need for the individual skill categories, ***the need for interacting skills*** stood out in the interviews and workshops undertaken as part of the research undertaken in the BEYOND 4.0 WP4 and WP8. While it became apparent that “digital plus x” skills are required for the digital transformation, they are rarely delivered by education and training systems. It is the interaction of digital and job-specific skills, digital and methodological skills, and digital and personal skills which is required by the employees. This finding may seem obvious but the relevant literature appears to be silent on this important issue. Silo thinking appears to predominate, where clear distinctions are made between the different skill categories. This is reflected by offers of the skill supply side, which usually provides job-specific ***or*** digital skills, but rarely training that is designed to deliberately address the interact of both skill categories. So, this report presents examples and observations in which way interacting skills are needed in a digitalised environment and how education and training system respond to these needs.

Methodologically, this finding was derived from the empirical material, where anecdotal evidence was drawn from the interviews, surveys and observations gathered from the ecosystems in six different regions, including from 30 different companies. As this approach of focusing on interacting skills was not evident in the extant literature, this report serves as a basis for further theory development with regard to interacting skills in the context of the digital transformation.

After this introduction, the paper is structured into five main sections. Section two sets out details of the methodology for the report. The section begins with an explanation of the framework developed earlier in the BEYOND 4.0 Work Package on understanding future skills (WP6). An explanation of the skills categorisation developed for the framework follows, outlining the approach adopted for classifying skills into five main categories: digital, personal, social, methodological, and job-specific skills (see Kohlgrüber et al., 2022; D6.1 for details on framework development). A description of the research process used to identify, collate and synthesise sources of primary empirical data gathered from the two other work packages is then provided. Section three synthesises empirical findings on skills demand in the digital transformation. By way of illustrative examples from the fieldwork, anecdotal evidence is presented for each category identified as necessary for digital transformation. That is, digital, personal, social skills, methodological, and job-specific skills, in turn. The fourth section presents evidence of the interaction of skills from across the five categories, from the demand side. The fifth section considers supply-side issues. The final section (section 6) summarises the findings, including bringing back together the demand and supply sides to discuss the policy implications emergent from this novel research.

2. Methodology

This section describes the methodology used to produce this report. First, what is meant by the concepts of skills, skill levels, skills development, skills utilisation, and skills mismatch is discussed by way of outlining the general framework that was followed. Then, details on how the skills categorisation was developed is described. Finally, details are provided on the sources of empirical data drawn upon from other work packages in BEYOND 4.0. The section explains the skills categorisation, including details about the data synthesis and analysis process.

2.1 General Framework

This report is based on a general skills framework covering the demand- and supply-sides of skills. The aim of developing the general framework was so that the two sides (demand and supply) of the skills equation could be compared in to help identify future skill imbalances arising from the digitalisation of work. Before providing an overview of the general skills framework, five key concepts are defined: skills, skills levels, skills development, skills utilisation and skills mismatch.

While there is general agreement that skills mismatches need to be addressed, challenges remain when it comes to defining what skills are being referred to (Green, 2011). Different organisations and agencies tend to use the term skills meaning very different things (Palmer, 2017, p. 8).

First, while skill is often a core object for policy interventions resulting from the impact of technology on work, there remains no consensus about the meaning of the concept of skill (Green, 2011). As a result, different organisations and agencies tend to use skills to mean very different things (Palmer, 2017, p. 8). The BEYOND 4.0 concepts paper (D2.1, Warhurst et al., 2019) conceives skills as objective requirements demanded by tasks, where task compositions between jobs may vary and thus require different levels of skill. The concepts paper highlights that despite it being possible to separate these concepts conceptually, the terms of skills, attitudes and knowledge are sometimes intermingled. The concepts paper also points out that skills are often designated as domain-general ('generic') or domain-specific, where the former skills are transversal across occupations and the latter confined to particular occupations (i.e. job-specific).

Green (2011) argues that the lack of clarity and consensus over the concept of skill can conflate employers' demand for the skill with workers' demand for skill formation opportunities, among other problems. Following the same line of argument, the BEYOND 4.0 concepts paper notes that importantly, while skill is commonly used with reference to accredited vocational knowledge acquired through a mixture of formal and on-the-job training, skills need to be distinguished from qualifications (D2.1, Warhurst et al., 2019, p.v).

Green (2011) explains how, in neo-classical economics, skill is one of the main ingredients of 'human capital', the other being health. The human capital approach to skill is individual, where the value of a person's current and future prospective earnings are investments in the accumulation of skill/human capital. If skill is transferable between workplaces, workers pay to acquire their own skills. If there are labour market imperfections, or if the skills are firm-specific, the costs and benefits of training are shared between worker and employer. Green (2011) argues that the neo-classical approach to skill misses the social context of skill, where skill acquisition, valuation and utilisation are socially determined processes.

Situating skills within the tradition of political economy, Green (2011) suggests that skills have three key features: they are ***productive*** (i.e. using a skill is productive of value), ***expandable*** (i.e. can be enhanced by training and development) and ***social*** (skills are socially determined). This approach, known as Green's PES concept of skill, has been adopted in this report.

As skills lack a common measurement, what gets counted as a skill is that which can be measured. As some skills are credentialised with qualifications (Felstead et al., 2017) and become so-called 'hard' skills, the remaining types of skills are bundled into a catch-all category of 'soft skills' (Felstead et al., 2017; cited in Warhurst et al., 2019, p. 32). To compound the definitional problem, understanding of skill is dynamic, changing over time, and it can also be spatially specific (D2.1, Warhurst et al., 2019, p. 31).

Secondly, this leads to the next key concept of skill use. In line with (Felstead et al., 2019), skill use refers to the level of skills required of workers to carry out their jobs, the extent to which workers use the skills and abilities they possess and the extent to which workers receive training that develops job-related skills.

Third, and related to the concept of skill use, skill level is assessed through the complexity and range of tasks associated with a job and skill specialisation associated with the field of knowledge required, the tools and machinery being used, the material being worked on or with and the kinds of goods and services being produced (Elias & Day, 2017; cited in D2.1, Warhurst et al., 2019).

Fourth, skills development can also vary, as skills can be acquired in different ways and acquired at different life stages, work tasks can be vertically or horizontally distributed, and organisations can modify their skill needs through work design, including technology use. Actions related to each of these four strategies come with costs and benefits, and strategic choices are made (Keep, 2017; cited in D2.1, Warhurst et al., 2019).

Fifth, having outlined the approach taken to define the key concepts of skills, skill levels, skills development and skill use, the next concept of relevance is skills mismatch. The issue of skills mismatch is a common concern to policymakers, employers and workers alike. However, the concept of skills mismatch is often not well understood (Green, 2016; Payne, 2017). The OECD (2015) defines a skill mismatch as the suboptimal allocation of workers to jobs resulting in over or under qualification. This definition uses qualifications as the proxy of skills and measures skill mismatch at the level of the employee (cited in D2.1, Warhurst et al., 2019).

Palmer (2017, p. 8) defines skills mismatch as the lack of matching between the skills that are available in (or supplied to) the labour market and the skills that are in demand in the labour market. Like the term skill itself, the term skills mismatch has been used to refer to a variety of situations (Comyn & Strietska-Ilina; Green, 2016; Palmer, 2017). Palmer (2017) identifies three circumstances where the term 'skills mismatch is used, as follows:

- where individuals are over- or under-qualified or skilled for a job (vertical mismatch);
- where firms are not able to attract the right skills or where there is a genuine lack of adequately skilled people (skills gaps, skills shortages, horizontal mismatch); and
- where individuals have skills that have become obsolete (skill obsolescence).

Along similar lines, the Comyn and Strietska-Ilina (p. 2) notes that skills mismatch has been used to describe over-qualification (over-education), under-qualification (under-education), over-skilling, under-skilling, skill shortages, the field of study mismatch and skill obsolescence.

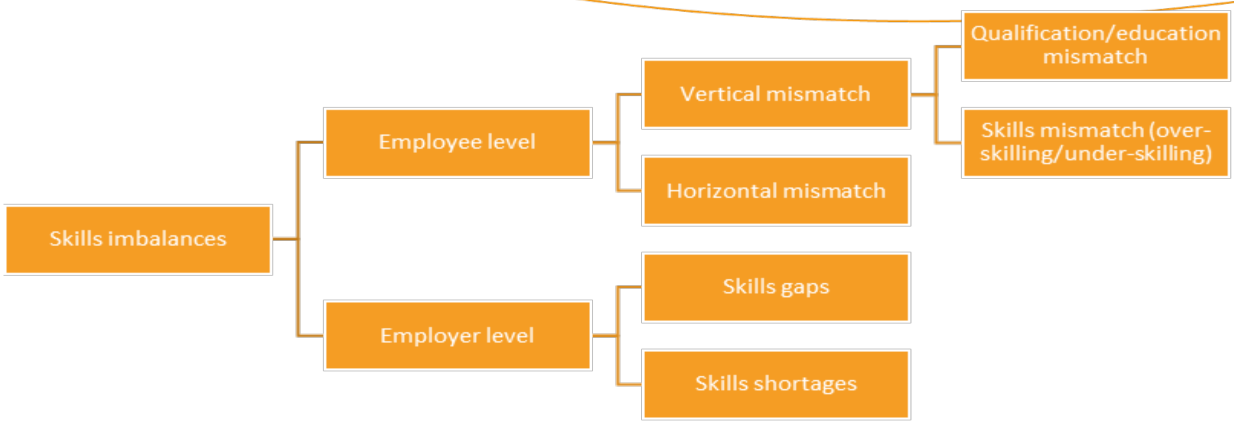
A short description of each type of skills mismatch is set out in Table 1 below. While from Figure 1 it is shown that mismatches can occur for organisations in both internal and external labour markets. The first is called a **skills gap** and refers to a situation in which an employer believes that existing employees do not possess the skills to perform their tasks successfully. The second is called a **skills shortage** and refers to aggregate supply in the labour market not meeting demand and is manifest for employers in recruitment problems due to a lack of suitably qualified candidates (McGuinness et al., 2018; cited in D2.1, Warhurst et al., 2019, 34–35).

Table 1: Types of Skills Mismatch description

Skill shortage	Demand for a particular type of skill exceeds the supply of people with that skill
Skill	Supply for a particular type of skill exceeds the demand of people with that skill
Skill gap	The type or level of skills is different from that required to perform the job adequately
Horizontal mismatch (field of study)	The type/field of education or skills is inappropriate for the job
Over-skilling (under-skilling)	Workers have more (less) skills than the job requires
Over-education (under-education)	Workers have more (less) years of education than the job requires
Over-qualification (under-qualification)	Workers hold a higher (lower) qualification than the job requires

Source: Palmer (2017, Table 1, p. 11)

Figure 1: The impact of skills imbalances at an employee and employer level.

