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SKILLS FOR THE FOURTH INDUSTRIAL REVOLUTION

A response to Industry 4.0 challenges

Master's Thesis
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Abstract of master's thesis

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Abstract

Many countries are now entering the stage of the Fourth Industrial Revolution, also referred to as Industry 4.0, in which technological advances enable significant changes in industry. Industry 4.0 will not only increase resource and time efficiency, it will also change the way people work.

The Universities of the Future (UoF) project aims to address the educational needs arising from Industry 4.0 in Europe by creating educational offerings in collaboration between industry, universities, and public bodies. To this end, the project takes two approaches: the identifying of skills required for succeeding in the Industry 4.0 environment, and a report on Industry 4.0 challenges and education focusing on Finland, Poland and Portugal. This thesis serves as part of that report.

One of the most important challenges is skilled labour scarcity, which has forced companies and countries to find novel ways to attract or create talent.

For every professional, a good understanding of their own discipline is the basis for job performance, but it is also necessary to have the curiosity and motivation to continue lifelong learning, and to have a wider vision that allows them to understand complex problems or situations. Mastering the scientific process and developing creative thinking helps develop problem-solving skills. In addition, everyday life requires working effectively and communicating with people from different backgrounds, and the possibility to learn from our peers. Particularly when developing technology for human use, the synergy of work with people from different disciplines and backgrounds is key. Human work in the fourth industrial revolution is not meant to be discarded, but its role must transform in order to thrive and find new solutions to increasingly complex challenges.

Keywords skills, competencies, Industry 4.0

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This work would not have been completed without the unwavering love and support of my awesome teammate in life, David, nor without the faith of my very own personal cheerleaders – my parents.

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1 Introduction

Many countries are now entering the stage of the Fourth Industrial Revolution, also referred to as Industry 4.0, in which technological advances enable significant changes in industry. The term was originally coined by Kagermann in 2011. Industry 4.0 will not only increase resource and time efficiency, it will also change the way people work. If Industry 4.0 is to become the standard in production, it is not for only a select few people to have the expertise to work in such an environment, but a better understanding of the skills required to work and implement it are necessary to democratize the knowledge among the future workforce. The underlying idea in this work, is for people to learn to work with, and complement, the new technology with the most important thing: the human skills that cannot be replaced.

At the moment there is limited understanding regarding the skills needed to work in Industry 4.0, particularly from the point of view of industry. Previous work on professional skills related to Industry 4.0 has been more oriented toward personality profiles for recruitment purposes rather than skills that can be developed in education1. This thesis, on the other hand, focuses on skills that can somehow be developed. What skills are most important for future professionals in the context of Industry 4.0? What, if any, initiatives are being created to address educational needs?

1.1 Universities of the Future Project

The Universities of the Future (UoF) project aims to address the educational needs arising from Industry 4.0 by creating educational offerings in collaboration between industry, universities, and public bodies.

To this end, this three-year project begins its activities with a report that serves to identify the skills required for succeeding in the Industry 4.0 environment, and Industry 4.0 challenges and education focusing on Finland, Poland and Portugal. This thesis serves as part of that report, where the efforts in the different regions in terms of education, up/reskilling the workforce, and a comparison of their educational/technological maturity and challenges is explored through a mixture of desk and field research. Subsequently, this report will be used as one of the two cornerstones to build a blueprint for future education, the other one being a benchmark on state-of-the-art education initiatives across the world.

As the first generations that grew up with digital technology as a regular part of their life enter the workforce, the differences in skills with non-digital natives become starker, and industry and public bodies face the challenges of upskilling and reskilling the workforce to address the inequality of opportunity through education. As this is the first time that an Industrial Revolution is predicted before the actual event, (Kagermann, Lukas, & Wahlster, 2011), there is an opportunity to begin to address the challenges of the digital era in anticipation of the coming change.

1.2 What is Industry 4.0?

Technologies driving Industry 4.0 are wearables, augmented reality, simulation, autonomous vehicles and robots, additive manufacturing, distributed ledger systems (such as blockchain), big data analytics, mobile computing, and cloud computing. These technologies affect and enable the creation of different business models, for example digital platforms (Hofmann & Ruesch, 2017) (Lu, 2017) (Abele et al., 2015) (Laiho, 2017).

Adding to these technologies, the following social and economic factors are also driving the Fourth Industrial Revolution: Telecommuting, emerging platform economies, more freelancing and consultant-style services, which are enabled by technology. While at the same time more people get used to this flexible kind of work, it also means that work relationships become more interdependent (Kilpi, 2016). Figure 1 below shows the paradigm shift in manufacturing, as the different social and market changes, combined with technological advancements, create added value in products, business models and processes, and human work is seen in a new light.

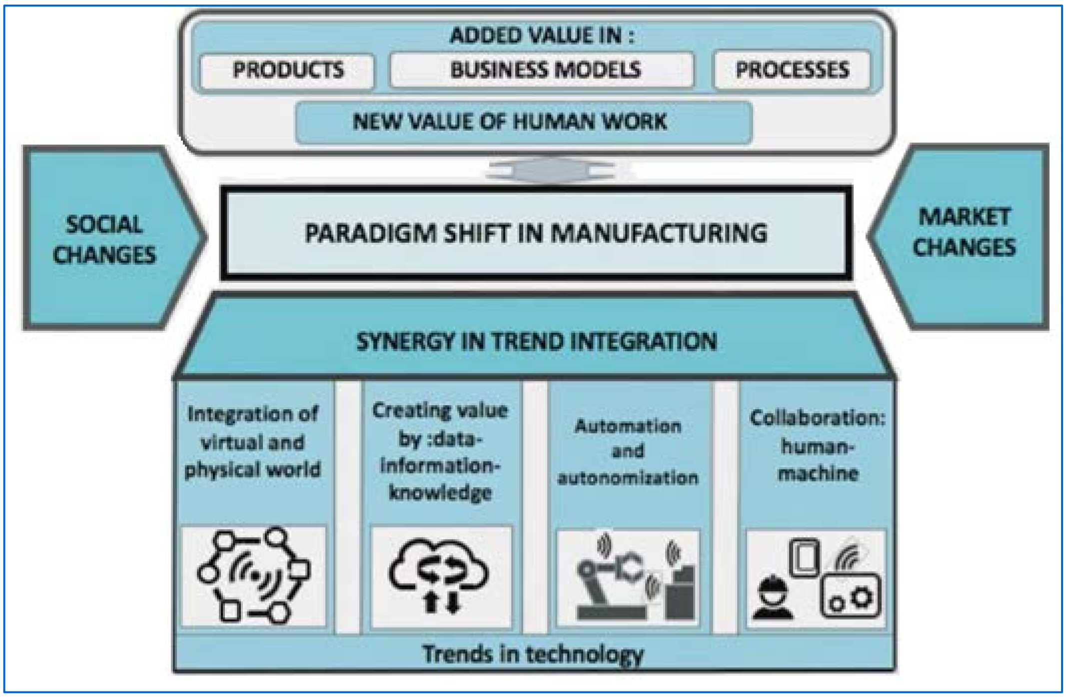

Figure 1 - Drivers of transformation in manufacturing

Business models are changing to become more *network oriented*, vs traditional vertical integration. As industrialization changes the economy from capital-intensive to knowledge-based, networks enable better cooperation for the creation and exchange of knowledge. (Möller, Rajala, & Svahn, n.d.) As companies and people begin to work in networks of value, the definition of value changes from being focused on the physical object, to the interaction and exchange that occurs between people.

Emerging markets shift the demand for products to their larger consumer markets and rising middle class, in addition to greater imports of intermediate goods for local production (Joonkoo Lee & Garaffi, 2015).

Other factors driving the fourth industrial revolution are: climate change and natural resources, geopolitical volatility, consumer , and privacy issues, young demographics in emerging markets, women’s economic power, and rapid urbanization (Gray, 2016).

Brought about by advances in technology and the Internet of everything, Industry 4.0 refers to the changes in industry that will allow for the creation of “smart factories”, vertical networks, and horizontal networks. The factory of the future will be a fully automated “smart factory” that will expand the roles of workers, moving beyond routine work that will require decision-making and a wider range of skills, thereby changing the way people work.

Smart factories are enabled by **cyber-physical systems** and the Internet of Things. Cyber-physical systems create a virtual copy of the factory through sensors and actuators

(Jay Lee, Bagheri, & Kao, 2015) which enables decentralized decision-making. Interconnections allow for collaboration between machines, between machines and people, and between people. A smart factory has an element of “consciousness” through artificial intelligence that enables it to make decisions about its own maintenance and manufacturing processes (self-optimized) (Hofmann & Ruesch, 2017; Qin, Liu, & Grosvenor, 2016).

Smart factories allow for **smart products.** A smart factory is able to track each individual product the factory produces, and at what stage of production it is, even in a mass production setting. Smart products “can store data about themselves” (Filho, Liao, Loures, & Canciglieri, 2017), communicate with the factory, and make decisions about their production process, transportation, and potentially post-sales use via RFID, sensors, actuators, and mobile phones. It allows for flexibility and customization, even for batches of one. This is enabled both by wireless and cloud technology and by the Internet of Things. In this environment, data mining, cybersecurity and communications standards that allow for modularity become essential (Hermann, Pentek, & Otto, 2016).

Industry 4.0 is also characterized by integration and **interoperability** (Lu, 2017). Interoperability is defined by the ability of systems to communicate and function with each other (Chen, Doumeingts, & Vernadat, 2008)

Vertical networks refer to the **integration** of actuators and sensors in systems. Robots and systems have self-learning capabilities (learn and produce own code), and the physical processes and computations affect each other continuously, gathering information and modifying behaviour as needed (Hermann et al., 2016). In this situation, the role of the operator changes and becomes more complex, as it becomes more about decision-making and problem-solving, rather than mechanical labour. Dangerous, difficult or highly unpleasant tasks can be done by robots and need less human involvement (Hermann et al., 2016). Vertical integration, from the point of view of information systems, also refers to the integration of the different management systems into the same format, and the same database (Lu, 2017).

Horizontal networks refer to the value networks between businesses, with suppliers, customers, and other support entities. An industry 4.0 customer could, for example, directly order and customize the kind of product desired, and know what is the status of production and delivery. There are, for example, factories that already allow customers to order personalized muesli or to colour-customize their soap (Hermann et al., 2016). Industry 4.0 allows for real-time information to be shared among different organizations, leading.to a more efficient use of resources (Qin et al., 2016).

Technological advances will bring about new opportunities to create and design new business models to offer solutions to the challenges presented by this new environment. Some of these challenges are:

- Technological and infrastructure resources
- Changes in business processes
- Training and education
- Organizational work, work design, and working culture
- Regulatory and legal issues

As for the technical and educational challenges, there is a great opportunity to tackle these problems through multidisciplinary, collaborative work.

1.2.1 Implications for society and education

This technological innovations are creating a greater transformation of work, where people and organizations become more connected and interdependent. Society as a whole needs to be better prepared to navigate this new environment, and so education becomes paramount. At the moment there is limited research regarding an overall view of the professional skills needed, particularly from the point of view of industry. What skills are most important for future professionals in the context of Industry 4.0?

1.3 Previous research, research questions and research gap

Professional skills, soft skills, or working life skills refer to non-discipline-specific skills needed to do a job successfully (Rautavaara, 2015). Passow and Passow (2017) provide a literature review on the skills required for engineering and compare them to the Washington Accord or ABET accreditation requirements (Passow & Passow, 2017). The ABET is an accreditation agreement for engineering programs in the United States and other countries. This was done to provide a comprehensive list of competencies, and their relative importance (“Engineering: Washington Accord | ABET,” n.d.). Rautavaara classified skills and provided an initial framework for professional and personal competencies, mostly based on ABET and McQuaid et al.(McQuaid & Lindsay, 2005).

An initial literature review on Industry 4.0 provided a starting glimpse on what the future of work would look like, with the corresponding skills. For example, discipline-specific skills such as data-mining and advanced analytics.

Previous work on skills related to Industry 4.0 has been more oriented toward personality profiles for human resource management (Cotet, Balgiu, & Zaleschi, 2017) (Hecklau, Galeitzke, Flachs, & Kohl, 2016) rather than skills that can be developed in education. Other work related to skills in Industry 4.0 has focused on teaching tools such as learning factories (Abele et al., 2015) for developing engineering capabilities. This thesis focuses on skills that can somehow be developed, whether through training, but also, for example, through a problem-solving approach (Kuhlmann and Sauter, 2008) which are most needed in the Industry 4.0 context.

1.3.1 Research problem and research gap

At the moment there is limited research regarding an overall view of the skills needed, particularly from the point of view of industry. What skills are most important for future professionals in the context of Industry 4.0? How do they relate to Industry 4.0?

1.3.2 Aims of the thesis

This thesis aims to identify the discipline-specific and non-discipline-specific skills required for Industry 4.0. The objective of the interviews will be to find those skills, and the reasons why, through an empirical process. Therefore, the objectives of this thesis are the following:

- To identify the competencies related to Industry 4.0 in literature
- To identify the competencies related to Industry 4.0 through an empirical study

1.4 Thesis Structure

This thesis aims to identify the discipline-specific and non-discipline-specific skills required for Industry 4.0, thus the structure of the thesis follows a narrative in which an overview of Industry 4.0 is introduced in Chapter 1.

Chapter 2 looks at the state of academic research related to skills and Industry 4.0, and creates a framework of reference for skills in Industry 4.0.

Chapter 3 takes a closer look at the research methodology and data gathering methods, including the development of the questionnaire, and the interviewee profiles. The objective of the field research is to obtain valuable insight from experts in the field, as well as enriching the information by considering the point of view of industry.

Chapter 4 presents an overall view of the state of maturity of Industry 4.0 of Finland, Poland, and Portugal, as it relates to education. This section sets the stage for the challenges and megatrends identified in the field research.

Chapter 5 presents the results of the field research as it relates to the type of skills needed in Industry 4.0, and relates them to the challenges identified in Chapter 4.

Finally, Chapter 6 contains the conclusions of the work.

1.5 Definitions

- **Baseline assets:** Basic skills like numeracy and literacy.
- **Basic income:** A national programme that guarantees minimum income. It aims to solve the problem of scattered income and enable people to take time to develop their skills or engage in entrepreneurial activities without sacrificing their financial stability.
- **Clusters:** A network of business organisations working in the same field to achieve better productivity. For example, clusters in the construction field would include suppliers and other related services.
- **Career account:** A national programme that counts benefits accrued throughout people’s careers, without having to restart them when changing to a new job.
- **Certifying platforms:** Platforms created for the purpose of certifying the skills people learn through informal processes.
- **Commercial awareness** or **business thinking:** The knowledge of basic business principles or awareness of commercialization possibilities.
- **Cyber-physical system:** Systems of sensors and actuators that create virtual copies, or digital twins, of the physical world.
- **High-level assets** or **high-level transferable skills:** Skills that create value for the organisation, and include professional competencies, teamwork, and commercial awareness.

- **Horizontal networks:** The value networks between businesses, with suppliers, customers, and other support entities. This is a type of integration between companies where value is created through collaboration, and the co-creation and exchange of knowledge. (Möller et al., n.d.)
- **Industry 4.0** the **Fourth Industrial Revolution**, where technological advances enable significant changes in industry.
- **Intermediate key assets** or **key transferable skills:** Transferable skills that include problem solving, adaptability, work-process management, and teamworking.
- **Internet of Things:** Objects that can communicate with each other, and with people, via RFID, wireless networks, the cloud, and mobile platforms.
- **Intrapreneurship:** A model for promoting innovation in companies, where management fosters and supports entrepreneurial thinking within the organisation.
- **Knowledge management:** the ability to obtain, evaluate, analyse, interpret, and apply information.
- **Metacognitive skills:** A set of skills that enable awareness of one’s own skills. They enable the creation of learning strategies and facilitate lifelong learning.
- **Peer-to-peer learning platforms:** Platform initiatives meant to empower people to learn from each other.
- **Platform economies:** Virtual platforms that enable the exchange of goods and services, lowering the transaction costs.
- **Professional competencies**: Knowledge, skills or attitudes needed to perform a job successfully (Rautavaara, 2015)
- **Real-time account:** A national programme that permits people to calculate their income in real time, for the calculating taxation or social benefits based on current income (without having to wait a year).
- **Smart factories:** Fully automated factories enabled by digital twins, AI, and IoT technology that permit decentralized decision-making.
- **Smart products:** Factory products that can interact with their environment and “make decisions” about their own production process, enabling customization and interaction with the customer.
- **Systems thinking:** Skillset related to having a wide perspective, knowledge of contemporary topics and cross-disciplinary knowledge to understand complex issues and how they might relate to each other.

- **Technology literacy:** Familiarity with modern engineering tools and how they can be used to solve problems. Also familiarity with the different engineering disciplines, and the modern possibilities of different technologies.
- **Transferable skills:** Sets of skills that can be used in many different settings and contexts. They include problem-solving skills, and personal skills.
- **Vertical networks:** Refer to the integration of actuators and sensors in systems.
- **Working life skills:** discipline-specific professional competencies and transferable skills needed to perform a job successfully

2 Literature Review

The objective of this section is twofold: to identify the competencies associated with Industry 4.0, and to create a taxonomy of skills to use as a reference for the empirical research.

Section 2.1 identifies the Industry 4.0-related competencies through a literature review on Industry 4.0. Peer-reviewed, academic papers on Industry 4.0 were retrieved from a university database, and classified according to themes. Within each theme, the different elements of Industry 4.0 were identified. By identifying its different elements, a general sense of the required discipline-specific competencies were induced. This search also uncovered the works related to Industry 4.0-related education.

To create the skills framework, the main literature used were mainly review articles on working life skills and skills for professional work (Hillage & Pollard, 1998; McQuaid & Lindsay, 2005; Passow & Passow, 2017; Rautavaara, 2015). Additional material was used for better definition of skills (Cornford, 1999, 2002; Pintrich, 2002; Schein, 1972; Schön, 1983; Senge, 1990; Turiman, Omar, & Daud, 2012; Weinstein & Meyer, 1994). This provided a very general overview on skills related to working life, and relevant to the field of technology. Section 2.2 covers the work on the taxonomy of skills.

In this report, the framework of reference for Industry 4.0 skills will be **working life skills**, which are defined as the knowledge, skills or attitudes that are needed to perform a job successfully(Rautavaara, 2015). This section will present a general overview of skills related to professional work with the aim to create a working life skills taxonomy. Working life skills refer to both **professional competencies and knowledge** as well as **transferable skills**. Figure 2 reflects the classification of working life skills in this report.

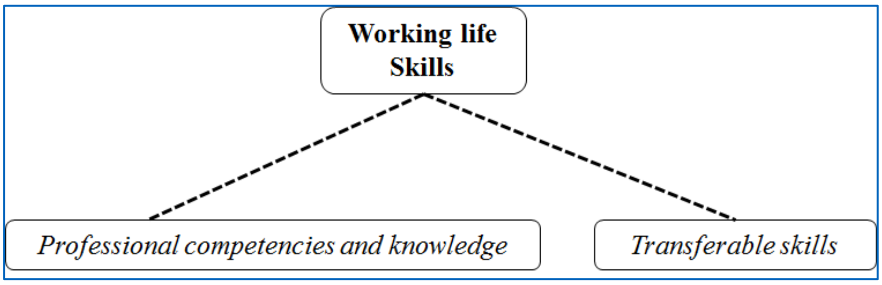

Figure 2 – Working life skills

Professional competencies refers to **discipline-specific** professional knowledge. This knowledge is combined with personal and “social-communicative” skills to enables people to take independent action(Cachay, Wennemer, Abele, & Tenberg, 2012; Erpenbeck, John; von Rosenstiel, Lutz; Grote, Sven; Sauter, 2017). Personal competencies will be explored in the Industry 4.0 literature review of section 2.1.

In contrast to discipline-specific professional competencies, transferable skills may be applied in many different professional settings and contexts. These skills will be discussed more closely in Section 2.2

2.1 Identifying discipline-specific competencies in Industry 4.0

The objective of this section is to find the Industry 4.0-related competencies by looking at Industry 4.0 literature.

After Kagermann et al. coined the term *Industry 4.0* in 2011, the amount of papers published on the subject increased exponentially.

The latest search in Aalto University's digital library returned two thousand papers which included the phrase Industry 4.0. Therefore, a search of articles with the phrase "Industry 4.0" in the title, and using "peer-reviewed" as a constraint was conducted. To these, the relevant scientific articles from Science Direct (defined as within the scope of the project, plus focusing on maturity models or skills sets) were added to the list. The term Industrial Internet is related to Industry 4.0, as it is defined as the technological advancements that will enable changes in all industries and services (Evans & Annunziata, 2012). In order to get more results, a search of Industry 4.0 + skills, and Industrial Internet (a term related to Industry 4.0) were carried out in the Aalto University's digital library, however this yielded only seven results more. The results of these searches are presented in the following sections.

These searches yielded a total of 195 articles. From these, 57 were discarded due to them being in a non-English language or being magazine articles, leaving 137. Table 1 shows the articles found in literature.

Table 1 - Total articles found

Total articles found	195	Percentage
Discarded:	57	28%
Used:	137	72 %

The articles were then classified into the following themes: overviews, basic concepts and literature reviews; legal implications; implications for small and medium enterprises; implications on sustainability; quality control issues; maturity models; elements for implementation; clusters for collaboration; and applied cases. The elements for implementation include technology and engineering, business and management, design and innovation, human interaction, and skills and education. Table 2 shows the categorisation of articles used.

Table 2 - Total articles used

Total articles used	**137**
Overviews, basic concepts, literature reviews	18
Legal Implications	2
SMEs	5
Implications on sustainability	10
Quality control	1
Maturity models	7
Elements for implementation:	92
Technology and engineering	60
Business and management	21
Design and Innovation	3
Human interaction	7
Skills and education	10
Clusters of collaboration	3
Applied cases	23

The articles on implications on the legal fields, sustainability, and SMEs, although important for understanding Industry 4.0, will not be considered for researching skills as that is beyond the scope.

The articles talking about the elements needed for implementing Industry 4.0 were themed in the following ways: technology and engineering, business and management, and design and innovation. The majority of previous research has focused on technology and engineering (60), followed by managerial elements (11) and then by skills and education (10). The results of this research are shown in Figure 4.

The articles on human interaction focused on the changing nature of work and the role of the operators. The literature on skills and education found on the Industry 4.0 search had mostly a focus on personality profiles for human resource management (Cotet, Gabriela; Balgiu, Beatrice; Zaleschi, 2017) (Hecklau, Galeitzke, Flachs, & Kohl, 2016) rather than skills that can be developed in education. Other work related to skills in Industry 4.0 has focused on teaching tools for developing specific engineering capabilities. They present problem-solving approaches as a valuable teaching method for Industry 4.0 concepts (Abele et al., 2015; Cachay et al., 2012; M. Tisch, Hertle, Abele, Metternich, & Tenberg, 2016; Michael Tisch, 2014). The following sections will take a closer look at discipline-specific, professional competencies associated with the different elements of Industry 4.0, based on the literature found on Industry 4.0.

2.1.1 Technical and Engineering competencies

As mentioned previously, Industry 4.0 is driven by key advances in technologies. This section takes a more detailed view of some basic engineering elements of Industry 4.0: Cyber-physical systems, and the Internet of Things, and their related skills.

Cyber-physical systems consist of sensors and actuators controlled by microcontrollers(Lu, 2017). As mentioned previously, they enable smart factories by creating a virtual copy of the physical factory (Hofmann & Ruesch, 2017).

Lee et al. (Jay Lee, Bagheri, & Kao, 2014) describe a cyber-physical system composed of the 6Cs, where information is strategically used to give value to the system through six components: i. Connection (sensor and networks) ii. Cloud (data on demand) iii. Cyber (model and memory) iv. Content (meaning and correlation) v. Community (sharing and collaboration), and vi. Customization (personalization and value).

Qin et. al (Qin et al., 2016) present five levels of development for the implementation of the system: i. connection level (communicable), ii. conversion level (informational), iii. cyber level (controllable, automated), iv. cognition level (early aware, predictive maintenance), v. configuration level (self-configure, intelligent).

The **Internet of things** refers to objects that can communicate with each other, and with people, via RFID, wireless networks, the cloud, and mobile platforms. This will enable new types of business processes and business models and digital services for consumers, for industries, and for public services. Figure 5 shows the different engineering elements related to Industry 4.0.

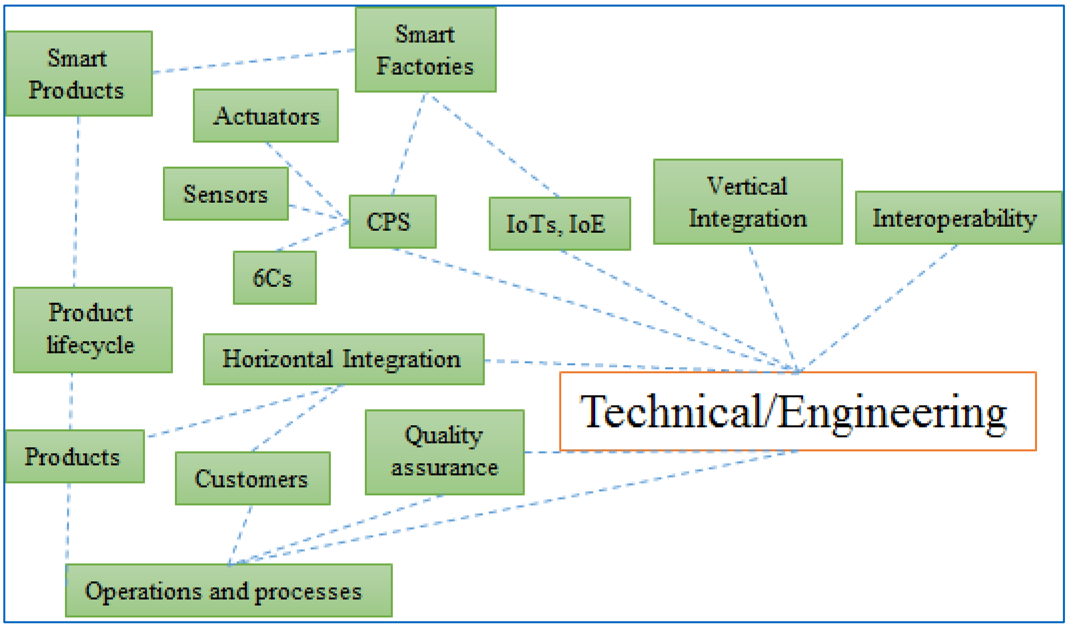

Figure 3 - Technical/Engineering elements of Industry 4.0

More specific suggested **competencies** for Engineering Industry 4.0 are: Advanced analytics, novel human-machine interfaces, digital-to-physical transfer technologies, and data communications and networks (Sackey, Bester, & Adams, 2017). Passow and Passow's engineering-specific competencies mentioned in section 2.3 are also relevant to this section.

2.1.2 Business and Management competencies

The transition to Industry 4.0 starts with the commitment of management, the allocation of resources, and a leadership that has a dedicated strategy (Abersfelder, Bogner, Heyder, & Franke, 2016).

For logistics, it is important to be aware of the latest existing technology and how to apply it to processes and process integration. In this case, most of the literature regards case studies for implementation (Hofmann & Ruesch, 2017).

As it relates to quality management, big data and analytics will automate quality assurance processes, so the role of quality management will also change.

Business processes need to be integrated and automated within the company, while creating value chains through **horizontal integration**, be it for customers, suppliers, or other companies. As task and schedule assignment becomes automated, as specific tasks no longer need to be assigned by managers, but by platforms running with algorithms (Fu, Ding, Wang, & Wang, 2018). As the organizational structure changes, the operator becomes more of a decision-maker. Then the manager becomes more of a facilitator, with technology also enabling the creation of new organizational teaching tools (Longo, Nicoletti, & Padovano, 2017).

For Industry 4.0 to be developed, commitment is needed from top management, with a dedicated strategy and allocated resources. It is also necessary to create a technology culture within the company, in which employees are trained and familiar with the systems.

As new business models are emerging, it is important to understand new ways of using digital products and services, and integrate post-sales services and or servitization of products into the business model. Figure 6 shows the different elements of Industry 4.0 as it relates to Business and Management.