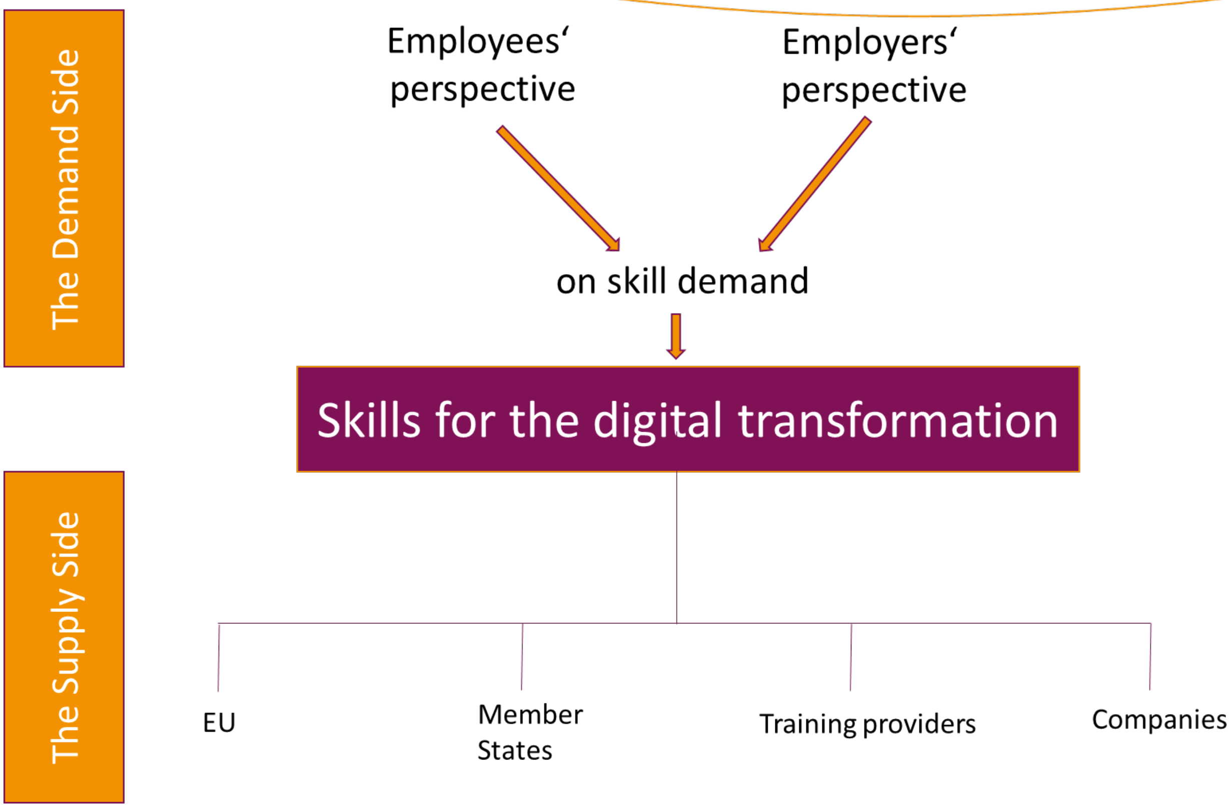


Source: Warhurst et al. (2019, p. 35); based on McGuinness et al. (2018)

Crucially for policymakers, these various forms of skills mismatch are very different in how they manifest themselves, how they are measured, what causes them and how their consequences are felt. For example, some relate to mismatches experienced by employees, others to employers and firm-level difficulties such as uncompetitive wages and poor working conditions, and others to factors such as low-quality education, demographic change, rapid technological development and new forms of work organisation (Comyn & Strietska-Ilina).

The concept of skill mismatch thus requires an understanding of both the skills possessed by workers and the skills needed in work (D2.1, Warhurst et al., 2019). Here, Green´s (2013) framework of "skill formation and the deployment of skilled labour" provides a helpful starting point for integrating both sides. Green identifies two markets for skills. On the one hand, there is a market for skills supply, in which different actors provide learning and training. On the other hand, a market for skills demand exists. On the demand side, the requirements of employers and employees have to be estimated. On the supply side, the consequences for different education and training actors (at EU, national, sectoral, regional and company levels) have to be estimated to fulfil the employers´ and employees´ current and future skills requirements (Figure 2 below).

Figure 2: General framework of skills demand and supply



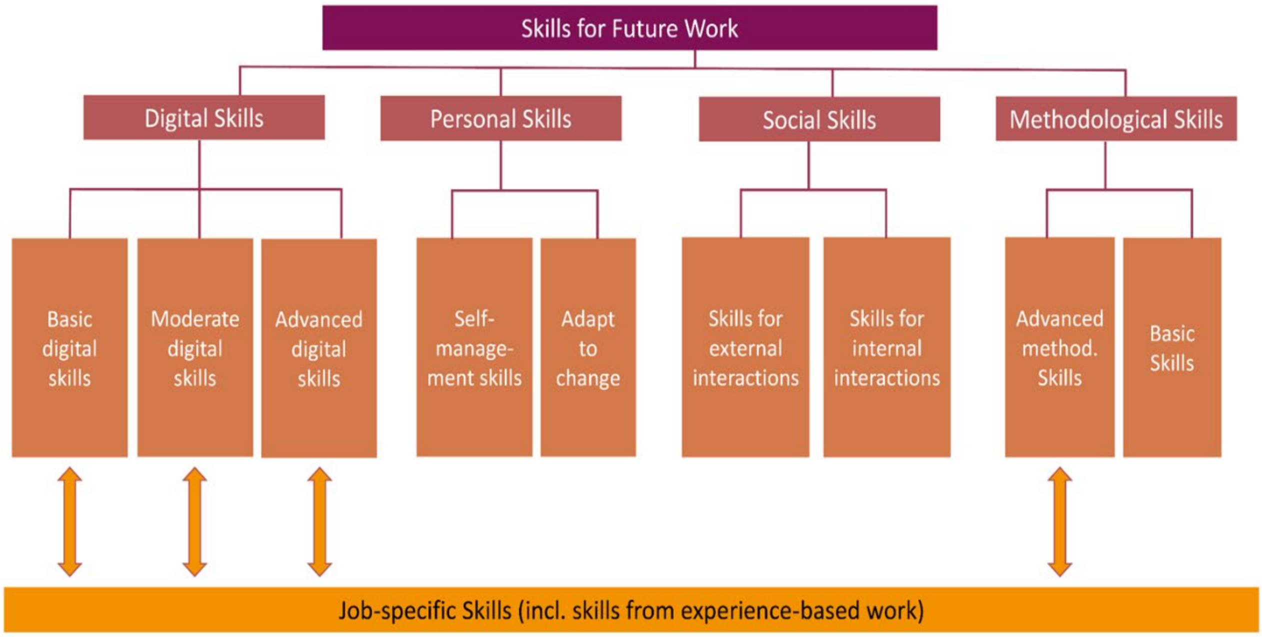
2.2 Skills categorisation

To classify the skills needed for digital transformation and related to which there can be a skills mismatch, a categorisation of skills was developed within two reports produced as the first and second deliverable of 6.1 in Work Package 6. Considering the strengths and weaknesses of different stages of skills frameworks, BEYOND 4.0 developed a new framework based on a systematic review of the literature and practical experience derived from the Blueprint projects for sectoral skills alliances (such as the European Skills Strategy and Alliances, ESSA). The skills debate in the EU and OECD countries has been deducted from an analysis of 59 reports on the European level (mainly European Commission, Cedefop, ILO) and 48 reports on the international level (mainly OECD), respectively (see Kohlgrüber et al., 2022)).

The skills classification distinguishes between digital, non-digital transversal, and job-specific skills. Digital skills are further classified as basic, moderate and advanced skills. Advanced digital skills are typically needed by workers in IT-specific occupations, but are increasingly required in other occupations. While many other non-IT specific occupations increasingly require moderate, rather than basic, digital skills. Sometimes digital skills incorporate skills needed for researching and developing digital technologies (see the European Digital Competence Framework for Citizens (DigComp) understanding of digital skills (Vuorikari et al., 2022)). BEYOND4.0 classifies non-digital skills using the non-technical skills categories of Janis and Alias (2018). It covers social skills (communication, collaboration, leadership), methodological skills (problem-solving, creative thinking) and personal skills (adaptivity to change, self-management, entrepreneurial thinking).

Figure 3 shows the skills classification BEYOND4.0 uses for analysing skill demands for digital transformation.

Figure 3: The BEYOND4.0 classification of skills for future work



While there is a consensus that digitalisation of work will require constant up-skilling and/or re-skilling of workers, Dhondt et al. (2021) identified what appears to be contradictory opinions about whether digitalisation will mean that future skills use is likely to change towards more generic skills, or, on the other hand, more specialised, technical knowledge. This report adds to the empirical evidence in this domain. This framework shows several single skills categories needed for future work (coping with new technologies and changing work organisation).

Crucially, however, the digital transformation requires not only single skill categories but also an interaction between different skill categories to complete job tasks (shown by the arrows between skill categories). This report extends the skills debate by taking a novel approach that extends the analysis from a siloed approach that considers single skill categories to a more holistic approach that looks at the interaction of different skill categories.

The methodology adopted in this report looks at the interaction between different skill categories instead of a clustering approach.

A **clustering approach** to skills shows how skill types are distributed across occupations by assessing how skills are related and connected. It is typically used to determine the transferability of skills across occupations. Skill clusters group together clusters of similar specialist tasks. These tasks are seen as broadly transferable. That is, if a person can do one task in the cluster, they will most likely be able to do the others. Skills clusters do not measure skills gaps but are one way of determining whether an already identified skills gap is similar or different from the existing skills supply. This skill intelligence can help determine whether a skills gap can be met by recruitment or on-the-job training (National Skills Commission, 2021, p. 11).

Skills clustering techniques are used to group occupations with similar skill sets into comparable groups. For instance, the Australian Skills Classification provides information on skills requirements associated with specific occupations. It also groups similar skills into skills clusters, and these clusters are further grouped into 29 skills cluster families.

While the skills cluster approach is useful for identifying occupational pathways, as national and sectoral data are typically used to undertake these types of skills exercises, it is less useful for understanding the impact of digitalisation in the regional ecosystem and at company levels. So, rather than using the skills cluster approach, the methodology adopted in this report adopts an alternative lens by considering the **interaction of skills** across different skill categories to consider the impact of digitalisation of work at the regional ecosystem and company levels. In adopting this approach, one of the contributions of this paper is that it uses empirical evidence not only to analyse demand- and supply-side issues associated with specific skill categories but also demand-side issues related to the combination or interaction skills across skill categories. That means that different skills (from different clusters) are needed to perform a single job task (e.g. process control in manufacturing), whereby the skills are directly intertwined/interacting.

Skills anticipation exercises help guide policy makers and education and training providers to predict and address labour and skills shortages and mismatches resulting from structural and technological change. One of the aims of these types of exercises is to align with regional skills initiatives to support occupations that are anticipated to grow within regional economies rather than those likely or already on the decline (Khalaf et al., 2021). This report adopts a regional ecosystems lens to identify illustrative examples of skills requirements necessary to adapt to changes due to digitalisation.

The next section provides a description of the data sources from the analysis of incumbent and emerging regional ecosystems that have been applied to operationalise (thus empirically pilot or test) the skills categorisation outlined in this section.

2.3 Data sources and analysis

The above skills framework has been applied to empirical data on skills demand and supply found within two BEYOND 4.0 empirical work packages: regional perspectives and prospects for digital transformation (WP4) and company strategies for leading economic and social performance (WP8). These data sources are described.

Work Package 4

In WP4, fieldwork was undertaken in six countries (eight regions): Germany (Dortmund and Duisburg), Finland (Salo and Oulu), the UK (the West Midlands), Bulgaria (Sofia), Spain (The Basque Region) and The Netherlands (Noord-Brabant).

The concept of an entrepreneurial ecosystem (Stam & Spigel, 2018) was used in WP4 to examine productive entrepreneurship within the eight regions. While the research in WP4 considered the interaction of all ten elements in Stam and Spigel's model of an entrepreneurial ecosystem (see D4.1, Dhondt et al. (2022) for further details), the analysis in this report narrows in scope by considering the evidence about the regional ecosystems that is pertinent to current and future demand and supply side skill issues arising from digital transformation. The data utilised from WP4 were extracted from the research tasks and activities related to the regional ecosystems analyses, including regional reports, interview summaries, regional ecosystems survey data, and summaries generated from the regional workshops and inter-regional workshops. The findings are cited below as "D4.1 regional ecosystems data" and if the data does apply to a specific region, the respective country from which the data originate is named. For example, "D4.1 regional ecosystems data, Bulgaria".