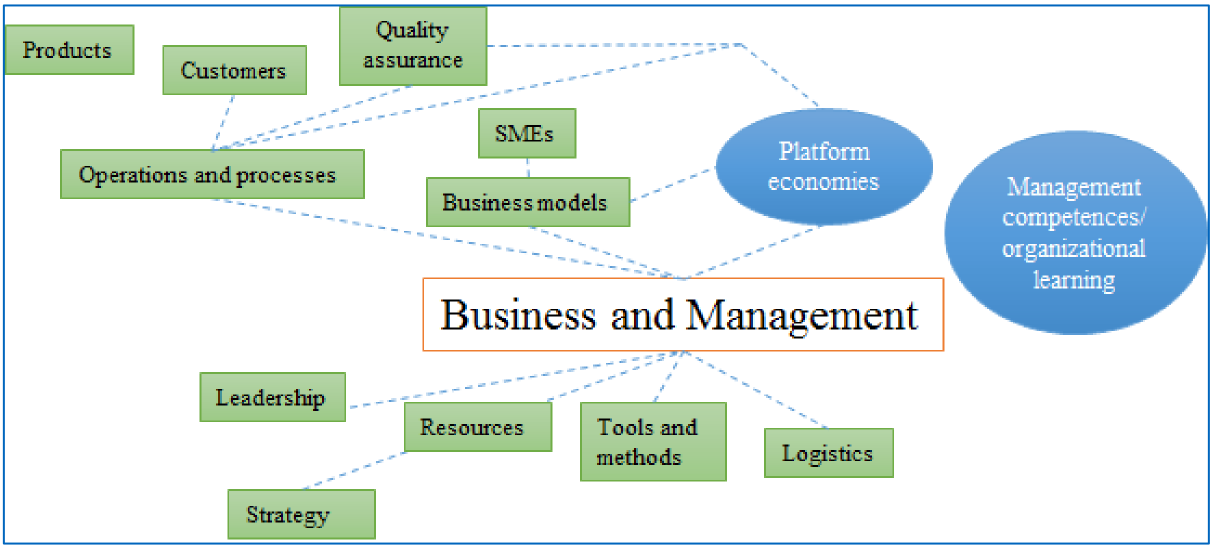

Figure 4 - Business and Management elements of Industry 4.0

Competencies related to management are: technology awareness; change management; using forecasting data and planning metrics for strategy development; and understanding technology tools for talent management. Technology and information can be leveraged to predict labour needs and create talent management strategies for attraction retention and training/lifelong education (Gray, 2016). Organizational structures can be changed to enable the exchange of knowledge, and for workers to participate and choose their own tasks, making the organizational model more like a platform that enables work. Managers can help workers understand their role and value for the organization's strategy, and at the same time empower them to make decisions in regards to their own work. At the same time, it is necessary for them to understand their new role as facilitators, as well as technology trends such as new, tech-enabled contracts or on-demand hiring trend to integrate with talent management strategies (Gorecky, Schmitt, Loskyll, & Zühlke, 2014; Kilpi, 2016).

2.1.3 Design and innovation competencies

The literature on Industry 4.0 and design focuses on the interaction between robots and humans (Laudante, 2017), and user interfaces. Most technology fails because the human use was not taken into consideration, and people utilize it in a different way than intended. Advancements in technology permit better ergonomic solutions and an improved user experience, as well as the design of customized, unique products and services (Petrelli, 2017).

Morrar et al (2017) address the issue of social innovation in the Industry 4.0 context, acknowledging the importance of understanding the greater impact of technology on society, and the need for these issues to be addressed from the point of view of the different stakeholders (Morrar, Arman, & Mousa, 2017).

2.1.4 Framework of professional competencies for Industry 4.0

The figure below presents a summary of those skills identified in literature as relevant to working life. On the left of the figure are the. The discipline-specific professional competencies and knowledge related to Industry 4.0 that were identified in the previous sections. To the right are the transferable skills.

Literature on Industry 4.0 suggests that a combination of professional competencies and transferable skills will be required in future work. For example, the professional competency of strategy implementation and change management mentioned in the Business and Management competencies section will likely require **people skills**, and strong **oral communication** and **persuasion skills**.

Figure 8 below presents a summary of those skills identified in literature as relevant to working life. To the right are transferable skills, which include problem-solving skills, soft skills, systems, thinking, business thinking, and technological literacy. On the left of the figure are the professional competencies and knowledge.

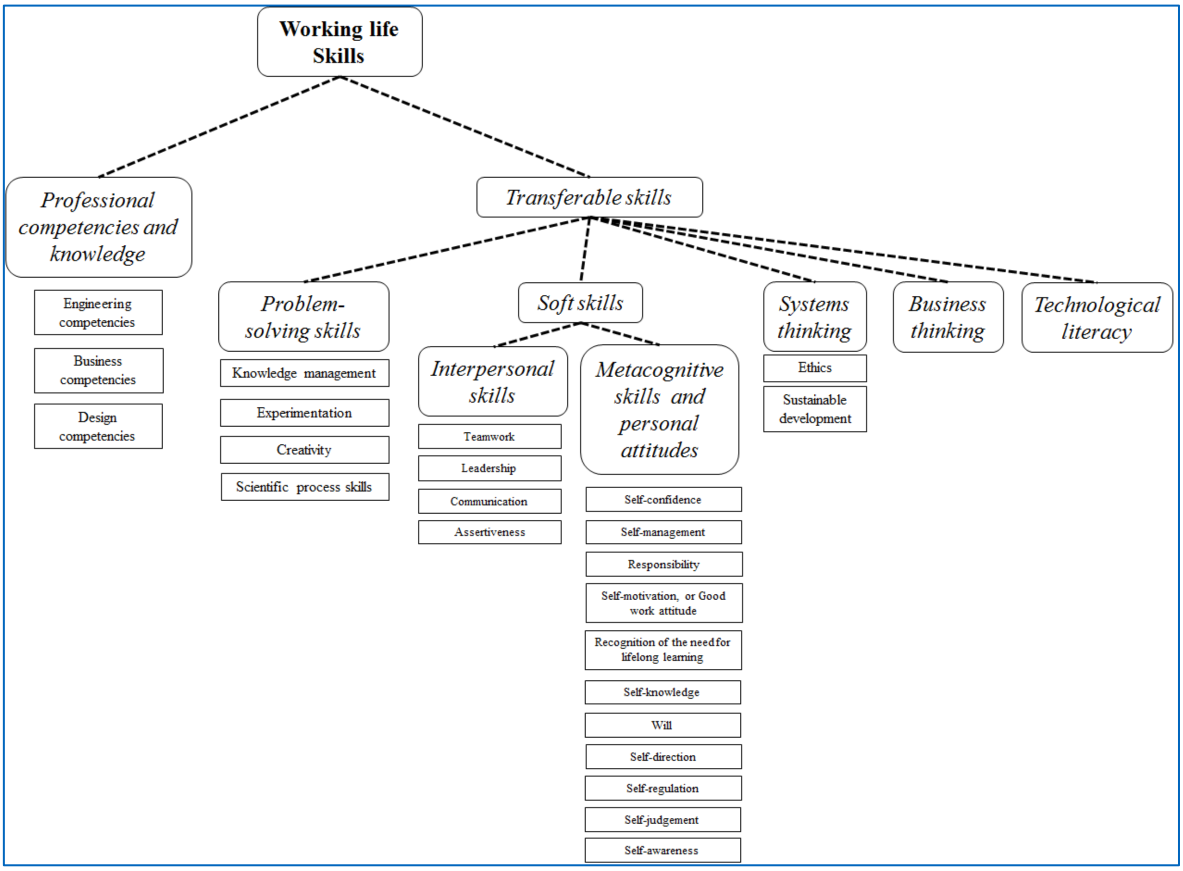

Figure 5 - General taxonomy of working life skills found in working life skills literature and Industry 4.0 literature

2.2 Transferable Skills

This section expands on the transferable skills related to working life which can be developed. Transferable skills include problem-solving skills and personal skills, referred in this report as soft skills. Systems thinking, commercial knowledge, and technological literacy are also classified as transferable skills, as they may be applied in a variety of contexts. The figure below provides a general overview of how these skills relate to each other.

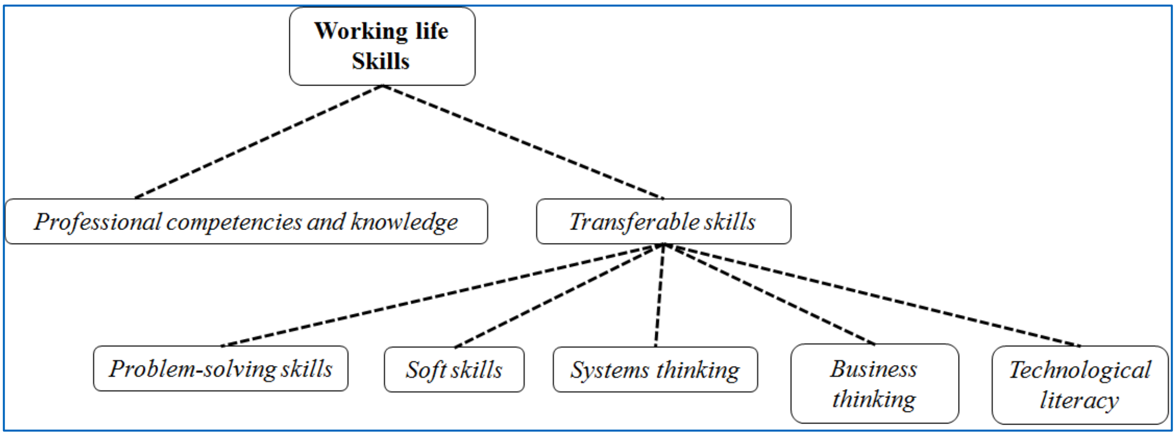

Figure 6 – Framework for classification of skills(Bridges, 1993)

2.2.1 Problem-solving skills and the science process

Problem-solving skills are transferable skills essential for modern work, as professional work is continuously problem-solving (Bridges, 1993; Passow & Passow, 2017; Schön, 1983).

Schein (1972) identifies three aspects to problem-solving: the basic science component; the applied science for problem-solving; and the skills and attitudes used for solving the problem (Schein, 1972).

Turiman et al (2012) and Passow and Passow (2017) list the importance of science skills partly because scientific literacy helps to critically understand the world around us and sort through vast amounts of information, and partly because the scientific process is necessary not only for advancing technology, but as an important tool for solving problems(Passow & Passow, 2017; Turiman, Omar, & Daud, 2012).

Problem solving includes the process of observation, problem identification, reflection, formulation or problem-framing, and experimentation, with creativity as an enabling factor for the thinking process. These processes are also essential in the scientific process (Passow & Passow, 2017; Schön, 1983).

To this process, it is important to add the analysis and interpretation of data and information, both as working life skills, and as components of the problem-solving process (Passow & Passow, 2017; Rautavaara, 2015).

2.2.2 Soft skills

Soft skills include social and interpersonal skills, are another identified component of professional work. Soft skills enable people to work and learn with and from each other. They include the ability to work in teams, particularly in multidisciplinary teams, leadership, networking and social skills, as well as different types of communication skills, such as written communication, oral communication, negotiation, persuasion and presentation skills, and assertiveness ("Engineering: Washington Accord | ABET," n.d.; McQuaid & Lindsay, 2005).

In addition to social and interpersonal skills, awareness of one's own skills and knowledge is important to career management (Hillage & Pollard, 1998). This is known as **metacognitive knowledge** (Passow & Passow, 2017; Pintrich, 2002). Developing self-knowledge requires personal attributes of will, motivation, self-direction, self-regulation, self-judgement, self-awareness, and self-regulation (Cornford, 1999, 2002; Pintrich, 2002; Weinstein & Meyer, 1994). Rautavaara (2015) emphasizes similar personal attributes, such as self-confidence, self-management, responsibility, self-motivation, and recognition for lifelong learning, as skills for employability. All of these personal skills and attitudes can also be considered soft skills (Rautavaara, 2015).

All these attributes form the basis of metacognitive skills. They include all the personal attitudes required to develop learning-to-learn skills and life-long learning (Cornford, 1999, 2002). In this thesis, these personal attributes are viewed not only as innate characteristics, but as soft skills that can be fomented and developed, and therefore, included in this thesis. Metacognitive skills and knowledge are not situation-specific, as they can be used in a variety of situations and contexts, for example for problem solving.

2.2.3 Systems thinking

Previous work on professional skills touch on the importance of having a wide range of knowledge to be able to understand the impact of their decisions in different fields, for example in society or in the environment (Passow & Passow, 2017). Systems thinking (Senge, 1990) refers to the ability to understand things in a larger context, their impact, and possible applications and implications.

In the context of professional work, people will be facing complex dilemmas every day. They need to understand the consequences of their decisions, not only as they affect the company, but also their impact on a larger scale – on society, on the environment, etc. Knowledge on ethics and sustainability can be useful tools for guiding people to make better decisions.

2.2.4 Business thinking

Previous work introduces **commercial awareness** as a skill that improves employability (Hillage & Pollard, 1998; McQuaid & Lindsay, 2005). Commercial awareness, also referred to as **business thinking**, is defined in this thesis as the general understanding of basic business concepts and the ability to think of the commercial value of products or services. Business thinking is classified as a transferable skill because it is not discipline-specific, that is, a business degree is not required to develop some commercial awareness. More business-specific knowledge and competencies are discussed in section 2.3.2.

2.2.5 Technological literacy

The knowledge or familiarity with modern engineering tools is defined as **technological literacy** (Passow & Passow, 2017)**. Technological literacy** can be simply defined as the knowledge or familiarity with modern engineering tools (Passow & Passow, 2017). A wider definition by Dakers would refer to the language necessary to talk about technology, and about technology education. There are therefore two aspects when talking about technological literacy, one which refers to the artefacts (technology tools) and another which refers to knowledge. The knowledge can be about the physical properties of the artefact, about its functions, or about the relationship between these two (how the physical properties affect the function) (Dakers, 2006; de Vries, 2006). In this report, technology literacy does not refer to the more in-depth knowledge of technology tools which results from formal education, but rather to the more limited definition of the familiarity of function of the tools.

2.2.6 A framework for transferable skills

Section 2.2 provided an overall view of the transferable, working life skills found in literature. A visualization of the framework with more detailed information is presented in the figure below:

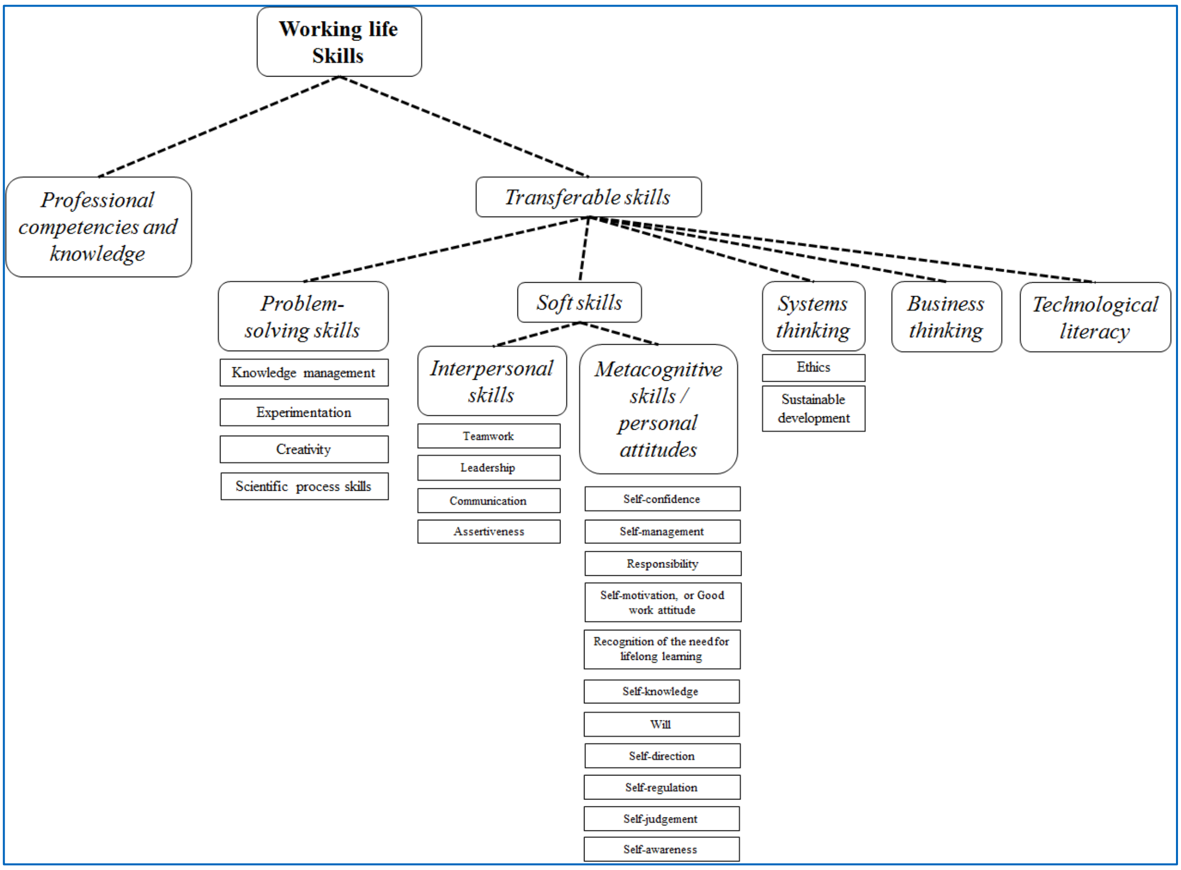

Figure 7 - Transferable skills(Bridges, 1993; Hillage & Pollard, 1998; McQuaid & Lindsay, 2005; Passow & Passow, 2017; Rautavaara, 2015; Schein, 1972; Schön, 1983)

2.3 Working life skills

Although the framework lists each skill as individual, the interplay between them represents the constant interaction and relationships between them. Not all of them are on the same level, though. Hillage and Pollard (1998) in McQuaid (2005), explain that higher-level skills are built on other basic skills, for example the sort that are developed and nurtured in basic education, that is, numerical and literacy skills. Complementing these **baseline assets** are personal attributes, which include basic social skills, confidence, diligence, and motivation.

Building on these baseline skills are the **intermediate assets**, or key transferable skills, which include **problem-solving, communication, adaptability, work-process management,** and **teamworking**.

Finally, the **high-level assets**, or high-level skills, are those that create value for the organization, and which, in addition from the professional competencies, include **teamwork** and **commercial awareness** (Hillage & Pollard, 1998; McQuaid & Lindsay, 2005). An example of this relationship would be mathematical skills being the baseline asset necessary for building other high-level competencies, such as data analysis. Professional competencies could be considered high-level assets.

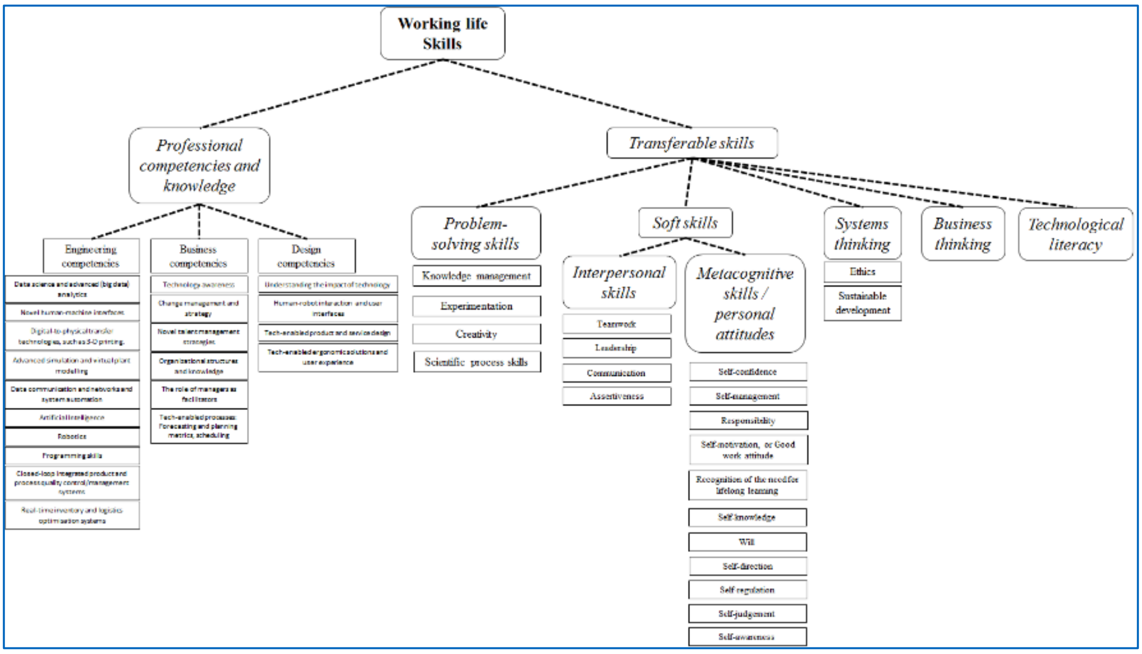

Figure 8 - Working life skills

The purpose of section 2.1 and 2.2 was to provide a background of working life skills in literature to provide a context for the Industry 4.0-related skills gathered from the empirical research. Section 2.3 will look at the higher-level competencies that literature indicates is directly related to the Industry 4.0-environment.

3 Research methodology

The research for this thesis takes a qualitative approach. While there are several surveys for gathering skills-related data, a qualitative approach allows for a deeper understanding of the reasons for the skills chosen, and how they relate directly to Industry 4.0. The longer conversations also created a context for the interviewee to expand and elaborate their answers beyond the initial thoughts.

The study has two parts: the literature review previously presented, and the empirical research.

In the skills literature review, a taxonomy of skills provides an initial framework of reference for the data analysis. The literature review of Industry 4.0 provides a general sense of the discipline-specific knowledge and competencies required for Industry 4.0. These competencies were induced through a grounded theory approach in which the essential elements are identified, and served to enrich the taxonomy of skills by complementing it with Industry 4.0-related skills from literature.

The empirical data was collected through ten semi-structured interviews and 20 structured interviews. The purpose of the semi-structured interviews was to create themes inductively (Braun & Clarke, 2006) to create a more targeted set of questions for the structured interviews

When processing information there is always the risk of researcher bias, as the author’s own perspectives and previous knowledge (*personal paradigm*) might influence the research. (Collis, J. & Hussey, 2003). This thesis operates under a *phenomenological paradigm*. Under this assumption, previous knowledge is used to interpret and classify the data, and observation and interaction with the research subjects guides the process to find patterns. The process was not a linear one, though. The empirical data often illuminated the need for further investigation in literature.

For the interviews, the objective was to approach data saturation in the thematic analysis to generate grounded theory. The whole research process was thus designed in the following steps:

i. Data collection
    a. Interview design
    b. Developing interviewee profiles
ii. Data analysis

3.1 Data collection

This section will look a closer look at both the demographic and working background of the interviewees of both the in-depth and brief, structured interviews.

3.1.1 Interview design

The objective of the interviews was to cover the basic elements of Industry 4.0 while addressing its challenges and therefore, the skills required to meet them. In order to develop the questionnaire that would reflect the elements, an Industry 4.0 framework for maturity needed to be developed. In order to understand what companies need to develop for Industry 4.0, a series of models were reviewed. These models were taken from the articles found in the literature review described in Section 2.

Maturity models

Schumacher et. al (2016) describes maturity of organizational entities as “the state of advancement of internal and external conditions that support Industry’s 4.0 basic concepts such as the vertical and horizontal integration of manufacturing systems and enterprises as well as the digital integration of engineering across the entire value chain” (Schumacher, Erol, & Sihn, 2016). This section presents an overview of previous frameworks and maturity models.

Lu (2017) mentions three frameworks for interoperability: “Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR); Interoperable Delivery of European eGovernment Services to public Administrations, Business and Citizens (IDABC); and Advanced Technologies for Interoperability of Heterogeneous Enterprise Networks and their Applications (ATHENA)”, and presents a framework that measures the level of interoperability in four levels: operational (referring to concepts, standards, and languages), systematical (referring to guidelines), technical (referring to tools), and semantic (referring to information exchange) (Hofmann & Ruesch, 2017).

Leyh et al.’s SIMMI model looks at maturity from the perspective of Information Systems, and suggests a five level digitization model (Leyh, Schäffer, Bley, & Forstenhäusler, 2016). Referenced in several articles, the SIMMI model defines maturity in terms of vertical integration, horizontal integration, digital continuity, service-oriented architecture, cloud computing, information aggregation and processing, and IT security, and provides a model based on five stages of digitization.

Schumacher et. al mentions five previously-existing maturity models: IMPULS – Industrie 4.0 readiness, Empowered and Implementation Strategy for Industry 4.0, The Connected Enterprise Maturity Model, the I4.0 Reifegradmodel, and the Industry 4.0 /

Digital Operations Self-Assessment. Their own model is based on nine dimensions: Strategy, Leadership, Customers, Products, Operations, Culture, People, Governance, and Technology (Schumacher et al., 2016). Schumacher's model takes a holistic view of the maturation assessment, taking into consideration both internal and external factors. This model is meant as a self-assessment tool for companies.

From a process point of view, Schumacher also develops a general Envision, Enable and Enact roadmap for companies. This same roadmap is applied for SMEs, as an Industry 4.0 Three Stage Maturity Model for SME's. This maturity model is also a more general picture, rather than a technological assessment.

Qin et. al present a matrix model combining automation level with intelligence level that produce a CyberPhysical System development level.

Ganzarain et. al present a Five-level maturity model: Initial, Managed, Defined, Transformed, and Detailed Business Model. It is meant to help envision the project, enable a roadmap to Industry 4.0, and enact it.

Zezulka et. al's Reference Architecture Model for Industry 4.0 (RAMI), is also referenced on several articles. It is based on a VDMA (Association of German machinery and equipment and equipment constructors, 2015) model (Abersfelder et al., 2016) and the Smart Grid Architecture Model (SGAM).

Table 4 is a summary of these models:

Table 3 - Summary of maturity models

Author	Model	Focus
Qin et. al	*A Categorical Framework of Manufacturing for Industry 4.0 and Beyond*	*Automation and Intelligence level*
Yang Lu	*Framework for interoperability*	*Integration and interoperability*
Schumacher	*Nine dimensions model*	*Strategy, leadership, customers, products, operations, culture, people, governance and technology*
Leyh et al	*SIMMI*	*System integration maturity*
Ganzarain, Jaione, et al.	*Three Stage Maturity Model in SME's*	*Based on SIMMI principles applied to SMEs*
Zezulka et. al	*RAMI* (Zezulka, Marcon, Vesely, & Sajdl, 2016)	*Reference Architecture Model for Industry 4.0, a three-dimensional organizational analysis*

Based on these models and the different elements of Industry 4.0 identified in Chapter 2, the following elements of Industry 4.0 maturity model were identified: Technical and

Engineering, Business and Management, Laws and Governance, Design and Innovation, and Skills and Education.

The semi-structured interviews begin by asking the person about themselves and their work. Moving on to the main part, there are some questions about Industry 4.0. In case they are unfamiliar with the term, or they know it by a different name, they are given a brief description. The questions in the main part are related to Industry 4.0's elements identified in these models, plus, obstacles, resources, level of implementation in their own organisation, if applicable, etc. Then the conversation moves on to skills and education, with follow-up questions. The final thoughts were on the recommendations and thoughts on development potential. The structured interviews follow a similar pattern but with more closed yes or no questions. The complete questionnaires are in Appendix 1.

3.1.2 Interviewee profiles

Bogner and Menz (Bogner, Alexander, Littig, Beat, and Menz, 2013) propose a profile of the interview to "generate theory via the interpretative generalization of a typology". In this case, the interviewee possesses "interpretative knowledge," or a diverse, practical, and heterogeneous set of points of view that helps provide an expert picture. This person has subject matter know-how, is reflective or observational on the subject, and has an external point of view. This perspective would be useful for answering the question "What are the competences required?"

Qualitative questionnaires were developed for conducting exploratory interviews with different industry representatives and experts. These interviews are meant for identifying the skills for working in Industry 4.0 and integrating them/mapping them to the initial elements. From these interviews, an initial hypothesis regarding the different kind of skills could be developed for further testing.

To answer the question "What is out there?", which is "What are the current skills found in the workforce?" through people who have a representational view of the industry (the current practices and industry standards). The people with a more "hands-on" view of the industry would be able to answer the questions related to the status quo: what are the current standards and competences currently found in the workforce?

In contrast, we aim to compare that to the question "What is the potential?" "What could be?" or "Where are we going?" The question "What is needed?" fills the gap between what is and what could be. To achieve this, the profile of the interviewee we seek is more theoretical “hands-off”, such as a researcher. The objective of these interviews is to complement the literature review in terms of the latest trends and research.

Combining the initial skills categorization with the Theoretical vs. Practical approach results in a quadrant of four categorizations. The first quadrant, A, refers to the practical, technical view, so CTOs or tech industry representatives. The second quadrant, B, would be the human approach from Industry, so Human resources, or Management. It is important for the practical profile to be Representative of current practices.

The third quadrant, C, refers to the Theoretical, Technical approach, so technical researchers, and the fourth quadrant, D, refers to researchers in human studies. The aim was to have people representing all four quadrants to have diverse points of view.

A questionnaire was developed asking questions related to the identified elements. The extended conversation about Industry 4.0 also served as a primer for thinking about skills within an Industry 4.0 context.