Work Package 8

Fieldwork in WP8 continued in the same six countries and regions studied in WP4; however, the focus of analysis shifted from the regional to the company level. The empirical data extracted from the research tasks and activities in WP8 was drawn from 30 company case studies (selected as exemplary cases because of their positions in the studied incumbent and emergent ecosystems), including data contained in the case study reports, interview summaries as well as data generated from company surveys of managers (survey A) and employees (survey B) and the company skills surveys (survey C) (see D8.1 for further details; Dhondt, Oeij, & Hulsegge, in press). While Deliverable 8.1 presents a synthesis of general findings from across the 30 company cases, again, this report narrows the scope to incorporate the empirical evidence relevant to current and future skills requirements. The findings from Work Package 8 are cited as "D8.1 company case study data" and the respective country from which the data originates. For example, "D8.1 company case study data, Bulgaria".

Data analysis

The same research questions were investigated in all six countries in WP4 and WP8, where the interview guides, surveys and workshop contents were standardised as much as possible. The focus in both WP4 and WP8 was much broader in scope than skills, so the level of detail collected on skills varied between countries. While the range of interviewees, workshops and surveys undertaken as part of the empirical research completed in WP4 and WP8 provide a broad spectrum of perspectives on the effects of digitalisation on skills, the data sources do not provide a comprehensive representation of the picture of skills demand and supply. Nevertheless, taken all together, the combination of data sources delivers valuable observations, insights and illustrative anecdotal examples at the regional, sectoral and company levels of requirements within each of the various categories of skills, as well as anecdotal examples of how digital skills interact with skills from within the other four categories.

In a first step in analysing the available data, the demand for individual skill categories was mapped against the five categories of digital, personal, social, methodological and job-specific skills. In a second step, the need for interacting skills was analysed. Finally, the step involved interrogating the various data sources to gather insights about the supply-side of skills.

Limitations

When the BEYOND 4.0 project research design was originally formulated, it was envisaged that results from work package 5 (WP5) on analysing socio-economic consequences of technological transformation would feed into WP6. In particular, findings generated from task 5.2 are a quantitative analysis of the structural transformation of occupations, tasks and skills. While the EU cross-country database compiled by WP3 was used to produce a working paper in WP5 on structural transformations of occupations, tasks and skills (D5.1), data from the different European surveys (that is, 2010 and 2015 data from the European Working Conditions Survey [EWCS], 2010 and 2014 data from the ICT Usage in Enterprises Survey [ICT Survey]; and 2011 and 2015 data from the European Labour Force Survey [EU-LFS]) was aggregated through the common cell of sectors (using the NACE standardisation in countries using the NUTS 0 standard). This meant that it was only possible to track trends in skills requirements connected with technological transformation by looking at the change in shares of certain ISCO groups along with the change in the overall occupational structure within sector-country cells. It was not possible to disaggregate the data generated by task 5.2 to a level that would allow the meaningful application to the skills categorisation classification (Figure 3 above). Moreover, given the periodicity constraints of the quantitative data, there would have been limited utility in comparing quantitative results based on survey data from 2010 to 2015 with the qualitative results collected during the past three years (2019-2022). For these reasons, findings from the analysis in WP5 were not incorporated into this report.

3. Skill Demands in the Digital Transformation

3.1 Demand for Digital Skills

As foreshadowed in the introduction, the OECD identified two main lines of increasing use of digital technologies at work raises the demand for two specific digital skills: first, *specialist digital skills* to programme computers, develop applications and manage networks and, second, *generic digital skills* to use such technologies for professional purposes (OECD, 2016c). The digital transformation means that workers who can code, develop applications, manage networks and analyse Big Data have more labour market opportunities (OECD, 2016b). However, digitalisation also calls for all workers to have a relatively high minimum level of digital skills, even those in low-skilled jobs (OECD, 2016b).

Across all ecosystems and many job groups, analysed in WP4 and 8, the demand for digital skills is rising to a high level. More specifically, results from BEYOND 4.0 show that understanding and implementing digital technologies in companies require not only basic digital skills but often advanced digital skills in the workforce and the presence of IT specialists (D4.1 regional ecosystem data; D8.1 company case study). The case studies show that digital skills not only pertain to the availability and level of digital skills but also to more topics such as the digital divide, the ability of job candidates to estimate their own digital skill level and the capability of public authorities to understand the shift in digital skills.

In several ecosystems, a dedicated **lack of skilled workers, especially with digital skills**, was identified (D4.1 ecosystems data). In the two West Midlands region ecosystems, high demand for digital skills, in general, was identified, where almost two-fifths (38%) of employers reported finding digital skills challenging to find in the pool of current job applicants (D4.1 regional ecosystem report. United Kingdom). Many firms cannot recruit workers with the necessary digital skills. It also depends on the type of digital skill that is required. In the Basque Country's Smart Mobility ecosystem, the high demand for ICT skills, or "4.0 skills" such as ICT and Internet of Things, particularly stood out. In addition, a particular demand for AI and Big Data was emphasised in the Basque Country, the Netherlands and the UK (D4.1 regional ecosystems data).

For the ecosystems in Spain, Netherlands and UK, **future digital skills** requirements are expected to be at advanced level, with practitioner-level digital skills sometimes sufficient at the moderate or basic skill levels. Operational production workers in a Dutch ecosystem reported such levels. The course of the digital transformation leads to this expectation. However, an exception could be found in the Basque country where the level of skills needed to be decreased when digital tools were implemented (D8.1 company case study data).

In the German ecosystems, the need for digital skills depends on the skill levels of the respective employees. Basic digital skills are becoming increasingly important as people must adjust quickly to working with new software programmes and digital tools. However, concerning the low-skilled workers employed on the shop floor of industry, attempts are being made to keep the requirements for introducing new tools and technologies as limited as possible. For this group of workers, an expert interviewee believed that basic digital skills were typically sufficient (D4.1 regional ecosystems data, Germany). At the next qualification level up, on the part of the production management and the quality managers, it becomes apparent that skill demands have increased through the use of digital technologies. These employees now have to deal with complex tools and fulfil requirements in connection with digital skills (D4.1 regional ecosystems data, Germany). Also, in the logistics ecosystem, more in-depth IT skills are playing a role at higher qualification levels, even in professions where this may not have been the case a decade ago. But, on the other hand, basic digital skills are required at almost all qualification levels and for the majority of jobs in the logistics sector (D4.1 regional ecosystems data, Germany).

Regarding the Bulgarian ICT ecosystem, the demands for advanced digital skills are so high that there are virtually no job opportunities for lower-skilled people. However, the BEYOND 4.0 qualitative research results suggest that some experts are confident that the future need for digital skills and IT specialists in Sofia will be met (D4.1 regional ecosystems data, Bulgaria). Quantitative results based on RIS 2021 data also show that the Sofia region is an IT-intensive area characterised by a high presence of IT experts. Despite this optimism other estimations show current major shortages concerning digital skills, such as experts in the Sofia region who have estimated the need for an additional 20,000 to 30,000 ICT/mathematics professionals in the region (D4.1 regional ecosystems data). In particular, Big Data, and more specifically data-scraping, is an emerging area where a shortage of people with the right digital skills has been identified. This type of skills shortfall was evident not only in Bulgaria but also in the UK (D4.1 regional ecosystems data, Bulgaria).

When digital skill levels are compared between the studied ecosystems and the general populations, signs of a **rising digital divide** are apparent. Even if the number of IT specialists in Sofia is significantly higher than in the other regions in the BEYOND 4.0 evaluation, the level of digital skills in the population is rather low. Accordingly, one can speak of a significant digital divide in the Sofia region, as digital technologies in the current workforce do not seem to be shared across all Bulgarian households (D4.1 regional ecosystems data, Bulgaria). The level of basic digital skills in the general German, Basque and UK population tends to be relatively high, while the number of suitably qualified IT experts is relatively low, despite the high demand for advanced digital skills in the respective ecosystems and sectors in Germany, the Basque Country and the UK. For example, in the Basque Country, regional data show that almost three-fifths (59.4%) of the population aged between 16 and 74 have basic knowledge of ICT, which is slightly above the national average (57.2%) (regional ecosystem data). In contrast, the region of North Brabant in the Netherlands was found to be well-positioned in both respects, as the high demand for digital skills currently appears to match the digital skills in the population and the number of IT experts (D4.1 regional ecosystems data, Netherlands).

Solving the demand for digital skills requires that candidates **know what their digital skill level is**. For example, in the Oulu ICT sector in Finland, one interviewee noted that a translation gap often existed, where employees with digital skills often found it difficult to recognise, explain and demonstrate the digital skills that they actually possess. So, a skills gap was identified in the ability of employees and job-seekers to talk about their skills rather than relying on employers to infer their skills from diplomas and other educational achievements (D4.1 regional ecosystems data, Finland). Related to this lack of being able to demonstrate already acquired digital skills, the digital skills that workers may possess may be advanced yet narrow, making their digital skills less transferable to different jobs, companies or sectors.

Not only do candidates need to have this understanding, public authorities need to be able to assess the digital skills situation in order to be able to thoroughly implement digital strategies. Here, the reports indicate new problems. There is also limited **capacity and capability for data analysis** within local government in the West Midlands (D4.1 regional ecosystems data, United Kingdom). This finding is consistent with the situation in a German ecosystem, where local authorities lack digitally skilled employees to move forward with the digitalisation strategy of the region (D4.1 regional ecosystems data, Germany). Furthermore, when employees of local authorities develop these digital skills, they are often poached by other local employers, such as other administrative bodies or companies in the private sector (D4.1 regional ecosystems data, Germany). This also shows the great need for digital skills. For example, in the UK digital healthcare sector, the need for digital skills has been identified across the entire local government healthcare system, including specialist ICT skills, digital skills amongst clinicians and administrative staff, and communication and leadership skills to promote the uptake of digital technology. This is partly because comparatively low wages in the sector mean it has experienced difficulty in attracting and retaining workers with higher level digital skills (D4.1 regional ecosystems data, United Kingdom).

3.2 Demand for Personal Skills

Technological change is occurring faster than education and training systems can keep up with. Several interviewees in the regional ecosystems highlighted the importance of skills such as "**adapting to change**." Employees must adapt to technological change by continually learning how to use (and sometimes implement) new digital tools in the work environment.[1] Based on a systematic review of the literature, Janis and Alias (2018) characterise this requirement as **personal skills**, including self-awareness, self-organising, self-discipline, positive work attitude, and proactive. Abel (2018) also includes **entrepreneurial skills**, such as readiness to take the initiative and risks, into this skill category.

Among the respondents to the company survey on skills and inclusiveness, many from Spain, the Netherlands and the UK expected the future needs for **personal skills** (such as "adapting to change") to either remain at the current level or increase. That is, the future demand for personal skills at the practitioner/expert level will continue or even increase to the expert/master level (D8.1 company case study data, Netherlands; United Kingdom). In one case study company in the Basque Country, engineers estimated a substantial increase in the demand for engineers with higher levels of personal skills (from practitioner to master level). The same assessment was made about the demand for high-level personal skills for managers in an automotive company in the UK incumbent ecosystem (D8.1 company case study data, Basque Country; United Kingdom).

In the German ecosystems, the experts repeatedly mentioned personal skills as becoming more important in digital transformation. Digitisation is associated with new freedom and more flexibility on the side of employees, resulting in high demand for self-organisation skills – a finding not only relevant for the German ecosystem but also for the Bulgarian and UK ecosystems (D4.1

[1] One might argue that these requirements are more concerned with motivation rather than skills per se, where such an understanding implies the risk that skills gaps might be considered only as a lack of motivation. However, it is an empirical finding (which is also reflected in literature) which should not be disregarded. Nevertheless, it will be critically discussed in the conclusions of section 5.

regional ecosystems data). Employees are thus required to personally recognise their skill deficits and, if necessary, to work on them or undergo further training in consultation with their managers. In turn, this demands a degree of **honesty and self-reflection** on the side of the employees (D4.1 regional ecosystems data). In the other German ecosystem, openness and adaptability to technological changes in particular play a major role, as digitalisation leads to new challenges that employees have to face in the workplace (D4.1 and D4.2 regional ecosystems data, Germany).