A second, shorter, questionnaire was designed for 20 different entities, mostly from quadrant A, in Finland, Portugal, and Poland, to test or add to the initial set of skills resulting from the interviews.[1]

The first set of data was collected from ten interviewees with both technical and humanistic backgrounds, for example in social studies or management. Interviewees also held positions in research or were practitioners with a representative point of view, as shown in the table below:

[1] See Annex for a closer look at the questionnaires

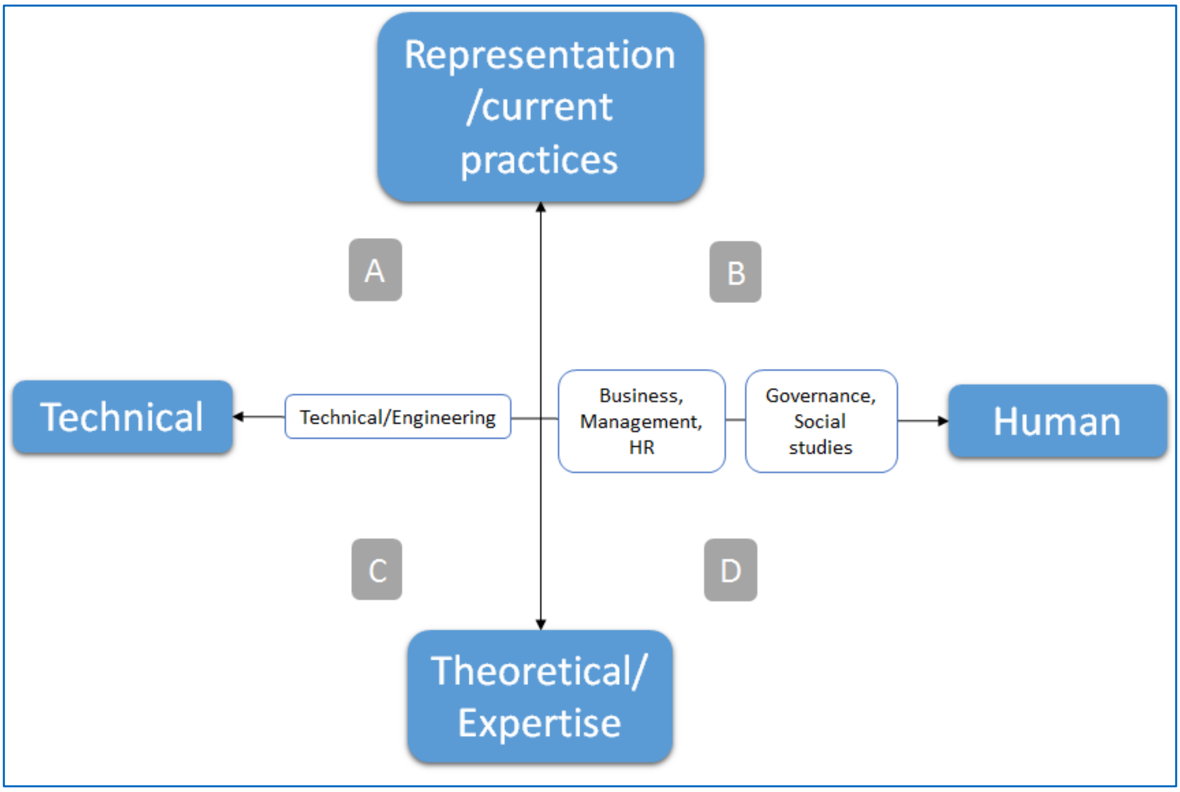

Figure 9 - Interviewee profile

The first set of data was collected from ten interviewees with both technical and humanistic backgrounds, for example in social studies or management. Interviewees also held positions in research or were practitioners with a representative point of view, as shown in table 5:

Table 4 - Profiles of first ten interviewees

Interviewee	Gender	Country of origin	Profile	Length of interviews
1	*Male*	*Finland*	*CTO at a large technology company*	*37 minutes*
2	*Male*	*Poland*	*Founder of an Industry 4.0 national initiative*	*53 minutes*
3	*Female*	*Finland*	*Director of an industry organization*	*56 minutes*
4	*Female*	*Finland*	*Sales director of a large technology company*	*38 minutes*
5	*Male*	*Finland*	*Researcher and entrepreneur in AI technology*	*37 minutes*
6	*Male*	*Finland*	*Engineering researcher and professor*	*58 minutes*
7	*Female*	*Finland*	*Researcher on post-industrial work*	*49 minutes*
8	*Male*	*Finland*	*Foresight specialist on megatrends*	*36 minutes*
9	*Male*	*Finland*	*Researcher on the future of work*	*34 minutes*
10	*Female*	*Finland*	*Researcher on governance*	*49 minutes*

Twenty structured interviews were carried out, each one about twenty to thirty minutes. Their profile was mostly from industry, either from technical or management or human resources, although quite many performed dual roles in research and industry. Table 6 shows the profiles of the structured interviews.

Table 5 - Profiles of structured interviews

Interviewee	Country of origin	Practitioner or researcher (self-reported)	Profile
1	*Finland*	*Both*	*University researcher and board member of technology companies*
2	*FInland*	*Both*	*Engineering and research in a technology company*
3	*Finland*	*Both*	*Researcher in a telecommunications company*
4	*Finland*	*Both*	*Engineering development in a technology company*
5	*Finland*	*Practitioner*	*Manager in a technology products company*
6	*Finland*	*Practitioner*	*Manager in a retail company*
7	*Finland*	*Both*	*Engineering and development in a technology products company*
8	*Poland*	*Practitioner*	*Technology transfer expert , business consultant*
9	*Poland*	*Practitioner*	*CEO (Company Owner -) sensors industry*
10	*Poland*	*Practitioner*	*Head of Industry Department 4.0*
11	*Poland*	*Practitioner*	*Industry 4.0. expert*
12	*Poland*	*Researcher*	*Researcher (heating)*
13	*Poland*	*Researcher*	*Operational Management Board Automatics and robotics*
14	*Portugal*	*Both*	*Business and strategic relations in a technology research lab*
15	*Portugal*	*Both*	*Head of Innovation in a multinational company*
16	*Portugal*	*Practitioner*	*HR manager in retail industry*
17	*Portugal*	*Practitioner*	*State industry advisor*
18	*Portugal*	*Practitioner*	*HR manager in an industrial company*
19	*Portugal*	*Both*	*Head of strategy and business development in a telecommunications company*
20	*Portugal*	*Both*	*Director in an industrial company*

As for the interviewees' familiarity with Industry 4.0, only one interviewee had no knowledge of the term Industry 4.0, and most of their companies (70%) were including Industry 4.0 elements in their strategy. Regarding their companies' approach to Industry 4.0 and education, only six organizations out of 23 had no training programs at all.

The following graphs present a brief glimpse of the approach to training for Industry 4.0 from the interviewed companies from the three countries. The majority of them have training programs, and particularly in Portugal, the interviewed companies were carrying out educational collaborations with universities.

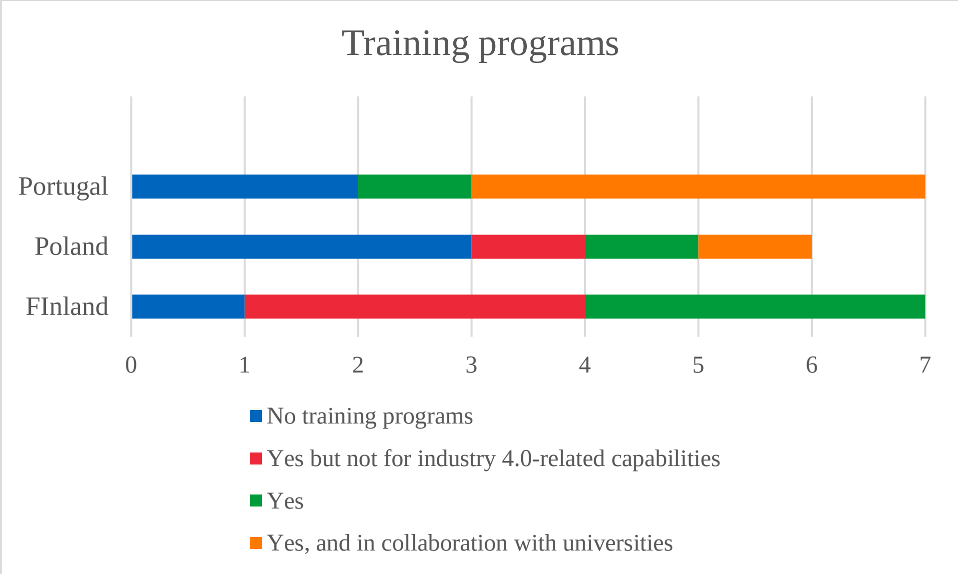

Table 6 - Training programmes of structured-interviewed companies

3.2 Data analysis – coding

Interviews were analysed thematically. During the coding process, a hierarchical approach was used for categorisation, with two main categories: challenges and skills. Within the skills section, the taxonomy for skills was used as a basis for the coding process. The analytical process began with open coding and towards the end an axial approach was used to establish connections between the themes. For the challenges, cause and effect relationships were discovered. For skills, it was hierarchical relationship (subcategories) (Strauss, A. L. & Corbin, 1990).

When asked about challenges and skills in Industry 4.0, interviewees responded with several answers, for example, *skill a, b and c, and challenge d, e, and f.* These answers were not ranked for importance, but rather deemed as all equally important, and quantified as such. During the coding process, the focus was on the meaning of the phrases, and not only the specific words, so for example, “a mindset that you can learn”, or “growth mindset” was classified under *continuous learning.* The aim of the thematic analysis was to create a picture in which the different pieces of information complement each other.

The context in the answers was very important in the process, as similar terminology is used for terms having different meanings. An example of this was information management. This term was used in two contexts: One in the macro level of information systems for organizations, the other one on an individual level in which a person is able to gather, evaluate and categorize information for problem solving, or to increase their own knowledge. While similar terms were used, the implications for each are very different, and require different skillsets. For this reason, during the coding process, whole paragraphs were used for categorising, instead of merely searching for keywords. For example, note the response, "… but I also need someone who is able to talk with other departments… and convince them to [use the technology], because it will improve their work, and how he/she can reach this person to show how a new technology can be beneficial". In this example "communication skills" is not mentioned at all, but that is where this response was categorised.

The categorisation notes from the interviews was also reviewed several times to allow for categorisation corrections. The aim was to achieve stability for coding reliability (Krippendorff 2004 in Campbell, Quincy, Osserman, & Pedersen, 2013). The limitations for this study comes from intercoder reliability, as the coding process was not reviewed by third parties.

In the analysis, it was noticeable which answers were pervasive across all backgrounds, and which were noticeable only on certain profiles. Differences in responses according to national background did not present as much discrepancies as professional profile, where there was greater variety of responses. For this reason, findings are presented as representative of all three countries

4 Industry 4.0 challenges and megatrends in Finland, Poland, and Portugal

The main objective of this section is to present the challenges faced by these countries in respect to Industry 4.0. To set the scene, a brief national background based on state reports is presented in section 4.1. The findings of the empirical research are presented in section 4.2.

4.1 National Industry 4.0 backgrounds

The aim of this section is to identify the challenges faced by each country as well as those shared by the three of them. For the comparison between the three countries, this thesis looks at macro factors and initiatives meeting each country's challenges. This provides comparative background information to the results of the interviews. The information is gathered mostly from the European Commission's 2017 Digital Economy and Society Index. This section is meant to serves as background for the empirical research findings.

This section will provide a bird's eye view of each country through various reports, including:

World Reports

- The Future of Jobs - Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution, 2016, World Economic Forum

European Union-level reports

- Digital Economy and Society Index
- Digital Skills and Job coalition
- Recommendation of the European Parliament and of the Council of 18 December 2006 on key competences for lifelong learning
- The future of Industry in Europe

National reports

- Europe's digital progress report – Country profile: Finland
- Europe's digital progress report – Country profile: Poland
- Europe's digital progress report – Country profile: Portugal
- Finland's Action plan for the implementation of the key project and reforms defined in the Strategic Government Programme

- Information Security Strategy for Finland - The World's Most Trusted Digital Business Environment
- Finland’s Government Report on the Future
- Digitising European Industries - Member States Profile: Poland
- Poland on the way to Industry 4.0
- Time to speed up – The digitalization of the Polish economy

In Finland, Poland and Portugal, a variety of national, regional and local initiatives have been implemented for Industry 4.0 development. Between them, there are 33 public-private initiatives meant for developing digital skills among the population, the workforce, among ICT professionals, and students through private and public collaborations(European Commission, 2017a). Most of these programmes are in all three countries, with a few exceptions[2].

4.1.1 Finland: High demand for technology graduates

In education, digital skills are being integrated into the curriculum, as well as the development of digital skills for teachers. As a region that greatly relies on ICT services economy, this reflects the higher-than-average amount of ICT and STEM specialist graduates. Finland’s high levels of STEM graduates and digital skills reflect their economy, which is highly-based in ICT services. However, there is still a great demand for STEM jobs in Industry. It is projected that the next four years 53,000 positions in technology will need to be filled, with not enough workers to fulfil them. The reason for this high number is the large number of tech-oriented business-to-business companies in the Finnish economy. This does not take into consideration any possible job reskilling that current workers might need to do. Furthermore, the lack of basic digital skills for 27% of the population must still be addressed (Juvonen, Karikorpi, Mannonen, & Ahkola-Lehtinen, 2018). There are several programmes being launched in Finland for the promotion of digital and technology skills, they are addressed in Section 4.2.6.

[2] See Annex for more detailed information about these programmes

4.1.2 Poland: Sixth in Europe in improving technological skills, especially in the youth

Although only 44% of Poland's population masters basic digital skills, their ranking has been slightly increasing, particularly among the youth (16-24 years old), as well as the number of STEM graduates. One of the objectives of the aforementioned *Operational Programme Digital Poland*, is to increase digital skills through education and information. Special efforts are being made also for primary school programs. It is people from higher age groups, who have more limited digital skills, and might need more support for acquiring them (Arak & Bobiński, 2016).

As far as development of skills specifically for Industry 4.0, Poland is currently developing a network of competence Centers for students and researchers to learn and apply Industry 4.0 concepts in the industry[3]. Project Air 4.0 from WUT was created for developing the education in automation and robotics (Mattauch, 2017). Another initiative is the *Broad Alliance on Digital Skills in Poland*, which brings together cooperation between HEIs, organizations, and industry to increase technology education.

4.1.3 Portugal: Low basic digital skills in the workforce, but a high number of STEM graduates

Only 68% of Portugal's population uses the Internet, and about 48% has basic digital skills. Similarly, 26% of the adult population has never used the Internet, and 22% of the active labor force has no digital skills at all. However, this might be due to the country's type of economy, as only 32% of companies reported having problems filling ICT vacancies, compared to EU average of 41% (European Commission, 2017c). This lack of digital skills is more common particularly for the elderly and in rural areas. However, overall, 2% of students graduate from a STEM field, which is higher than the EU average. In 2017, Portugal launched the *National Initiative on Digital Skills*, as part of its *Indústria 4.0* plan, for the purpose to address these challenges and make access to digital technology more accessible to all members of the population.

Although rural areas are not traditionally associated with digital technology, there is a huge area of opportunity to develop agricultural solutions through the so-called Internet of

[3] See Annex for more information about competence centers

Farms. Connectivity and higher digital skills for the population in the countryside have the potential to bring about a positive transformation.