The analysis of interviews from WP4, which explicitly asked about skills in different ecosystems, shows a similar picture. Here, the needed level of personal skills is generally estimated as either already important or increasing. In one of the Finnish ecosystems, company representatives emphasise the need for **entrepreneurial/business skills** among its clerical employees in wood procurement (D8.1 company case study data, Finland). One issue with the education system is that graduate professionals might not be ready for the business side of this industry, such as being able to sell and to negotiate product prices. These specific skills overlap with social/communication skills and will therefore be taken up in the section on interacting skills (D4.2 regional ecosystems data, see Oeij et al.).

The speed at which changes occur particularly places high demands on the **adaptability** of employees. An expert in one of the German ecosystems emphasised that changes in the labour market, which in the past took place within the timeframe of several years, now takes place within the space of months, also due to the influence of digitalisation (D4.1 regional ecosystems data, Germany). Employees and managers must repeatedly familiarise themselves with new systems, programmes and digital tools concerning concrete work tasks. Accordingly, adapting to change is often closely linked to the ability and motivation for lifelong learning (D8.1 company case studies data, Germany). Comparable findings on the fast pace of the world of work, underlining the importance of the adaptability to change and the high importance of lifelong learning, can also be found in the UK ecosystems. In this instance, the connection with COVID-19 is particularly emphasised, as the pandemic led to a rapid spread of digital tools and to changes in the world of work (D4.1 regional ecosystems data, United Kingdom). Bulgarian experts of the Sofia region also stressed that the motivation to undergo further training throughout an employee's career is crucial for skills to stay relevant for the labour market (D4.1 regional ecosystems data, Bulgaria). The importance of lifelong learning was also stressed in the Basque Country (D4.1 regional ecosystems data, Basque Country).

3.3 Demand for Social Skills

As technology automates certain tasks, the value of skills needed for non-automatable tasks, such as social skills, also increases (Autor, 2015; Deming, 2015). For example, Deming (2015) estimated that labour market return to social skills was much greater in the 2000s than in the previous two decades. Digital transformation is increasing the need for social skills such as **communication**, **teamwork** and **leadership skills** to take up opportunities arising from digitalisation (leadership) and collaborate across different disciplines and professions.

Respondents of the survey on skills and inclusiveness (Survey C) indicate that the required **level of social skills** will be stable (on expert level) or increase from practitioner to expert level or from expert to master level. Experts estimate this across the ecosystems in Spain, the Netherlands and the UK, and across a significant range of job groups identified in the survey (D4.1 regional ecosystems data). Among engineers in a company of the Dutch ecosystem, this is due to the need for advanced communication between different disciplines (D4.1 regional ecosystems data, Netherlands).

The high importance of communication and other social skills is also repeatedly confirmed in the other ecosystems of Finland, the Netherlands and the Basque Country (D4.1 regional ecosystems data). For example, the Finnish ecosystem reveals that clerical employees in wood-procurement industries increasingly need social skills, such as communication and negotiation skills. In the case of Dutch ecosystems, experts emphasise that "soft skills", mainly in the form of communication skills, are increasingly in demand by companies (D4.1 regional ecosystems data, Finland; Netherlands). Communication and teamwork are also considered important transversal skills in the Basque ecosystems. Due to the high demand, social skills are also becoming increasingly important in terms of training and skills transfer in the Basque Country (D4.1 regional ecosystems data, Basque Country).

Interviews with company representatives from the German steel ecosystem, UK automotive ecosystem and UK digital healthcare ecosystem emphasised increasing communication skills because of **organisational demands** (D4.1 regional ecosystems data, Germany; United Kingdom). In the German steel ecosystem, for example, the requirements for *teamwork* and communication have risen sharply, as there is an increasing exchange between different professional groups and communication cultures, which in itself stands as a challenge (D4.1 regional ecosystems data. Germany). In addition, the importance of intensive *customer contact* is increasing in various areas, including engineering, which increases the level of the social (communication) skills required for such cross-occupation collaboration. Also, in the German logistics ecosystem, social skills are becoming more important across different professions in the course of digitalisation. Due to changed organisational structures, more work is being done on *projects with interdisciplinary teams*, especially in more highly qualified areas (D4.1 regional ecosystems data, Germany). In the UK digital healthcare ecosystem, experts observed that digitisation of health records means that health and social care professionals, technicians and support workers all need to communicate (increasingly via digital means) with one another, particularly as the health care system attempts to move towards a more *integrated approach to treatment* (D4.1 regional ecosystems data, United Kingdom).

In the UK digital healthcare sector, interviewees also mentioned the likely need for improved **communication and leadership skills** to promote the uptake of digital technology. Specifically, in terms of the digitalisation of healthcare, skills shortages have been identified in terms of lack of communication skills and shortages of high-skilled IT and analytical capabilities (D4.1 regional ecosystems data, United Kingdom). Interviewees from the UK automotive sector also estimate that, in the short-term, the most immediate skill requirements are those of team-working and leadership. The future of digitalisation particularly raises a need for knowledge, leadership and management skills, as indicated by an automotive sector expert in the UK.

3.4 Demand for Methodological Skills

Advanced methodological skills are needed to find strategic solutions to achieve a defined objective. Employees need a systematic approach to analyse and understand problems; creative solutions must be found and prioritised. Therefore, methodological skills are needed, such as

problem-solving skills, creative and analytical thinking, critical thinking, and decision making (Abel, 2018; Janis & Alias, 2018). Additionally, basic skills such as numeracy and literacy are another sub-category of methodological skills analysed by the Survey of Adult Skills being part of the PIAAC programme (OECD, 2016d, 2019).

Basic skills typically acquired in the early years of life through family and primary schooling include **basic literacy, numeracy, basic language skills and cognitive skills**. They form the basis for lifelong learning (and developing digital/advanced methodological skills) and have become a minimum requirement for recruitment in Europe (D6.1 version 2.0). Regional employers mentioned particular skills gaps, such as **basic skills deficiencies**, as increasingly important (D4.1 regional ecosystems data). Interviews in the Finnish ecosystems show that methodological skills are sometimes required. For example, immigrants need Finnish **language skills**, such as where employees working in international wood-procurement companies need basic English skills (D4.1 regional ecosystems data, Finland). While this was an isolated example in the empirical data, we suspect that, in order to work, immigrants across all of the case study countries would need the relevant language skills to perform their work. Furthermore, basic methodological skills such as **literacy and numeracy** are considered preconditions in working with digital technologies (D4.1 regional ecosystems data).

Based on the BEYOND 4.0 survey on skills and inclusiveness, the trend for methodological skills is similar to the changes in social skill requirements. That is, the **level** of needed methodological skills will be stable (often at the expert level), or the demand is predicted to increase, commonly from practitioner to expert level (D8.1 company case study data).

The importance of methodological skills is also evident in the other ecosystems. In the Sofia region of Bulgaria, the topic was discussed by experts against the background of automation potential. According to Bulgarian experts, it is mainly routine tasks that are gradually being automated. However, the demand for methodological skills such as **creativity** and problem-solving remains (D4.1 regional ecosystems data, Bulgaria). The high significance of creativity was also affirmed by experts in the Netherlands, especially when these methodological skills are combined with critical thinking skills (D4.1 regional ecosystems data, Netherlands). According to Dutch experts, creativity and critical thinking are important skills that are in demand by companies. As a consequence, the experts identified the importance of further education programmes becoming more active in this regard (D4.1 regional ecosystems data, Netherlands).

In the German steel ecosystem, workers increasingly need **problem-solving skills**. In highly automated working environments such as steel factories, the skill requirements for workers are quite low as process control systems complete many tasks. Paradoxically, however, when complicated problems occur in situations that are not in line with routine work processes, problem-solving skills, an understanding of the systems involved, expert knowledge and experience become vital (D4.1 regional ecosystems data, Germany). Also, methodological skills are increasing in the German logistics ecosystem due to digitalisation. **Advanced problem-solving** has also been identified as critical to future skill requirements in the UK automotive ecosystem.

3.5 Demand for Job-specific Skills

Based on the analysis of literature carried out in the second report of deliverable 6.1, it was not foreseen that job-specific skills would play an increasing role in the digital transformation.

However, the empirical results from the different regions in WP4 and WP8 revealed that job-specific skills were likely to remain important in the digital transformation – both, as single skill categories and as part of interacting skills, which, as already mentioned, will be discussed in further detail in the following section. Literature has highlighted an increasing demand for digital and non-digital (transversal) skills (see D6.1 version 2.0), while the need for job-specific skills has not really been the focus of policymakers due to myriad jobs and occupations in the EU. However, on the level of regional ecosystems, experts foresee the required level of job-specific skills will remain high (at expert or master levels) in the future (D8.1 company case study data). For example, company managers and employees interviewed or surveyed from the Dutch ecosystems indicated that domain knowledge and technical skills remain important (D8.1 company case study data, Netherlands). An expert from UK automotive ecosystem similarly highlighted that job-specific skills would need to remain current as the industry changes. Some UK respondents estimated that the level of job-specific skills required would increase (from practitioner to expert level); in rare cases, it was estimated that the level might decrease (D8.1 company case study data, United Kingdom).

Interviews in the Finnish ecosystems also revealed that job-specific skills would remain particularly relevant (D8.1 company case study data, Finland). In the Finnish electronic ecosystem in the Oulu region, core technological skills were identified as being important by experts participating in the WP4 inter-regional workshop. Moreover, stakeholders in the region were actively investing in trying to develop these skills (D4.1 regional ecosystems data, Finland). However, filling vacancies in the wood-procurement ecosystem that require hard manual tasks in forest work is difficult. There is a shortage of low-skilled workers in the Finnish forestry sector (for example, tree planting). As a result, forestry companies have been forced to recruit from abroad. Moreover, professionals in the wood-procurement ecosystem need to know the basics of forestry (D4.1 regional ecosystems data, Finland).

Also, experts in the German steel ecosystem underlined the importance of job-specific skills in digital transformation. German experts participating in the WP4 inter-regional workshop observed that the knowledge of processes was crucial for most jobs in their companies and that such knowledge cannot be bought in the market. They argued that such knowledge could only be developed from work-based experience, and workers with this knowledge need to be retained so it is not lost. (D4.1 regional ecosystems data, Germany). The German logistics ecosystem shows that there is also a need for low-skilled workers. In particular, experts participating in the WP4 inter-regional workshop identified a shortage of drivers for the mail-order. While these workers do not need any formal qualifications, they are confronted with low pay and short-term employment contracts, making these jobs unattractive and thus difficult to fill (WP4.1 regional ecosystems data, Germany).

In the UK automotive ecosystem, particular skills gaps in technical skills in engineering/manufacturing, logistics, construction and professional sectors, as well as basic skills deficiencies, were mentioned by experts during the inter-regional workshop (D4.1 regional ecosystems data, United Kingdom). Engineering skills related to lean manufacturing and manufacturing process knowledge were also identified as critical to future skill requirements. For both the incumbent automotive ecosystem and emerging digital skills ecosystems in the UK, problems in the Further Education system have resulted in skills shortages in many technical and vocational areas (D4.1 regional ecosystems data, United Kingdom).

4. Interaction of skill categories on the demand-side

As outlined in the methodology, in addition to separately considering the future skills requirements within each of the five main skill categories, the analysis in this report extends the analysis past the silos of each skill category to identify examples of interactions between these different categories of skills. This was because, during the process of analysing the data and identifying skill demands, it became apparent that certain combinations of skills from different categories of skills were needed in combination in individual employees for new or digitalised tasks. Despite the literature being silent on the interaction of skills, this section provides anecdotal evidence that shows how new combinations of digital skills and elements of one or more of the other skill categories interact. That is, *digital skills plus X*. Evidence from WP4 and WP8 of the BEYOND 4.0 empirical research was, in this instance, interrogated to identify how these so-called 'interacting skills' are shaping current and future skills requirements at the occupational, workplace and sectoral levels.