4.2 Findings - Overview of trends and challenges in technology and education

This section will discuss the future trends and related challenges to implementation of Industry 4.0, as described in the interview responses, and the initiatives that arise (national or grassroots) as a result.

4.2.1 Clusters and networks

As was mentioned in the previous section, networks and horizontal integration is one of the core elements of implementing Industry 4.0. Clusters and strategic use of information create value through new business processes and business models.

Interview findings were that technology-enabled clusters are already being created in different industries.

4.2.2 Platform economies and the future of work

Virtual platforms enable the exchange of goods, services, etc. and greatly reduce the associated transactions costs.[4] As more and more work is being "crowdsourced" through the platforms, traditional work in organizations becomes smaller. Work becomes more "project-based", or "task-based", and there is greater financial uncertainty when there is no fixed income, with "scattered income" becoming more common. This kind of "freelance" work is expected to increase beyond "blue collar" type of work, but unfortunately protection for workers in the virtual platforms are still greatly lagging (for example, Uber).

Furthermore, automation of clerical tasks, for example research assistance or task assignments, can be done with AI, so the role of management and information-intensive works will change, or are already changing, as managers already see themselves more as facilitators rather than task assigners, and more emphasis is being placed on creative work – that which cannot be replaced.

[4] For more information of Platform Economies, go to http://platformvaluenow.org

4.2.3 Education

There is demand for tech workers in industry. This impression was pervasive in the interviews, or as one of the interviewees put it, “There [are a] lot of positions open in the programming area, jobs available but nobody is applying”.

Initiatives to increase digital skills are currently focusing on grammar school education, by introducing digital tools into the learning environment. There is some work to be done, though, in terms of implementing these programmes, as teachers can often need further training in digital technologies and mathematics in order for these programmes to be successful.

Upskilling and reskilling is usually done through traditional open universities, but new programmes, platforms, and workers are arising in response to the demand for skilled labour. In the interviews, people with a researcher background tended to view the role of higher education institutions as a place to give the students a wide view of the world. While practical, problem-solving skills were emphasized, students should emerge with critical thinking skills and an understanding of the scientific and experimentation process.

4.2.4 Resistance to change and homogeneous cultures

Resistance to change and a lack of diversity in points of view can result in a narrow perspective. Both the homogeneous culture and the resistance to change were mentioned by the interviewees as related in an overall tendency for people to prefer to work with people with a similar educational background, same school, etc.

4.2.5 Lack of vision on the value of technology

Lack of information, skepticism about technology and/or not understanding the value of technology are three things often go hand in hand. Interviewees also mentioned “Lack of foresight”, “needing to have a broader view”, and “lack of understanding of the impact of technology”. Raising awareness, getting people involved and motivated, spreading information, creating “hype”, is necessary for understanding the often intangible benefits of technology investments.

In Poland, this is being addressed in the platform for Industry 4.0, which is a state-sponsored, joint collaboration project with several universities, with the purpose of building capabilities for students and researchers, for consulting industry on Industry 4.0 concepts.

The double aim of the project is to spread information about Industry 4.0 and to give the students practical experience, as well as an opportunity to create networks.

A lack of strategic vision on the potential use of technology and information could perhaps also be expressed as a need for research in new business models, or changing current business models. This could also be related to the lack of understanding on the strategic use of information, or "choosing the right cases" for investing in technology. Two challenges mentioned in relation to the use of information systems are **legacy systems** and the **use of information**. Legacy systems challenges refer to the integration different information systems not only within the company, but with other organizations when creating a cluster, can be a challenge. Use of information challenges refer to the kind of information to share, which data to use, how to use it to create value or new business models while at the same time having clear ethical and legal guidelines. At the same time, companies might still struggle with information silos within the organization.

4.2.6 Lack of skilled people in technology

The lack of skilled people in technology is being countered with alternative talent sourcing in the following ways:

Greater diversity of tech-skilled people in the industry

Greater representation of women in technology and more visible female role for girls can serve as inspiration for girls, as a counterpoint to stiff stereotypes. In terms of social change, as people's identity becomes more flexible, people can be more open to exploring previously unconsidered alternative life paths, or "breaking the mold", career wise. All around, more effort is needed to make younger people more aware of or attracted to, careers in science and technology.

Another source of talent can be found from foreign talent. This is already a solution many companies employ to solve their shortage for skilled workers. However, for more traditional companies this can be a challenge as there is resistance to change and people prefer to hire people from within their own networks. This problem has been addressed through programmes that integrate studies with work in order to make it more likely for students to get "into the network" and be hired at the end of their studies. One such example is the Tampere University of Technology International Sales and Sourcing programme. These programmes can help address the problem of the traditional networks, but more needs to be done from the companies' part into actively breaking the tendency of "hiring people like them".

Reskilling or upskilling workers

Reskilling or upskilling workers is necessary for people with outdated skills to re-enter the workforce. Adult education can take place in several ways:

- *Within companies:* Although many companies have their own training programmes, the limited amount of time available to take courses can be a limiting factor for education. Some companies reported beginning to integrate learning opportunities within tasks and projects, expecting that the workers will learn as they work. This is often not a conscious strategic decision, but rather an ad hoc solution that arose to solve a need. Treating work as learning, and vice versa, is a good opportunity for developing talent within companies, and will continue more and more, as work becomes more automated and routine or mechanical tasks disappear. It is important, then, for companies, to make allowances for the learning curve, and to be more aware of the learning process and the potential learning opportunities for workers.
- *Industry-university collaboration:* Education in collaborations with universities can take place in several formats: face-to-face or virtual, generic or company-customized. Generic or company-customized means that when companies purchase the education programmes offered by universities or other higher education institutions, they can opt for the general programmes they offer, or choose to pay for a program especially tailored for the company's needs.
- *Public programmes and collaboration with industry:* These programmes aim to reskill the public. Programmes may combine different needs, like reskilling and integrating the foreign workers by teaching them tech skills. Other programmes such are *industry-public collaboration* that aim to teach technology skills, such as AI or coding, to the whole population.
- *Peer-to-peer learning:* Peer-to-peer learning can be enabled by grassroots initiatives meant to teach or empower peers, often through social platforms.
- *Virtual learning and the rise of the no collar workers*: Online courses are currently answering a demand for acquiring tech skills quickly, and companies are responding more and more to this type of self-taught worker. When the certification of skills

becomes a challenge for hiring, companies can use platforms that validate people's skills through crowdsourcing recommendations, but are still working on alternative ways to more formally validate skills in the hiring process. *Certifying platforms* are arising to answer this need. They are a way to certify the skills that people are acquiring through their hobbies

4.2.7 Unequal access to education

As mentioned in the previous section, lack of access to Internet results in diminished access to information and education. Likewise, less educated people tend to receive less continuous training. People with more education are more likely to continue with lifelong training throughout their career, simply by easier access to information. It can be argued that a society with an unequal access to information is less democratic. The European Lifelong Learning project, particularly the Grundtvig programme, focuses on adult educational inclusion to address this disparity.

4.2.8 Promoting entrepreneurship for innovation and new business models.

Promotion of innovation can take place through the state or through private initiatives. For **state initiatives,** there is currently a framework for strategic *governance experiments* in Finland. The following two programmes are governance experiments that aim to address the challenges of future work. The results of these experiments were still in the works, at the time of this writing.

- *Basic income:* This is a potential response to the problem of scattered income created by platform work, basic income. It could help reduce the stress of poverty and serve as a catalyst for enabling "risky" behaviour, such as creativity, entrepreneurship, as well as permitting self-education.
- *Real-time account:* With the issue of platform-based, scattered income, taxation and social benefits should be closer to real time. Waiting a year for tax returns when having an unpredictable income can take a higher financial toll than when having a fixed income. Same with social benefits owed by the state. The real-time account is a state initiative, currently in the prototyping phase, that aims to give people and the

state real-time information about their income, to adjust taxation and benefits accordingly, month-to-month vs. year-to-year

Other governance initiatives in other countries include the *career account, or portable benefits*. This is an example of a French programme that appears as a response to the problem of people losing benefits when changing jobs (accrued holiday time, for example). It counts benefits as “points” which can be redeemed through the state. This means that a person can redeem the accrued points at any time to, for example, take a course or start a company. (“France: Employers obligation to provide skill development plans or training | Eurofound,” n.d.)

The objectives of all these state initiatives are to provide flexibility for workers to make it possible for them to pursue education or entrepreneurial activities that in the long term activate innovation.

As far as **private initiatives,** companies are also proactive in seeking innovation and participating in creating social change. The following are two examples of models that seek to create innovation within the organization:

- *Intrapreneurship*: Intrapreneurship is a model for promoting innovation in companies where management fosters and supports entrepreneurial thinking within the company.
- *Collaborations with research*: University researchers work in companies on a temporary basis, both to learn the current practices, and to give industry insights into the latest research (for example, podoco.fi).

4.2.9 Speed, innovation, and collaboration over exclusive rights

Companies are increasingly engaging in collaboration for the advancement of innovation, sometimes even sacrificing what would have been exclusive benefits, for example of intellectual property, or skilled labour, for the creation of “a bigger pie of communal benefits”. To this end, we see **collaborations** between competing firms for lobbying and R&D, more transparent **sharing of information and integration** within industry clusters, and **public training programmes** for a better-trained general population.

4.2.10 Regulations

As was discovered in the literature review, there are legal implications for Industry 4.0. The empirical research reflected this in the challenges that Industry 4.0 will bring in regards to laws and regulations. These include labor, liability, and the use of data.

Labor

As platform economy work is not yet regulated, or unionized, working conditions can be poor. There is a real risk, if more platform work becomes the norm, that many people will find that to be their main source of income, without the matching legal protections (wages, health benefits, holiday pay, etc.).

Liability

Regulations are not catching up with technology as quickly. Currently the main issue is liability for automated vehicles. Unmanned vehicles are becoming operational, but there is no clear framework for legal, ethical, or financial responsibility in case of accidents. This is particularly important in the marine industry, which is quickly advancing its technology for unmanned boats, where prototypes are becoming functional but cannot be used due to the lag in regulation updates from international maritime boats. As technology accelerates the rate of innovations, this problem will become more pervasive.

Data use

Although the European Union has introduced new consumer protections and regulations for data use, there is still some ambiguity in the general population in regards to how data is used. Researchers are also encountering ethically challenging questions in regards to the use of existing private data for research purposes, while maintaining anonymity.

4.3 Summary

Finland, Poland and Portugal are all stable countries, in the economic, social, and political sense, and the economic situation has improved in the past two years. In general, the business environment is friendly, with a certain level of transparency that permits investment in technology and human resources. In addition, all three countries have national initiatives for the implementation and development of Industry 4.0.

Overall, in terms of digital integration, the trend for all three countries is going up. In the Digital Economy and Society Index, Finland is number two in Europe, with Portugal being near the average, and Poland in the lower end. Better digital skills and attitude to technology, as well as good access to the Internet and digital private and public online services, is reflected in the higher and more diverse use of Internet activities.

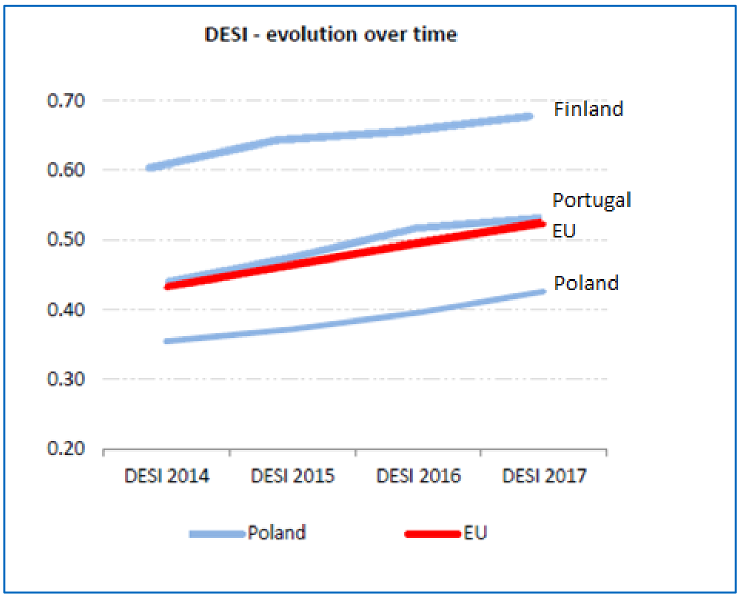

Figure 10 - Digital Economy and Society Index evolutionary trends for Finland, Poland, Portugal and EU average(European Commission, 2017b, 2017c, 2017d)

There is an active push from the state to develop digitalization in Poland through various programmes intended to build infrastructure, promote digitization in business and public services, and IT skills in the more marginalized population. This shows as it is one of the countries digitalizing most rapidly in Europe. (Arak & Bobiński, 2016).

While Portugal has a high score for connectivity and online services, the high costs of Internet access, and the lack of basic digital skills in a large part of the population make the Internet inaccessible for certain members of society.

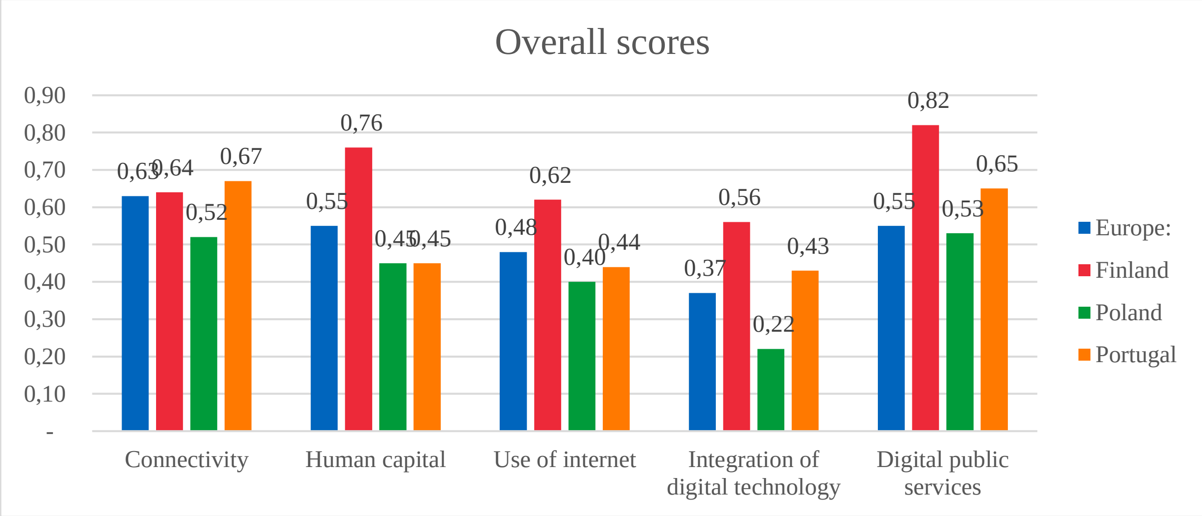

Figure 11 - Overall connectivity scores for Finland, Poland, and Portugal with the European Union average as a comparative base(European Commission, 2017b, 2017c, 2017d)

As for Finland, the large demand for STEM graduates and technical skills has meant that companies need to either get their skills from abroad or nontraditional sources, or nurture technical skills in their employees and the population.

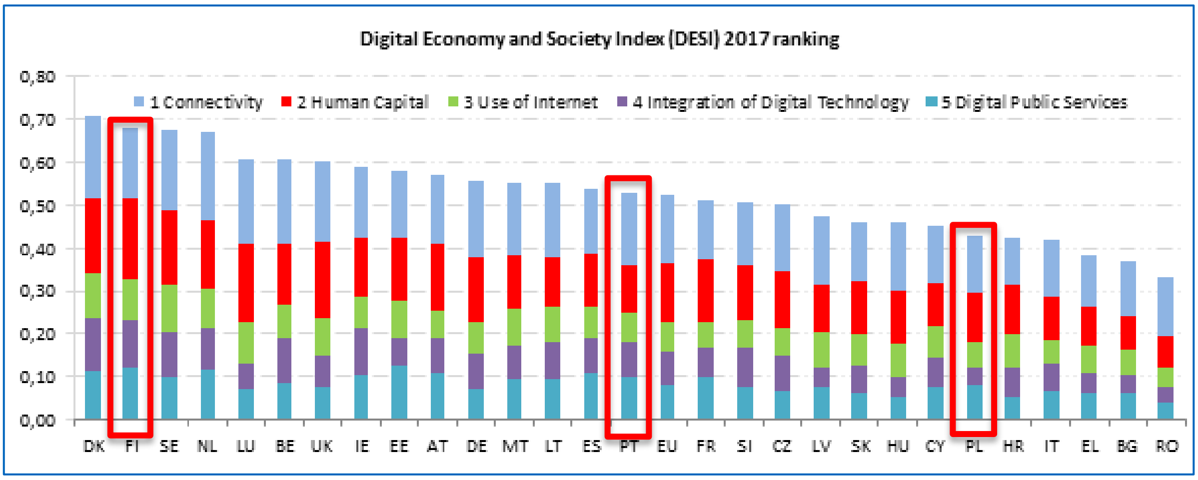

Figure 12 - Digital Economy and Society Index rankings for Finland, Poland, Portugal and EU average. (European Commission, 2017b)

Figure 12 below visually represents the relationships between the trends and challenges mentioned, as how they might relate to each other. In the figure, the darker bubbles represent the answers mentioned the most. The lighter bubbles are for less common answers (mentioned only once or twice). Collaboration is presented as a solution to alleviate the main challenges. In this figure, homogeneous cultures and unequal access to education is contributing to the problem of lack of trained people. The same rigid structures that make it difficult to break out of silos contributes to the problem of resistance to change, which leads to a myopic vision on understanding the value of technology. At the same time, megatrends such as platform economies and environmental challenges must be considered. The lack of vision also limits the creation of new business models, and investments in technological developments. Collaboration, on the other hand, is being used as a tool to address or alleviate problems in education, research, and industry regulations.

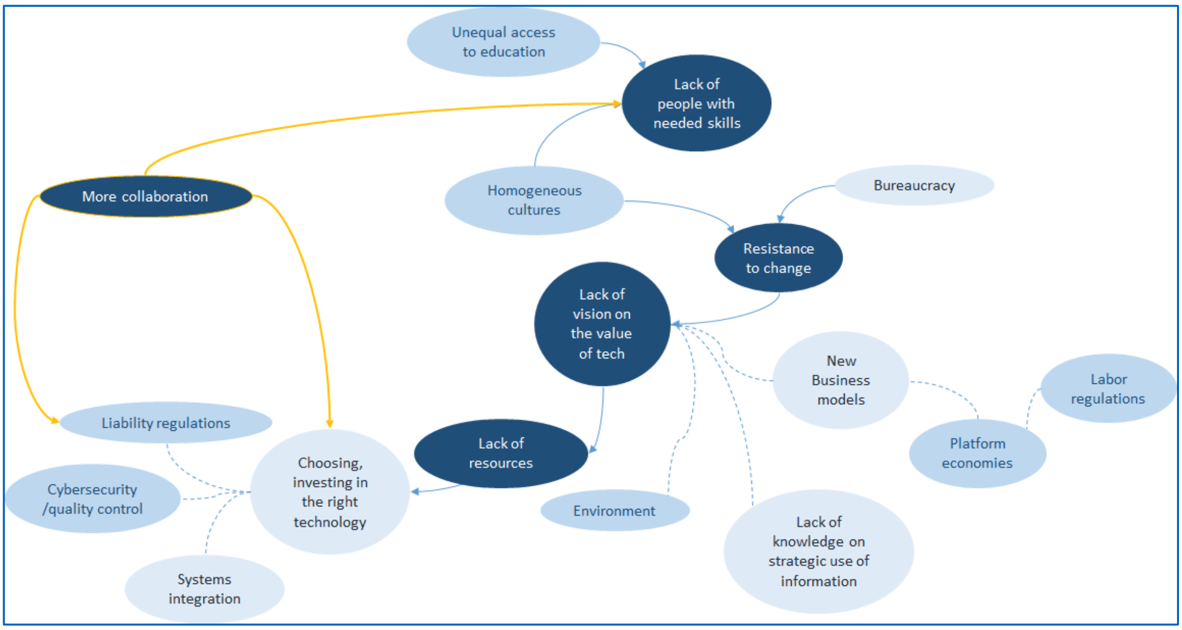

Figure 13 - Results of interviews: Challenges for Industry 4.0

5 Findings – Skills

This section presents the results of the interviews as it relates to skills. When asked about the skills needed in the workplace, responders gave a mix of professional competencies and knowledge, which are discipline-specific, as well as transferable skills. These are presented in sections 5.1 and 5.2, respectively. Section 5.3 presents a framework for transferable skills for Industry 4.0, and a table showing the challenges of Industry 4.0 and related skills is shown in section 5.4.

5.1 Professional competencies and knowledge

Just like in the academic research on Industry 4.0, many of the professional competencies interviewees deemed essential were in the technology and engineering field. All of them mentioned at least one engineering-specific competency. Information management was deemed a particularly important skill, both in the context of a soft, professional skill, but also as a more specialized, domain-specific skill for engineers and managers. The outlier was the tech-enabled ergonomic solutions for a better user experience at work. While it was mentioned only once, its importance had already been discussed in the literature review. In general, Portugal had comparatively more mentions of more discipline-specific skills, particularly those related to engineering, than Finland or Poland. The people who answered the twenty structured interviews were more explicit on which engineering skills they would like to see more of, which is in line with the findings that there is a big demand for people with STEM skills. Table 6 below summarizes people’s responses.

Table 7 - Domain-specific knowledge and competencies

Discipline-specific skills, knowledge and competencies		
Engineering	**Management**	**Design and Innovation**
Data science and advanced (big data) analytics	*Technology awareness*	*Understanding the impact of technology*
Novel human-machine interfaces	*Change management and strategy*	*Human-robot interaction and user interfaces*
Digital-to-physical transfer technologies, such as 3-D printing.	*Novel talent management strategies*	*Tech-enabled product and service design*
Advanced simulation and virtual plant modelling	*Organizational structures and knowledge*	*Tech-enabled ergonomic solutions and user experience*

Closed-loop integrated product and process quality control/management systems.	*The role of managers as facilitators*
Data communication and networks and system automation	*Tech-enabled processes: Forecasting and planning metrics, scheduling*
Real-time inventory and logistics optimisation systems	*Digital skills*
Artificial Intelligence	*Information Management*
Robotics	
Automation	
Programming	
Information Technologies	
Mechatronics	
Cybersecurity	
Augmented Reality and Virtual reality	
Knowledge of: - *IoT* - *Interfaces* - *Communication Protocols* *Understanding systems and the process behind the data* - *Cloud solutions* - *Software know-how* - *Technical know-how* - *Sensors and Electronics* *LEAN manufacturing, continuous improvement process*	

5.2 Transferable skills

The objective of this section is to give an insight into the kind of transferable skills interviewees deemed important for Industry 4.0. Discipline-specific skills will be presented in section 5.2.

5.2.1 Ability for continuous learning

For the category "continuous learning" or "lifelong learning", this was described as a mindset or attitude towards learning or "growth". It was also described as "being curious about things" or "willing to learn something outside their comfort zone", because "you don't know in advance what you will need to know", and "work and learning are interrelated". It was also presented as people's ability to understand what kind of skills they need to learn and then proactively acquiring them. Many interviewees mentioned the importance of hands-on learning and practical experience. This is interesting because at the same time, many interviewees mentioned, when having no formal training programs, that "employees learn as they do the work", so, in a sense, expecting that people will see work as a learning opportunity as well.

Lifelong learning was mentioned by twenty percent of participants, and at least once in every country. An attitude for continuous learning is related to openness to change, flexibility, and curiosity, as learning something different from the academic background was described as “going out of the comfort zone”. Interviewees sometimes mentioned interesting combinations of hard disciplinary skills “even if just a basic understanding” as something they valued in a person, for example, marketing or psychology with programming. In fact, “a broad set of skills (for example social studies or history)” was mentioned as something that can help develop critical thinking skills, as it allows to see the big picture, or view a complex situation from different angles. Having a broader set of skills or interests can also help facilitate the communication in the real-life, multidisciplinary working environment, which is crucial for the successful execution of everyday activities. A wide knowledge base beyond a person’s specialization is also helpful to develop systems thinking skills, or as one interviewee stated, “[it is necessary to have] broad knowledge to see the whole picture. People need to open their minds to different things.”

Interest and knowledge in multiple disciplines was mentioned by 17% of interviewees, in both Finland and Poland. Personal attitudes related to metacognitive skills and lifelong learning such as self-initiative, self-knowledge and flexibility was deemed important by 53% of participants.

5.2.2 Systems thinking

One the most commonly cited answers was about the importance of the ability for continuous learning. Interviewees referred to the importance of understanding a complex issue of environment from different angles, what the causes, and effects are, for example, “Think and have a broader view”, “Definition of purposes of the technology and its impacts on a social, human and political level”, as well as “…connecting unconnected areas… A person [should be] able to find opportunities where it appears that there aren’t, that is able to make connections between areas that seem disconnected”.

Senge (1995) refers to the study of complex systems as “system dynamics”, and the process of understanding that as “Systems thinking”. It deals with finding and understanding the causes of change, and what influences change. Understanding the implications of decisions, and particularly the potential, sometimes unintended, impact of new technologies, is key both to be able to make ethical decisions, for business thinking, and for being futures literate. Overall, the ability for systems thinking was mentioned by 23% of participants, with interviewees from the three countries indicating its importance.

Innovations increasingly present **ethical** dilemmas related to the use of technology. It is important for people to have some knowledge or guidance on making ethical decisions. In the context of future work, this might be especially clear in the area of data and information use for business or research, where there are many opportunities for creating value from data, but where ethical and legal matters must be considered.

Futures literacy was mentioned as the ability to guess the future, and act accordingly. For example, for sustainability, social trends, or even for personal health. For this it is necessary to understand "the big picture", what is happening around the world, and what might the consequences be (Miller, 2007). In this sense, Futures Literacy is related to Systems thinking. 20% of interviewees indicated the importance of this skill in the context of career self-management and decision-making.

5.2.3 Business thinking

Business thinking refers to being aware of the basics of business operations, commercial awareness, and vision, and finding business opportunities. 20% of interviewees connected business thinking to the application of technological innovation, as innovation, by itself, does not create value, especially if it is not properly communicated. In the context of Industry 4.0, it is important for people to have some basic understanding of business principles, or to be more aware of the potential commercial applications of technology.

5.2.4 Technological literacy

Interviewees described the importance of being able to understand the real possibilities of technology, and the abilities of people who work in different fields of engineering, to be able to work together, and to think up of tech-driven solutions. For this reason, in this thesis, the definition of technological literacy is expanded from the more narrow definition provided in the literature review, which focuses more on technological artifacts. "Understanding technology" was mentioned very often, not only within the context of knowing how to apply it at work, but also about being good technology communicators within the company to better explain its use and importance to other people. Overall, answers related to technological literacy were mentioned by 23% of participants, from interviewees in Poland and Finland.

5.2.5 Interpersonal, social and emotional skills

As one of the things that will never be replaced by a machine, it is highly valued as it helps people make emotional connections, and as “understanding human behaviour”. Technology without taking into consideration the human factor will likely fail. For this reason, **empathy** and **emotional intelligence** are a key factor to bring technology into real-life applications. This was mentioned by 23% of participants, from Finland and Poland.

Social skills and interpersonal skills

On the same vein as **communication**, the ability to “sell”, present and persuade effectively, is highly valued. Making networks, “connecting”, and negotiating are included in this category. Interviewees highly valued people’s ability to communicate or explain their own expertise, especially in a multidisciplinary setting.

All answers that related to working in groups, or answers related to “team-building” were included in “**Team working** and Multidisciplinary teamwork”.

Leadership was mentioned in the context of people’s role in team building and motivating others. It was another outlier, mentioned only twice, once in Finland and once in Poland.

Interpersonal skills in general were the most mentioned skills overall across the three countries, with 90% of participants highlighting its importance, particularly in the context of effective communication in technology work.

5.2.6 Problem-solving skills

Interviewees mentioned the importance of skills related to problem solving or the scientific process for problem solving, such as logical or analytical thinking for problem-solving. This includes knowledge management, creative thinking, critical thinking, analytical thinking, experimentation, and judgment, or decision-making.

Of these, critical thinking and analytical skills were each mentioned four times, creativity five times, and experimentation twice. Interviewees talked about the importance of theoretical knowledge and “understanding why things work” as an important component for problem-solving skills, as it is essential to understand the reasons why something works, and then apply this in different contexts in order to solve complex problems. This requires previous knowledge and at the same time an understanding of one's own skills. Problem-solving skills was mentioned by 37% of participants.

5.3 A framework of transferable skills for Industry 4.0

This section presents a summarizing model of the Industry 4.0 skills that resulted both from the desk research and from the interviews results, and their relationship with each other, . Working from Hillage & Pollard's model, the high-level and intermediate key skills build from the baseline skills. In the upper level, there are three key transferable skills: Technology literacy, business thinking, and problem-solving skills. While in Hillage & Pollard's definition the upper-level skills bring value to the organization, in this thesis, it can be argued that these skills are meant to create value for the individual, as they deploy them for their own growth and benefit.