Interacting skills indicate that different skill categories are interwoven to perform a single task within the job. For example, when one person uses digital skills and problem-solving skills for detecting and interpreting quality problems within a production process, where the digital skills and problem-solving skills are not similar in the sense that they belong in different skills clusters or families.

As part of WP8, the synthesis of data collected from surveys confirmed the importance of specific combinations of skill categories for the success of digitalisation processes within the companies (D8.1 company case study data, specifically Dhondt, Kangas, et al. (in press)). These companies have all invested in robotics, AI, Big Data and other data analytics, and connected technologies, where social skills, such as communication skills and critical thinking skills, all become relevant only in combination with technical skills (which in the context of the survey referred mainly to job-specific and digital skills). Similarly, experts attending the second round of workshops for both the emergent and incumbent ecosystems of the Rhine-Ruhr region and the Finnish regions agreed that "a bundle of skills" or "hybrid skills" were essential for the digitalisation in their industries (steel production, wood procurement, logistics and electronics respectively) (D4.1 regional ecosystems data, Finland; Germany). The group of experts at the inter-regional workshops also pointed to the relevance of these interactions of skill categories. For example, in the Oulu region in Finland, jobs in the health care sector increasingly require a high level of expertise in both health care (job-specific skills) and ICT/digital skills (D4.1 regional ecosystems data, Finland). This section explores the different interactions between digital and non-digital skills.

4.1 Digital and job-specific skills

While job-specific skills do not feature in the literature as playing a major role for digital transformation (s. second report of D6.1), the empirical findings show that the interaction of digital with job-specific skills is often mentioned as relevant for the digital transformation. In most cases, job-specific skills, especially within a particular job in one specific company, will stay fundamentally important during digitalisation. As new digital technologies permeate an increasing number of jobs and tasks, combining digital skills with job-specific skills is becoming increasingly important. From the research evidence, interacting skills result from high degrees of automation in the companies surveyed. Automation does not limit interacting requirements to highly skilled workers but to all levels of workers. The data also show that digital skills need to be added to the job-specific skills, not the other way around. The consequence is new skilling and recruitment strategies by the companies.

Consistent with other research in the manufacturing sector (Pfeiffer et al., 2016, 108-?), case studies undertaken in the UK incumbent West Midlands automotive manufacturing ecosystem highlighted the increasing importance of the interaction of digital and job-specific skills when handling Big Data (D8.1 company case study data, United Kingdom). In this ecosystem, automation, including robotisation, is prevalent in large car manufacturing companies, and the use of Artificial Intelligence (AI) is burgeoning. In addition, production processes in the Original Equipment Manufacturers (OEMs) are typically **fully or nearly fully automated**, so labourers, skilled technicians and engineers use digital devices in most aspects of their work. As a result, digital skills have become crucial for virtually all occupations and all skill levels (D4.1 regional ecosystems data; D8,1 company case study data, United Kingdom).

While basic to moderate digital skills often suffice for low- and medium-skilled workers, high-skilled professionals require advanced digital skills, especially engineers and high-skilled technicians. These digital skills interact with the field-specific knowledge of automotive manufacturing. For automotive engineers, high-level programming skills using specific software solutions that combine job-specific and advanced digital skills are already prevalent (D8.1 company case study data, United Kingdom). For technicians and maintenance workers, as more and more production processes are automated, there is a growing requirement for these workers to combine traditional skills from their fields of work with knowledge about how to calibrate machinery, understand sensors and adapt business processes (D8.1 company case study data, United Kingdom). The digitalisation of processes produces a large amount of data, and making sense of these data requires not only the analytical skills to handle Big Data but also the job-specific skills to interpret the output in a domain-specific way. For example, there is a requirement for ICT professionals to understand the manufacturing process for them to construct effectively, process and store Big Data and for engineers and skilled technicians to combine their domain-specific knowledge with sophisticated data analytics at all stages of the production process (D8.1 company case study data, United Kingdom).

Empirical evidence at the regional ecosystems and sectoral levels in the Rhine-Ruhr area in Germany similarly supports Pfeiffer et al. (2016) findings that digital skills are becoming more important **across all skill levels** in different occupations and fields of work (D8.1 company case study data, Germany). As numerous different types of sensors and other digital tools are being introduced into the steel-making process, steel plant operators are increasingly required to make decisions based on digital systems at the same time as drawing upon their own job-specific skills (developed from practical knowledge and work experience) (D8.1 company case study data, Germany). In the incumbent steel ecosystem in the Rhine-Ruhr area, digital control of the different steps of the steel-making process has been standardised, and an increasing number of operators, technicians and engineers now use at least one kind of digital device or more when doing their work. Consequently, highly skilled professionals, especially engineers and high-skilled technicians, need to understand and modify specific software solutions in the steel-making process, thus needing a combination of their job-specific and advanced digital skills. In contrast, technicians need to be able to interpret digitally-monitored sensor readings and understand digital networks and related cybersecurity issues. Furthermore, more technicians need specific basic programming skills (D8.1 company case study data, Germany).

The second regional workshop supported this requirement to combine job-specific with digital skills within individual workers with the steel ecosystem, where, for example, one expert stressed that **up-skilling the digital skills of workers in the region alone would not be sufficient** as the digital skills can only be put to use in combination with an in-depth understanding of the process of steel-making in place in the particular steel plants in conjunction with the practical experience gained on the job. Only then can advantages arising from the uptake of digital technologies for the specific process be identified, adequately evaluated and implemented (D4.1 regional ecosystems data, Germany). In the first round of workshops in Germany, participants also predicted that both metallurgists and IT experts would be needed, but ideally, those skilled professionals who can combine both specialisations, underlining the importance of the interaction of skills among the high-skilled occupations (D4.1 regional ecosystems data, Germany). One expert reported that experienced workers in a cold rolling mill who make work decisions based solely on advice derived from digital tools resulted in lower output at the plant. In the BEYOND 4.0 project, various sentiments expressed by experts at the inter-regional workshops confirm that should companies find themselves with workers without the right mix of digital and job-specific skills, this can be costly (D4.1 regional ecosystems data, Germany).

Similarly, a logistics company in the emerging Dortmund Ecosystem reported looking to recruit professionals with specific combinations of several different categories of skills. For example, in the administration of one of the logistics companies interviewed, basic skills of using the software MS Office in combination with more general moderate digital skills have been required for most administrative jobs, while more specific digital solutions for personnel administration and accounting more explicitly require a combination of specific digital skills in using these software and accounting/administrative skills (D8.1 company case study data, Germany). In other departments in logistics companies, such as the IT department, advanced digital skills must be combined with job-specific skills in delivery logistics. For example, one company was looking to recruit an IT expert where the job posting specifically mentioned how the successful applicant would need to have, in addition to advanced IT skills, process-related knowledge specific to the logistics sector (D8.1 company case study data, Germany).

In the Netherlands, the company case study research revealed that salespeople who are experts in the sale of maintenance parts now apply a software tool to help them proactively evaluate customers' purchasing needs. This partly standardised tool allows salespeople to make offers to clients quicker and more efficiently. This, in turn, increases the number of offers that can be produced. In addition, there are special offers to be developed by the salespeople that require the expertise to make client-specific evaluations. To do this, the salespeople must bring together their job-specific knowledge and proficiency in using the purchasing software (D8.1 company case study data, Netherlands).

4.2 Digital and methodological skills

In the context of digital transformation, a high complementarity between digital and methodological skills is recognised (Gonzalez Vazquez et al., 2019, p. 32). For example, the international PIAAC study explicitly analyses ´problem-solving´ in technology-rich environments, exemplifying the interaction of methodological and digital skills. Furthermore, PIAAC examines which information-processing skills people in OECD countries possess and to what extent these skills are required in the workplace (OECD, 2016d). These information-processing skills have been identified as fundamentally important for the digital transformation, as they are seen as the foundation for the development of more advanced cognitive skills. There was also shown to be a connection between literacy, numeracy and the ability to solve problems with digital technologies (OECD, 2016d, p. 34). Additionally, combining digital and problem-solving skills, critical thinking, and analytical skills become more important in complex digitalised work environments.

The combination of digital and methodological skills was confirmed as important in the German logistics sector. For example, one expert in the German logistics ecosystem provided an example of a company job vacancy for a Scrum Master that described requirements for the successful applicant to have not only skills in agile methods for the digitalisation of processes but also the methodological skills of a Scrum Master (D8.1 company case study data, Germany). Other methodological skills are also directly related to digital skills. For example, the handling of Big Data means that companies also urgently need people who have the skills to evaluate and combine data at a very high level of abstraction, making complex analytical thinking necessary to use the advanced digital skills needed for Big Data analysis. Ultimately, people are needed who can understand how different digital processes come together and how they can be used in the best possible way in a specific complex company setting (D8.1 company case study data, Germany). A similar argument emerged in the Finland and Germany's inter-regional emergent ecosystems workshop**.** During the workshops, experts mentioned problem-solving as important for further implementing higher degrees of digitalisation (such as automation) in warehousing logistics, where the highly complex digitalised processes create challenges for automation and further digitalised processes from their complexity. Finding solutions for these complex problems and improving technology implementation requires both methodological and digital skills on the part of the employees (D4.1 regional ecosystems data, Germany).

Another example, this time illustrating the interaction of **advanced digital and entrepreneurial skills**, was evident in one of the German company case studies in media logistics. In this instance, data engineers require digital skills (data analytics) and entrepreneurial skills to be able to construct databases that are then used to identify potential new business opportunities. For example, an interviewee in the German logistics ecosystem observed that in the future, employees would be expected to possess skills in handling data and demonstrate proficiency in evaluating data. For example, highly qualified logistics employees of the future will need to act as data scientists in the sense that they will need a profound understanding of how data can be turned into usable business intelligence (D8.1 company case study data, Germany).

A similar need for combining digital skills and entrepreneurial skills, such as knowledge about business models, was reported by the experts in the business process outsourcing sector in Sofia (D4.1 regional ecosystems data, Bulgaria). Experts identified the requirement for IT specialists working in the sector to have not only good IT skills but also an understanding of the needs and business model of their clients (D4.1 regional ecosystems data, D8.1 company case study data).

Within the UK's advanced automotive manufacturing and engineering sector, automation is prevalent within the larger organisations with the resources to develop technology and engage with digital advancements. The workforce needs interacting skills, including **job-specific, methodological and digital skills**. Interviewees from the UK company case studies noted that automation technology in the automotive manufacturing and engineering sector is advancing in the larger multinational organisations in the sector (D8.1 company case study data). These changes have occurred due to moving away from combustion engines to the development of electric vehicles. Industrial and collaborative robots need a skilled workforce that can operate alongside robots, maintain and repair robots, and programme and re-programme robots to respond to changing manufacturing requirements. There is a growing demand for those with particular skills to support the sector advance in vehicle electrification. However, UK interviewees also reported a need for skills in data analytics to interpret data output from the automated process, plus AI to support future developments (D4.1 regional ecosystems data, D8.1 company case study data, United Kingdom).

In health and social care, digitalisation reportedly impacted jobs at all skill levels. The pandemic hastened the uptake of digital technologies and new ways of working (D4.1 regional ecosystems data, United Kingdom). While digitalisation of health care services means that patients may be able to access health services more easily, those involved in health administrative and support services now, in addition to their using their **occupation-specific skills, need to use their problem-solving skills** to manage digital appointments and digitised patient health information systems. At the higher end of the skills spectrum, increased automation and machine learning (AI) has increased the extent of e-diagnostics, requiring new or different problem-solving skills. Consequently, UK health care professionals must combine their methodological skills with digital skills to arrive at their diagnoses. In addition to the creation of new roles in the field of health analytics, the need for patient privacy has meant that new roles have emerged, which include the need for data security and cybersecurity skills, thus combining **information-processing skills with digital skills**.

4.3 Digital and social skills

The OECD identifies social and emotional skills as crucial to enabling the effective use of digital technologies by all individuals in their daily lives (OECD, 2016d, p. 4). Digitalised working environments also increase the demand for combining digital and social skills. Social skills such as coordination and collaborative skills have been found to complement digital skills (OECD, 2016b). For example, OECD research shows that higher use of digital skills at work is associated with tasks requiring more interaction with co-workers and clients, problem-solving, and less physical work (OECD, 2016c, p. 10). With the digitalisation, interdisciplinary teamwork is becoming more frequent, especially when teams are working on digital solutions from different perspectives. These work arrangements make digital skills necessary to deal with the technological side and social skills to make the teamwork successful. As communication takes place through digital media more often, communication skills are used in combination with specific digital skills. When the Covid-19 pandemic hit, digitally-aided communication became increasingly relevant for workers across a wide range of occupations, so the interaction of digital and social skills became increasingly important as many people started working from home for the first time.

In both German ecosystems**,** the combination of social skills with digital skills was highlighted, particularly in more highly qualified areas, where projects aiming at digitalisation are becoming increasingly important. The digitalisation of processes not only increases the demand for digital skills of medium and high-skilled employees in production, but it also causes changes in the way that work is organised so that more skills in communication and collaboration are needed for the joint work between the different occupational domains. For this, work in **interdisciplinary team-working** is common and brings up challenges for workers at a variety of levels. One of the examples is the cooperation between an IT developer and an employee from the marketing department in the anchor company of the logistics ecosystem, where both needed their **advanced digital skills and communication and team-working skills** to find a common process of problem-solving and project development. (D8.1 company case study data, Germany).

A trade union representative in the German steel ecosystem provided one example of combining digital skills and customer contact. Engineers now have a higher degree of direct contact with customers as digital technologies mean that **customers can influence production** process specifics. Thus, their digital skills of handling the digital technologies of production adaptation need to be combined with the social skill of customer communication. The increase in demand for these types of social skills is so strong that **education programmes** in the company are being adapted for engineers and medium- to high-skilled technicians (D8.1 company case study data, Germany).

A similar shift in skill demand was observed in the Finnish ecosystem of wood procurement. For example, within the international company, digital skills and communication and negotiation skills became important for employees working in harvesting and transportation as their jobs require them to manage the subcontractors using company-wide software. Similarly, clerical employees in wood-procurement industries need to be multi-talented, which includes social skills such as communication and negotiation skills (next to entrepreneurial skills) (D8.1 company case study data, Finland).

Also, in the Bulgarian ICT ecosystem, experts noted how the high-skilled ICT experts increasingly needed good communication skills to perform their jobs (D4.1 regional ecosystems data, Bulgaria).

While in the machine tool sector in the Basque country, the company skills survey findings revealed that half of the workers surveyed affirmed the importance of the interaction of job-specific skills in conjunction with social skills (D8.1 company case study data, Basque Country).

Another interaction between social and digital skills was reinforced during the **COVID-19 pandemic**. The situation under lock-down conditions required many workers to change to remote working, which among other changes, also included a shift from face-to-face to virtual meetings. Employees had to acquaint themselves with online digital tools such as MS Teams or Zoom to organise social interaction with digital tools. On the other hand, social skills for interacting via these digital tools and the specific requirement to make this type of communication productive need to be adapted. Our analysis of the empirical data identified that this interaction of social and/or personal skills with digital skills emerged as important during the Covid-19 pandemic across all ecosystems (D8.1 company case study data). For example, in the UK health care sector, the shift to remote working required workers at every skill level to not only become proficient in using digital tools such as Microsoft Teams or Zoom to participate in virtual meetings but also to use these tools to schedule medical appointments, make diagnoses, and develop treatment plans. While digitalisation of health records was already underway before the pandemic, arranging treatment for patients without face-to-face interactions required a new level of interaction of social and/or personal skills with digital skills; digital combined with communication skills, in particular.

4.4 Digital and personal skills

Among the empirical examples of the interaction of different skill categories is the recurring need for interacting digital and personal skills. Continuous change and adaptation of new technology within digital transformation processes demands workers to keep up with change and being able and being open to change and learning. The personal skill of **adapting to new situations** often comes along with the need to use new digital technologies. Also, the skill of being able to **reflect on one's knowledge and skill gaps** is increasingly needed in digitalised work environments and becomes more relevant for all skill levels (see section 3.2).

In interviews with stakeholders in the Steel and Logistics ecosystems in the Rhine-Ruhr region in Germany, demand for both digital and personal skills was often mentioned as a **prerequisite** for various types of jobs (D4.1 regional ecosystems data, Germany). On the topic of the skills in high demand among low- and medium-skilled operators, one company representative, said that their workers need to be punctual, hard-working and reliable. While employers wanting their workers to have these attributes is not new, it tells us that personal skills remain important during the digital transformation process. The same expert went on to say that these same operators need to be open and able to learn to control machines with a digital mobile device (industrial tablet) (D8.1 company case study data, Germany). Representatives of the anchor company viewed the ability to adapt to change and continue learning new things as fundamental for metallurgical engineers and IT specialists. This was because these workers were responsible for inventing and implementing digital solutions in the production process. The combination of digital skills and adapting to change was also viewed as important for workers in the administrative departments of this company (D8.1 company case study data, Germany).

Overall, digitalisation is associated with **uncertainties** for many actors in the German logistics ecosystem, not only in the corporate context. Therefore, awareness raising and sensitisation of the actors for digitalisation also play a role. Furthermore, curiosity and, once again, openness are important so that workers and management gain an understanding of the potential benefits of digital technologies (D8.1 company case study data, Germany). In this respect, the personal skills related to curiosity about new technologies, enthusiasm about opportunities that arise from such technologies, and the willingness to learn new things were also identified as being necessary by the company representatives in the German logistics ecosystem (D4.1 regional ecosystems data, Germany).

At a more fundamental level, basic skills such as numeracy, literacy and language skills are to be understood as **prerequisites for digital skills**. From the point of view of the Steel and Logistics ecosystems in Germany's Rhine-Ruhr region, language skills (in this instance, German language skills) are needed so that workers can undertake digital (and other) skills training. Moreover, while some migrant workers have well-developed digital skills, a language barrier can make it difficult for those without German language skills to find jobs or, if they do, to effectively communicate with their colleagues and supervisors (D4.1 regional ecosystems data, Germany). An example of this problem was mentioned by a German expert who participated in one of the regional workshops. When discussing the large proportion of applicants from migrant backgrounds, the expert observed that while digital skills would be important, there was a step before that, namely the language component (D4.1 regional ecosystems data, Germany). This was identified as an issue in Duisburg, where there is potential for quality people, including skilled workers, yet this was not possible due to the lack of (German) language skills. Instead of being able to employ migrant workers in skilled jobs, they tend to end up in unskilled positions. They are often prevented from utilising their digital skills due to deficits in their corresponding personal (language/communication) skills (D4.1 regional ecosystems data, Germany).

5. Interaction of different categories of skills on the supply-side

This section discusses the supply side of skills by presenting examples of how education and training providers (including companies) respond to emerging new skills requirements resulting from digitalisation.

Digitalisation is a significant challenge for the supply of workforce skills, not only in traditional skills policies aimed at formal training but also in relation to up-skilling and re-skilling of the existing labour force. Education and training providers face the challenge of providing graduates with qualifications suitable for the current labour market, as well as trying to anticipate constantly changing conditions and future skills requirements ((Felstead et al., 2013)). Skills policies also need to equip workers with skills that help them adjust to within-occupation changes in task requirements and to facilitate transitions into occupations in the same organisation or sector so that workers can move into different occupations or sectors (Geel & Backes-Gellner, 2011, p. 21). This introduction maps the actions in national skill policies and the degree to which they accommodate interactive skills development.

National skill policies on digital skills

Policies addressing skills mismatches tend to focus on improving supply systems to respond to labour market needs. National policies aimed at development of basic digital skills in the general population work on the assumption that many of these basic skills are learned either in early education or in the home (for example, through internet and mobile phone use). While the provision of moderate and advanced digital skills is mainly provided through the education and training pathways offered by educational institutions. Education and training systems play a key role in training new entrants to the labour market to help them acquire and develop the right skills. The six countries in the BEYOND4.0 project have plans or strategies in place that, in one way or another, aim to improve the supply of digital skills on the labour market.

- In **Germany**, the federal and state governments are jointly strengthening digital skills. The **Digital Strategy 2025** includes initiatives to support education providers, adult education institutions and companies in providing digital skills. In addition, the Federal Ministry of Education has introduced the **VET4.0 programme** to ensure that vocational training graduates acquire digital skills, taking full account of the effects of digitalisation on the qualification and competence requirements of qualified professionals.

- The Digital Strategy in the UK has established a new Digital Skills Partnership to provide digital skills training. In line with the **Lifetime Skills Guarantee,** the Government provides access to new digital skills qualifications.

- In **Finland,** the **Artificial Intelligence Programme** aims to strengthen the role of lifelong learning and adapt education and training systems. The VET system has been reformed, and digital competencies are included in the vocational and general units of the qualification requirements. The reformed Finnish VET system is aimed at work- life-oriented learning outcomes; skill provision is strongly connected to practical work tasks and the skills requirements of employers.

- In **Bulgaria,** the **Digital Bulgaria 2025 National Programme** fosters the modernisation of schools and higher education providers, as well as the improvement of the digital skills of the workforce through upskilling and reskilling programmes. Furthermore, the newly launched **Strategic Framework for the Development of Education, Training and Learning in the Republic of Bulgaria (2021-30)** places VET on the agenda.

- In the **Netherlands,** the **Dutch Digitalisation Strategy 2.0** focuses on digital skills and infrastructure development. One of the priorities within this strategy for the education system is to strengthen digital literacy and practical skills in both primary and secondary education. In addition, the country has a systematic process and structure (of committees) to convert (digital) developments in occupations into national VET qualifications (Westerhuis, 2020, p. 29).

- In **Spain,** the **National Plan for Digital Skills** addresses a variety of challenges related to digital inclusion, access to technology, and lifelong learning. The **Strategic Plan for Vocational Training in the Education System 2019-2022** includes a module on applied digitisation in VET programmes.

The Cedefop report series "Vocational education and training for the future of work" provides deeper insights into national education/4.0 strategies for most European countries (e.g. Huismann, 2020; Westerhuis, 2020). Cedefop analyses how basic digital skills are integrated into initial VET systems across European countries to provide additional insights into the teaching strategies for digital skills in the different IVET programmes in the various EU countries and sectors (Cedefop, 2020b). However, the Cedefop review found that digital skills are still being taught as a stand-alone subject in 28% of the IVET programmes. In just under half (47%) of cases, digital skills are imparted as a distinct key competence rather than being taught in combination with occupation-specific competencies. There are, however, several examples where digital skills training has been integrated into the occupation-specific training, as 35% of the analysed IVET programmes were found to provide combined training. The combined training can help meet the demand for interacting skills, as shown in section 4. The data of the BEYOND 4.0 shows observations how interacting skills are currently addressed by education and training providers (incl. companies).

5.2 Empirical findings on skill supply

This section of the report presents empirical results about supply-side skills issues at the level of regional entrepreneurial ecosystems and companies (drawing from data generated in WP4 and WP8). This includes examining how companies, employment offices and other actors in the respective ecosystems are working with vocational education and training systems (and, to a lesser extent, via higher education) to tackle skills shortages. Opinions and observations gathered from experts in the regional ecosystems about how they perceive the responsiveness of their respective VET systems and how companies and stakeholders in the ecosystem react are presented. Additionally, the WP8 Company survey's findings exemplify skills supply issues identified in the analysed regional ecosystems.

If we look at what is happening in the workplace, the data obtained from the companies studied in the different ecosystems analysed in BEYOND4.0 indicates some room for improvement of training. Less than one-in-ten (10%) of respondents to the WP8 survey of workers in jobs at the digital frontier felt that their previous training was perfectly suited to the requirements of their current job. Some two-fifths (40%) of the respondents believed that their previous training was not suited to the requirements in their current job; the remainder reported that their previous training was adequate for them to perform their current job (Dhondt et al., forthcoming).

However, the empirical work of WP4 and 8 reveals inherent differences in how issues around the demand for skills and issues around the supply of skills are understood. Experts from the regional ecosystems were better able to articulate the details about the demand for certain skills categories and we could clearly see a need for interacting skills but the experts were less able to articulate what responses were required to address the supply-side issues. This is true at least with regard to the responses required by the education and training systems to address changing requirements related to individual skill categories and interacting skills. Although the picture is gradually emerging as to which skills are becoming more important in the digital age, it remains unclear how and by which institutions these skills could be taught in the future (Interviews company expert, German steel sector).

In a first step, we present here the findings on how and to what extent the necessary digital skills are taught as this is the category of skills most discussed by the experts in the ecosystems in terms of skills supply. We then go on to explicitly discuss how the clear need for interacting skill for the digital transformation are acquired by the workers.

Companies as training providers for digital skills

Experts raised a general issue from several ecosystems: the response of education and training systems to changing requirements, which cannot keep up with the fast change of technologies and their impact on skill requirements.

In the German steel and logistics sectors, for example, specific demands for digital systems and programmes change so quickly that vocational training providers cannot fully prepare workers for workplace skill demands (D4.1 regional ecosystem data, Germany). At the North Rhine-Westfalian regional workshop, a company representative stated that while VET systems had to adapt their programmes to the technological change, skills were already outdated when this process went through (D4.1 regional ecosystem data, Germany). Also, in Finland, the problem in the educational system is that it **reacts slowly to change**s and demands in the labour market and processes to change curricula and educate students are slow. Therefore, it is important to develop further possibilities to **provide continuous and life-long learning**. In fact, the Centre for Continuous Education, a joint venture between the Finnish Ministry of Education and Culture and the Ministry of Economic Affairs and Employment, is attempting to tackle this issue. Due to the slow responsiveness of VET systems, digital content is often taught within the companies and, therefore, necessarily in a **company-specific manner** (D4.1 regional ecosystems data, Finland). A further example from the German steel ecosystem one of the surveyed companies provides specific training to meet the demand for digital skills to compensate for skills gaps left by the VET systems. The company does this by adding a two-month module on digital skills to the standard VET curriculum, for example. This is possible as the German dual apprenticeship system leaves some leeway for companies to adapt their own parts of the training.

Another **challenge for companies is to find suitable applicants** from the labour market. While there are recruitment challenges independent of those specific to digitalisation, difficulties in recruiting workers with the right combination of skills leave companies with little choice but to increase their focus on in-house workforce training and development (D8.1 company case study data, Germany). Therefore, in-house training plays a major role in the German steel sector. Representatives of large steel mills emphasised that investment in internal training of their workers was attractive due to the above-average length of company job tenure. Comparable findings can also be found at one of the large Dutch companies analysed in the project (D8.1 company case study data, Netherlands).

Company approaches to teaching interacting skills

Companies increasingly rely on lifelong learning and in-house training given the challenges of digital transformation. This fact is also reflected in the ways interacting skills are acquired. This applies above all to the combination of digital and job-specific skills. This combination of needed skills can often be company-specific or even process-specific. Here, the structure of a dual education system offers the possibility to combine job-specific skills taught by the VET system with the specific skills that play a role in the company. This is highlighted, for example, by experts in the Basque Country, who point out that through the dual system, apprentices learn not only job-specific skills but also internal company processes and the importance (and practical application) of digital and social skills in the workplace (D4.1 company case study data, Basque Country).

Another example of the importance of retraining employees to grow and make use of company-specific knowledge can be found in the German steel ecosystem (D4.1 regional ecosystems data, Germany)**.** During the second workshop, one expert stressed that up-skilling the digital skills of the region's workers would be insufficient because the necessary digital skills can only be put into use in combination with an in-depth understanding of the process of steel-making in the particular steel plants and the employees' experiential knowledge. It was contended that only then can advantages arising from digital technologies for the particular process be identified, adequately evaluated and implemented (D4.1 regional ecosystems data, Germany). This is fully in line with the findings of Pfeiffer et al. (2016), who came to similar conclusions for the (German) machine and plant engineering sector. That is, certain **process-related skills cannot be bought in the labour market**. It is a work-based experience, and it is needed, which shows the **importance of retaining**, rather than replacing, current members of the workforce so that the organisation retains valuable organisational knowledge.

In one logistics company in the Dortmund ecosystem, logistics specialist apprentices receive project-based training within the company via internal company projects, where conveying job-specific skills plays the main role, including the development of an understanding of logistics in light of the company's processes, but is combined with training advanced digital skills for developing simple software solutions for the company in one line of projects (D8.1 company case study data, Germany). As the company is large, various projects are underway involving apprentices at any time, including another project on waste disposal and avoiding waste, one on process optimisation and usage of existing equipment next to the one on simple programming of IT solutions needed in the company processes that is aimed at training the advanced digital skills. The goal of each of these projects is to create value for the company through the solutions the apprentices come up with; at the same time, teaching apprentices how to apply their new-gained theoretical knowledge and deepen their job-specific and green skills in their practical work. They also develop a better understanding of company processes. At the same time, the apprentices are provided with the opportunity to practice the types of social, personal and methodological skills needed in the particular company, such as teamwork, taking over responsibility, and presenting results to company executives (D8.1 company case study data, Germany).

The anchor company in the German logistics ecosystem uses apprenticeship engagement in project work to teach interacting skills similarly. The training programme of the anchor company includes the subject of "database and programming" in training to become a digital and print merchant. As some apprentices showed an interest in learning about how to develop software, a project was formed that brought together apprentices from different departments (IT department, editorial department, and print and online merchant clerks), and an instructor then taught the apprentices basic programming skills that are needed for the company's internal processes. As a result of this project, the apprentices have learned skills around artificial intelligence (AI) by developing chatbots that improved the company's internal flow of information. In this project, the advanced digital skills to develop the software solution and understanding the interfaces of different types of software were taught as well as the social skills of interdisciplinary teamwork and communication skills and the methodological skills of creative thinking and problem-solving. These skills were necessary together with digital and job-specific skills to fulfil the project's tasks in a meaningful way (D8.1 company case study data, Germany).

In this company, apprentices are also confronted with the topic of digitalisation in addition to job-specific skills in other areas of the company beyond logistics. For example, a requirement in one of the apprenticeship projects in the editorial media area was to take over the responsibility for operating an Instagram channel and manage the company's online presence in this area for a year (longer, if proved successful). By participating in this project, the apprentices developed the job-specific editorial media skills and digital skills needed in the company by undertaking applied workplace learning rather than attending training sessions where learning takes place away from the workplace (D8.1 company case study data, Germany).

The skill supply gap of interacting skills between SMEs and larger companies

In the German ecosystems, pathways to providing interacting skills to the employees were only found in larger (logistics and steel) companies. The SMEs did not provide any information on further training approaches for teaching these skills; they were more oriented toward acquiring the necessary skills through appropriate recruitment channels.

Also, in the UK automotive sector**,** a key finding from the company case study research is that alongside required job-specific skills, the workforce needs a combination of non-digital and digital skills, including leadership skills, analytical/problem-solving, and communication skills (D8.1 company case study data, United Kingdom). Several interviewees recognised that digital skills, particularly in automotive automation technology, are in demand in the sector. Larger organisations in the supply chain that need these skills from their workforce typically have the resources to train staff and recruit internationally to fill any skills gaps. However, those lower in the supply chain, which are typically smaller companies, often rely on a small number of personnel to develop these skills and drive skills development within their organisation (often when the initiative to learn comes from those employees who have a particular interest in latest technologies). Those lower in the supply chain understand the importance of digital and automation skills in the sector, but it is not seen as necessary within their own companies. **Skills development is often constrained by resources** due to the size and nature of the companies lower down the global supply chains (D4.1 regional ecosystems data, United Kingdom).

Drawing upon the operation and development of larger organisations and those further up the supply chain in the sector evidence the need for the workforce to learn, maintain and develop their non-digital skills and digital skills. Job-specific skills are often learnt with training and whilst on-the-job; workforce job-specific skills develop as the job changes. Local stakeholders are trying to shift thinking within the **smaller companies** that often supply niche products into the supply chain to recognise the importance of developing leadership skills to drive change, particularly digital changes. This is because smaller companies are often family-run businesses and/or they have a very small management team (often only the owner), so if the owner/managers are unable to see the benefits that might arise from investing in technology, they are not likely to show the leadership skills necessary to drive change. Also, the average age of small business owners is typically older than the general workforce, and as experts at the second inter-regional workshop for the UK and Bulgaria observed, owners who are planning their retirement **are less likely to introduce new technologies before they retire**. This means that these small businesses are not likely to invest in implementing new technologies, so their workers will not be able to develop the skills required for working with such new technologies.

Data-driven health and life sciences and healthcare innovation in the UK**,** including acceleration of commercialisation of treatments, diagnostics, medical technologies and software as medical devices, all require healthcare workers to develop new digital skills. AI and data analytics are key to driving growth and scale-up success. New combinations of skill requirements are not restricted to high-skilled workers, as digital initiatives impact workers' tasks at all skill levels. While new entrants to the healthcare sector are gaining digital and job-specific skills during the Higher Education (HE) or Further Education (FE) courses, existing workers have to learn new digital skills on-the-job. The shift to digital service delivery during the Covid-19 pandemic has hastened digitalisation in the sector. While the UK National Health Service (NHS) is investing heavily in digital skills, the training needs are high as digitalisation impacts all health care sector areas. In addition to providing digital skills, the NHS faced the challenge of needing to provide large sections of its workforce with training around social and personal skills related to changing job requirements due to digitalisation. At present, it seems that efforts in the NHS are largely restricted to stand-alone digital skills training and occupation-specific professional development showing a gap in training interacting skills.

The presented examples reveal a **two-fold challenge for the supply systems**. On the one hand, the ability of companies to provide relevant digital and interacting skills training depends on the availability of resources (financial and time, in particular). This situation is likely to exclude many employees from developing needed skills. But, on the other hand, this company-specific way of providing skills for the digital transformation excludes those people who are not currently employed from necessary training. This trend bears a significant challenge for **the inclusive growth** agenda envisaged by the European Commission in general and by the project BEYOND4.0 specifically. Up- and re-skilling should facilitate inclusiveness, especially for members of vulnerable groups, but the stated policy ambition of inclusive growth is highly likely to fail if training and development opportunities are restricted to those currently employed in large companies.

Approaches to better skill supply

The Finnish ecosystem provides an example of how to offer interacting skills in a less company-specific way. In Oulu, a hospital, a university, and a university for applied sciences developed and established a campus to develop an ICT-based health sector in Oulu and the development of the 'future hospital'. This campus allows training programmes combining skills from the ICT and the health sector (D8.1 company case study data, Finnish healthcare ecosystem). Another example of providing interacting skills is the ETHAZI programme in the Basque country. It is part of a key initiative of the European Commission, the Centres for Vocational Excellence. A particularly noteworthy aspect of these centres of excellence is that the curriculum is designed so that learners can acquire both occupation-specific vocational and other key competencies. ETHAZI is a high-performance programme, a system of 'collaborative learning based on challenges', also known as problem-based learning. The model comprises eleven steps, based on teamwork, rotating challenges, learning as evolution, moving towards social innovation and self-managed teaching teams. The high-performance programme is a learning model designed to respond to local and future competence needs. The **ETHAZI model can be understood as a programme focuses on the interaction of different kinds of skills**, namely digital, personal, social, methodological and job-specific skills.

These last two examples show how stakeholders from different sectors of society (e.g. public, education and an emergent sector - private economy, health, etc.) co-operate at the regional level and thus respond to region-specific skill needs beyond company-specific solutions. Such an approach is close to the concept of **"regional skills ecosystems"**, where the importance of the context in which skills are developed and used is recognised. While interest in skill ecosystems has primarily been concerned with understanding and promoting high-skill ecosystems, there exist merits in improving ecosystems for workers at all skill levels, including those with low and middle-level skills (see (Buchanan et al., 2017).

In this context, the results of the qualitative ecosystem analysis of the BEYOND4.0 project also emphasise that specific sectors and **regional skill structures are of great significance**, requiring region-specific approaches and the collaboration of different stakeholder groups. Furthermore, after the importance of the interaction of skills has been emphasised by empirical examples in this report, the potential of such regional skill ecosystems should also be examined regarding the systematic and far-reaching use for teaching interacting skills.

It is noteworthy that only a couple of examples of 'good practice' supply-side responses to the need for interacting skills emerged from the empirical data. There may be a number of reasons why these types of examples were not forthcoming. One reason may be that the companies are not yet fully aware of the need for interacting skills. The importance of this issue of the need for interacting skills was only identified by the BEYOND 4.0 researchers, post-hoc, after having analysed the data generated by the fieldwork undertaken in WP4 and WP8 analysing the various data sources generated by WP4 and WP8. At this stage, it became apparent that these are indeed interacting skills that are needed for digital transformation. Finally, the examples presented showed that while training may sometimes deliver the necessary combinations of interacting skills, this may not have been due to a conscious decision by training providers or employers. Moreover, there was scant evidence of interacting skills being delivered systematically.

Finally, it was evident from the empirical research that neither company managers nor workers were adept at providing details about their skills demands and supply issues. Not only did there appear to be problems with how skills are described (that is, often very generally), it was apparent that both sides of the skills equation (demand and supply) were not systematically monitored or audited at the company level. While policy initiatives to tackle skills at the regional level are in place in the regions, unless companies work closely with education and VET providers and regional authorities, it is likely that the skills required to adapt to digitalisation will remain lacking.

6. Summary and conclusions

The European Commission's objectives for the digital transformation are laid out in the Digital Compass and put both people and the European economy at the centre of the strategy. The BEYOND4.0 general skill framework is aligned with this perspective. The main stakeholders that define skill demands for the digital transformation are employers and employees. Both perspectives are important for understanding future skills. Empirical research from the BEYOND 4.0 Work Package 4 on regional ecosystems and WP8 on company cases were the main units of analysis. Perspectives from a range of stakeholders from the regional, sectoral and the company level were combined to provide insights into both the demand side and the supply side of skills for the digital transformation. In the company cases, efforts were made to include both employer and employee perspectives.

To better understand the demand for future skills (and their supply), beyond the literature analysis completed for the earlier versions of deliverable 6.1 (see Kohlgrüber et al. (2020); Kohlgrüber et al. (2022); first and second report), this report analysed data generated from work packages 4 and 8 by applying the Beyond 4.0 skills categorisation and the general framework. The approach to theoretically differentiate between tasks and skills proved helpful to detect changes in skill needs arising from the digitalisation of tasks, where the empirical data confirmed that different combinations of skills are required to perform newly configured tasks. Moreover, each of the overall skill categories was applied in the analyses, which proved useful in differentiating between the level of different separate and interacting combinations of skills required for digital transformation. The analysis was undertaken by comparing the various characteristics of regional ecosystems, related sectors, and companies in six countries. While some of the data generated by the other two work packages were not sufficiently detailed enough to capture the exact nature of the changes in skill needs at the level of single jobs, it was useful, nevertheless, for validating the classification by way of generating illustrative examples of skills demand and supply issues, skills-matches and gaps.

Key Findings

Regarding the individual skill categories, it was not surprising to find that the research confirmed that at all levels, **digital skills** would continue to remain important in the future. Various examples and observations garnered from the research undertaken in Work Packages 4 and 8 support this finding. The examples ranged from the basic digital skills required to use smartphone-like devices to steer machinery; to moderate-level digital skills required to use software like Microsoft Excel; up to examples illustrating the demand for advanced digital skills when developing tailor-made software solutions for factory set-ups in steelmaking or advanced manufacturing. To put it simply, **digital skills will be required in more jobs for more tasks**. Significantly, however, digital skills on their own will not suffice. Social, methodological, personal and job-specific skills are also increasingly needed to work in digitalised workplaces.

Social skills become increasingly important in more jobs. Digitalisation in companies requires demanding interdisciplinary teamworking skills and communication as workers are increasingly involved in collaboration with colleagues from other teams/occupational disciplines, who may have different communication cultures. While intensive customer contact requires advanced communication skills and negotiation skills.

Methodological skills arise mainly from the increasing need for problem-solving skills, creativity in finding new solutions, and analytical skills in digitalised work environments. At the same time, basic skills such as language skills, literacy and numeracy are also increasingly needed for migrant workers and low-skilled workers so they can adapt to digitalised work.

Personal skills are important as digitalisation brings with it accelerated technological and organisational changes. Skills like adapting to change, self-organisation and self-reflection, identifying own skill gaps and being open and able to learn new things has become increasingly required in digitalised work environments.

While **job-specific skills** are not explicitly considered as relevant for the digital transformation in literature, they remain important, as it continues to be indispensable for workers to have in-depth knowledge of production processes so they can understand, control and improve these processes in the best possible way. However, these tasks increasingly involve digital support via sensors and require skills to evaluate the data generated by these digitalised processes.

Our empirical findings are strongly aligned with the findings arising from the literature reviews carried out as part of producing the first and second reports of deliverable 6.1. What is largely new, however, is **the realisation that these skills are not only needed individually but that the interaction of skills is of considerable importance for digital transformation**. This means that skills from at least two apparently separate skill categories are needed to perform a task, and so these different categories of skills must be combined with each other to be able to perform the task competently. This has turned out to be a key finding in the evaluation of WP4 and WP8 results with regard to the future demand for skills.

This paper has drawn together a range of illustrative examples from the BEYOND 4.0 research that demonstrate how these interacting skills are increasingly needed in the ongoing digital transformation of the workplace. Tasks which require job-specific and/or methodological, social or personal skills are increasingly supported by digital tools, which makes the combination of digital and non-digital skills fundamental:

- when job-specific skills interact with digital skills because tasks are being worked that formerly did not involve using digital technologies;
- when technology-oriented jobs (for example, engineers) in production now entail dealing with customers directly (often online) because digital technologies facilitate the customisation of products and services;
- when increasing interdisciplinary teamwork requires both the skills to understand and make use of new technology as well as the social skills to communicate and work with people from different teams/ occupational disciplines; and
- when digitalised processes are shaped by experienced workers who can make use of the benefits of digitalisation when they bring together their digital skills, their job-specific knowledge, experience and skills, and their openness to change and innovate.

There are indications from the BEYOND 4.0 research that the digital transformation asks for both, **very specific interacting skills**, that is those skills that are only needed in a particular company setting and job, **as well as needs for more general interacting skills** that seem to be transferable. While the specific interacting skill needs are most likely to be supplied by company in-house training and on-the-job learning, it also seems apparent that more general interacting skill needs need to be incorporated into curriculum and training offers from the VET and HE systems.

Future research should address these skill gaps of interacting skills in more detail and identify which gaps can and should be filled by employers themselves, as opposed to those which occur frequently enough to make it viable for training in these interacting skills to be integrated into curricula of VET and HE programmes.

Table 2 gives an overview of the key findings of this report, including gaps between skills demand and supply and how to address such gaps.

When looking at the supply side of interacting skills in the ecosystems, we found examples of innovative types of training that was developed to impart these interacting skills. Often, these examples appear when companies have the resources and in-house capabilities to train their employees or where such skills can be acquired through on-the-job learning. In some instances, skills are provided through regional or local skills ecosystems, which was only possible because there was a very close exchange between VET providers and local companies. This made it possible for those who have leeway in the ecosystem to collaborate in developing targeted training offers (e.g. in the Basque Country ecosystems, the Finnish ecosystems and the German ecosystems).

The empirical examples from companies showed that they make use of a combination of teaching arrangements, but for interacting skills, they tend to rely on project-based and problem-based learning. In a number of examples, companies brought together employees from different departments and job roles. Other examples showed that companies also relied on on-the-job learning. While this approach may have addressed the needs of the company, it can make it difficult for these skills to be visible and externally certified. Nevertheless, these types of arrangements meant that once companies have identified a need for them, these skills can be delivered quickly and flexibly. Courses from third parties also formed part of the variety of learning arrangements. Here, the interaction of skills is taught less, and these courses do not tend to make use of problem- or project-based learning.

Table 2: Key findings

Interacting skills	Skill Demands	Skill Supply	Skills and inclusiveness gaps	Recommendations
Digital plus job-specific skills	Increasing demand for combining digital skills and work-based experience (e.g. with specific production processes now equipped with new sensors and digital systems)	Learning on the job is designed to offer company-specific additional training modules with the integration of job-specific and digital training	Digital skills and job-specific skills largely continue to be provided separately. Barriers to access for unemployed people, low-skilled workers and other traditionally disadvantaged groups	Reforming VET systems towards work-based learning where digital and job-specific skills are both integrated into curriculum/training offers
Digital plus methodological skills	Increasing demand for using digital tools for problem-solving, critical thinking, and decision-making (e.g. big data)	Project-based learning is designed to combine digital and methodological skills training	Barriers to access for unemployed people and other traditionally disadvantaged groups	Reforming VET and higher education systems toward work-based learning
Digital plus social skills	Continued demand for communication, team-working and leadership skills for digital collaboration across and between different disciplines/professional groups	Project-based learning in companies or regional training programmes	Only individual ad hoc examples, no systematic implementation of training or workplace initiatives to systematically address gaps resulting from the interaction of digital and social skills	(Further) Developing regional skill ecosystems who offer these interacting skills. Need for individuals to be able to recognise and talk about these skills.
Digital plus personal skills	Continued demand for personal skills to adapt to technological change	Offering attractive training to develop or enhance the personal skills required for working in an increasingly digitalised environment, e.g. developing apps or chatbots for youth in companies or employment measures	Limited offers to low-skilled people in companies	(Further) Developing regional skill ecosystems who offer these interacting skills Implementing learning and ex-ploration factories in companies and educational institutions Need for individuals to be able to recognise and talk about these skills

Recommendations

Based on the finding that interacting skills are mainly imparted within (large) companies, the question arises regarding how learning needs are to become a more regular part of workplaces and more systematically considered. And if so, how companies can be supported so they can design workplaces so that learning opportunities are improved and training available. Only then will companies, whether large or small, be able to use these skills most effectively.

The shift of the location of learning, taking place to a lesser extent in the formal education system and to a greater extent within companies bears the risk of leaving behind those not in employment or employed in companies with less leeway, resources and capabilities for developing their own in-house learning and training. There is a societal impact when more adjustments to new skill demands are taking place only in (large) companies rather than through the further education system, or by more openly accessible training providers.

Beyond the training efforts at the company level, the changes in work and skill demand induced by digital transformation need to be addressed by involving more stakeholders in the process of co-developing training. The VET systems and their organisations, policymakers, civil society and social partners are likely to be much more effective in developing adequate skill strategies when working together. This is particularly the case at the regional level, where innovation and economic development strategies are already being developed. As the skill demands depend very much on the direction and areas of innovation, a combination of innovation activities with skill activities seems most likely to be an effective way to adapt skill supply to skill demands, to reach a better understanding of skill shortages, and to address individual skills gaps and company, regional and sectoral skills shortages. Social policy effects of education and labour market developments are likely to be more inclusive when all of the relevant stakeholders collaborate on a joint skills strategy.

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