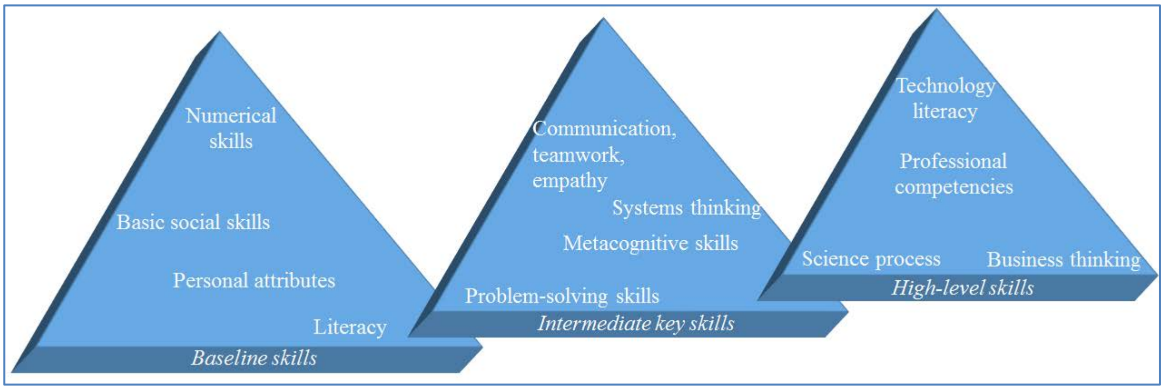

Figure 14 - Industry 4.0 working-life skills framework

In Figure 13, the three levels of skills are represented from the left, baseline skills, the center, intermediate key skills, and the right, high-level skills, building one on top of the other. On the left, basic social skills build to other interpersonal and emotional skills such as communication, teamwork, and empathy. These interpersonal skills enable learning strategies such as peer-to-peer learning, and the development of solutions that require collaboration and interdisciplinarity. Personal attributes like adaptability and motivation contribute to the development of metacognitive skills that enable continuous learning and aid with problem-solving. Other problem-solving skills (including creativity) enable the use of higher science process skills such as problem-framing and experimentation. Systems thinking helps with developing technology literacy and business thinking skils, as the objective is to understand the impact (positive or negative) or technology. Systems thinking in this model includes knowledge on ethics, sustainable development, and futures literacy. The high-level skills in this model include technology literacy, business thinking, the science process or other tools for advanced problem-solving, and Industry 4.0-related professional competencies such as artificial intelligence or user interfaces and user experience. In the model, empathy is added to the skills identified in the desk research as a result of the interviews, as something related with issues of design, engineering, and usability. Openness to change and flexibility were also added to the model as results of the interviews. A more detailed model is presented below. The skills in the orange boxes are supporting the development of the transferable skills in the green boxes.

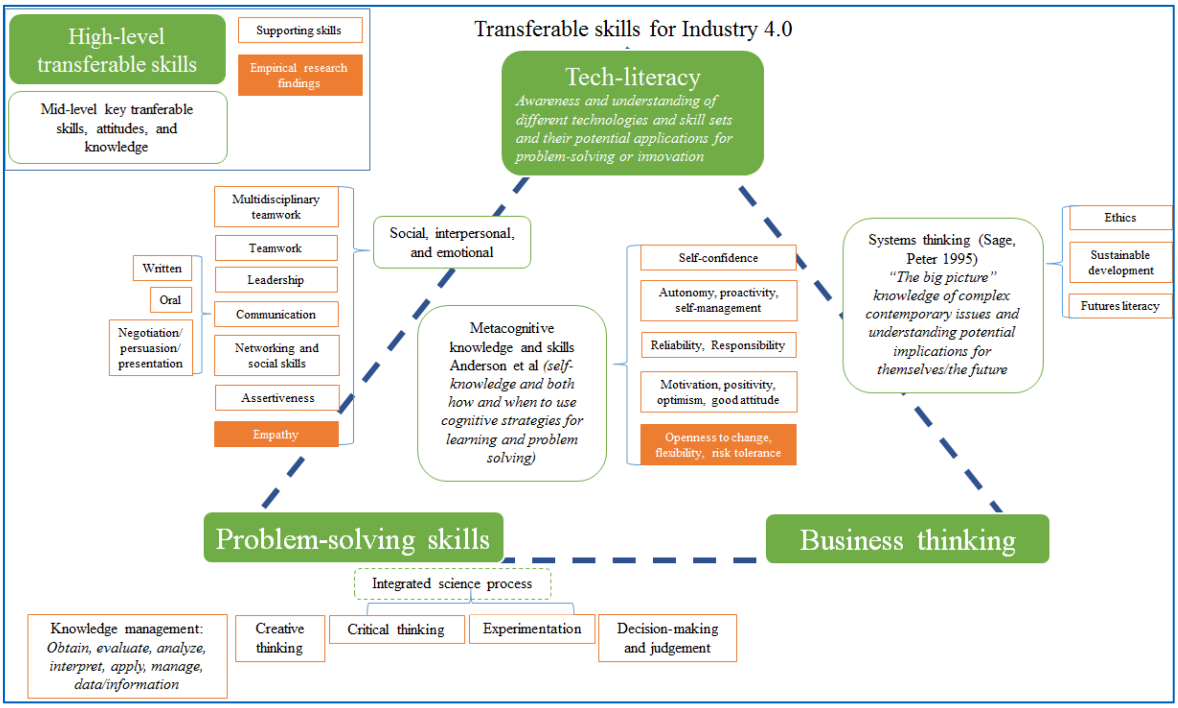

Figure 15 - Transferable skills for Industry 4.0

6. Conclusions

After presenting the results of the interviews, an image can be drawn where the skills are related to the challenges of Industry 4.0. Beyond the technological developments needed, a series of issues need to be addressed, both for enabling the technological developments, and to create the contexts in which technology creates value, both monetary and social. An underlying theme throughout, is understanding of technology and its implications and impact, and the interaction of technology with different fields for creating solutions in industry, and how those impact people. The table shows what skills are related to the most salient challenges in industry 4.0.

Table 8 - Challenges and skills of Industry 4.0

Challenges	Skills and competencies
Homogenous cultures and resistance to change	*Risk-taking, flexibility, adaptability*
Lack of vision on the value and impact of technology	*Technology literacy*
Choosing, investing in the right technology	*Technology literacy, business thinking*
Need of new business models	*Technology literacy, business thinking*
Lack of knowledge on the strategic use of information	*Competencies on Information management*
Cybersecurity and quality control	*Knowledge, competencies on cybersecurity and quality control*
Sustainability challenges	*Competencies, knowledge on sustainability*

In this table, homogeneous cultures and resistance to change can be countered with a more flexible attitude and adaptable mindset for people to actively examine their own idiosyncrasies that could lead to stiffness and rigidity. A lack of vision for understanding technology and its possible applications can be helped with a better understanding of technology solutions. This requires an effort and curiosity to be constantly updated on innovations and understanding where to invest technology development efforts. This knowledge, coupled with basic understandings of business foundations and commercial thinking can lead to the creation of new business models.

Increasing the knowledge on information management, and the foundations on data management (and ethical issues involved) is needed for the increasingly important topic of data management for value creation, as well as managing internal and external information needs. This becomes increasingly evident as network economies become more common. In the same vein, handling information necessitates knowledge and understanding of cybersecurity and strategic deployment of modern tools of quality control.

Finally, knowledge on sustainability issues and existing solutions need to serve as a guide, as understanding the impact that technology will have locally, regionally, and worldwide needs to become a consideration in the long-term decision-making process, especially as addressing issues of resource scarcity become a necessity for everyone.

This report suggests a model to visualize the Industry 4.0 challenges and skills. It is suggested that at the crossroads of tech fluency and problem-solving skills, there is innovation. In the intersection between tech literacy and business thinking, aided by systems thinking there is the possibility to create new business models and to better understand the impact of technology.

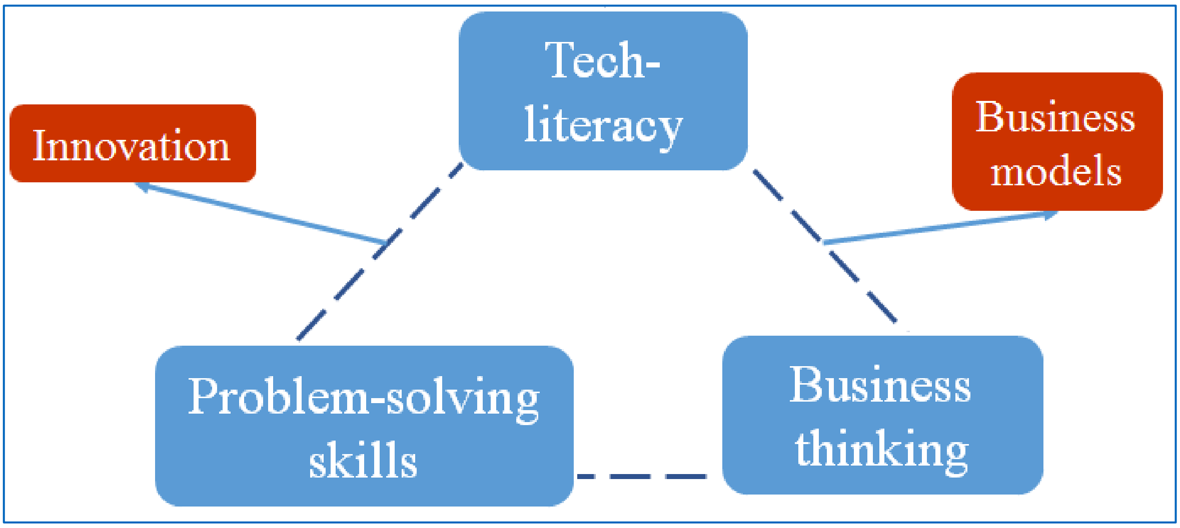

Figure 16 - Challenges and skills for Industry 4.0

Countries and organisations are implementing digital skills and other technology education programmes to prepare for Industry 4.0. As automation and cyber-physical systems become the norm, the work in the factories of the future will require more self-determination, initiative and decision-making. Making decisions will require cross-disciplinary knowledge to apply creative solutions to complex problems (Adolph, Tisch, & Metternich, 2014). Furthermore, when people are better able to understand themselves as well as the different aspects on any given issue, it is easier to understand their own role in work, both within organizations, as well as in more porous organizational work structures, such as those enabled by digital platforms.

As organizations and people become more interconnected, negotiation, communication and networking skills become essential. Technology may create new platforms to better measure or enable effectiveness and efficiency, and the emphasis of work changes from task-based to value-based. This challenging environment requires the abilities for continuous learning. Being flexible and open to change is necessary for continuous learning, and particularly when working with people from different disciplines, flexibility allows for mutual learning, better collaboration, and the creation of new solutions.

In the same vein, understanding the interactions and potentialities of different technologies helps in the process of working in multidisciplinary teams. A broader understanding of society, as well as business thinking, and technology literacy, enable the creation of novel business models, which is another challenge mentioned in the interviews. Understanding the user is another key element for success in technology solutions. Empathy is the underlying soft skill necessary for user experience design.

Leadership, communication, and interpersonal skills also help with the change management process when implementing new technologies and business models within an organization, as it is necessary to understand and then present the vision successfully in order to not only to engage people and align strategic objectives, but also to obtain resources for investments.

The issue of the use of information as a challenge came up as a response of what to do with the information, how to use it ethically but also how to enable new business models and strategies with the tech-enabled big data. In addition, even though ethical knowledge was not explicitly mentioned in the structured interviews, it was mentioned as a challenge, or a concern regarding the ethical implications of the use or development of technology.

This is in line with other industry reports related to Industry 4.0 skills. The World Economic Forum, for example, suggests "people skills, strong oral communication and persuasion skills, critical thinking, coordinating with others, emotional intelligence, judgement (as related to decision-making), service orientation, negotiation, and cognitive flexibility" (Schwab, 2016)**.** The European Reference Framework, on the other hand, define eight critical competencies for the future: native language and foreign language "communication, mathematics, basic science and technology competencies, digital competencies, learning to learn, social and civic competencies, sense of initiative and entrepreneurship, and cultural awareness and expression" (European Parliament, 2005)

A recurrent to topic throughout this research was the importance of having wide perspectives and interpersonal skills that complement well-developed domain-specific knowledge of their own field. Self-knowledge and lifelong learning are a staple of future work. Higher education institutions are fundamental in empowering professional workers to shape their own future by helping them develop the key transferable skills and attitudes they will need for continuously upskilling their own core professional competencies.

This work focused mostly on the future of professional work. The study and analysis did not look in-depth into the role of the so-called blue-collar work. The scope of the work also limited the age of the target group, as questions related more to “future workforce” information was not gathered about people closer to retirement age, or who have been in the workforce for a longer time. This thesis focused on the reasons why these skills might be important. Further research could also be applied on how skills are used or developed in the workplace.

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Appendix 1: Questionnaires

Questionnaire for semi-structured interviews

Intro

1. How did you end up in position x?
2. Are you familiar with Industry 4.0? Advanced manufacturing? what does it mean?

If not….Future trends, field, society, industry, education, workforce…

If yes… Is this something relevant for your field?

Main

3. What helps the development of the Industry 4.0? In organizations? In general? resources? Why?
4. Are there some things that can already be implemented? why? what is being implemented?
5. Which are the main obstacles/challenges? Why?
6. What sort of things need to be developed? Why?
7. What national/local/regional strategies do you know, if any, for advancing manufacturing technologies?
8. What competences/skills are required for working/implementing Industry 4.0? Why
9. Is it easy to find these skills currently? why?
10. Have you engaged or know of any collaborations between your and other organizations for education or training? What was the experience?

Final thoughts

11. What do you think are the next steps that should be taken?
12. Where do you see the greatest potential for development?
13. Are there any initiatives that you are interested in? Anything in particular that you would like to be working on?

Questionnaire for structured interviews

Background

1. Do you consider yourself to be in a researcher role or a practitioner role?

Researcher Practitioner Other:

2. Do you work in technical/engineering or management/business/sales

Engineering Business Other:

Maturity

3. Are you familiar with Industry 4.0 or the 4th Industrial Revolution?[5]

Not at all familiar Knows something about it Very familiar Working with it

4. How important do you consider it for your field?

Very important Somewhat important Not important

5. Do you or your company have a dedicated strategy for implementing Industry 4.0?

Yes No I don't know

6. If yes, which areas are covered by the development strategy?

Technology Business models/networks Operations

7. Does your company have any training programme for developing industry 4.0-related capabilities?

No training programmes

Yes but not for industry 4.0-related capabilities

Yes

Yes, and in collaboration with universities

8. What do you think are the biggest challenges for implementation of Industry 4.0 aspects/principles? Why?

Skills

9. What competences/skills are required for working/implementing Industry 4.0?
10. How easy is it easy to find the needed skills in the people currently in the workforce?

Thank you for your time! Is there anything else you would like to add?

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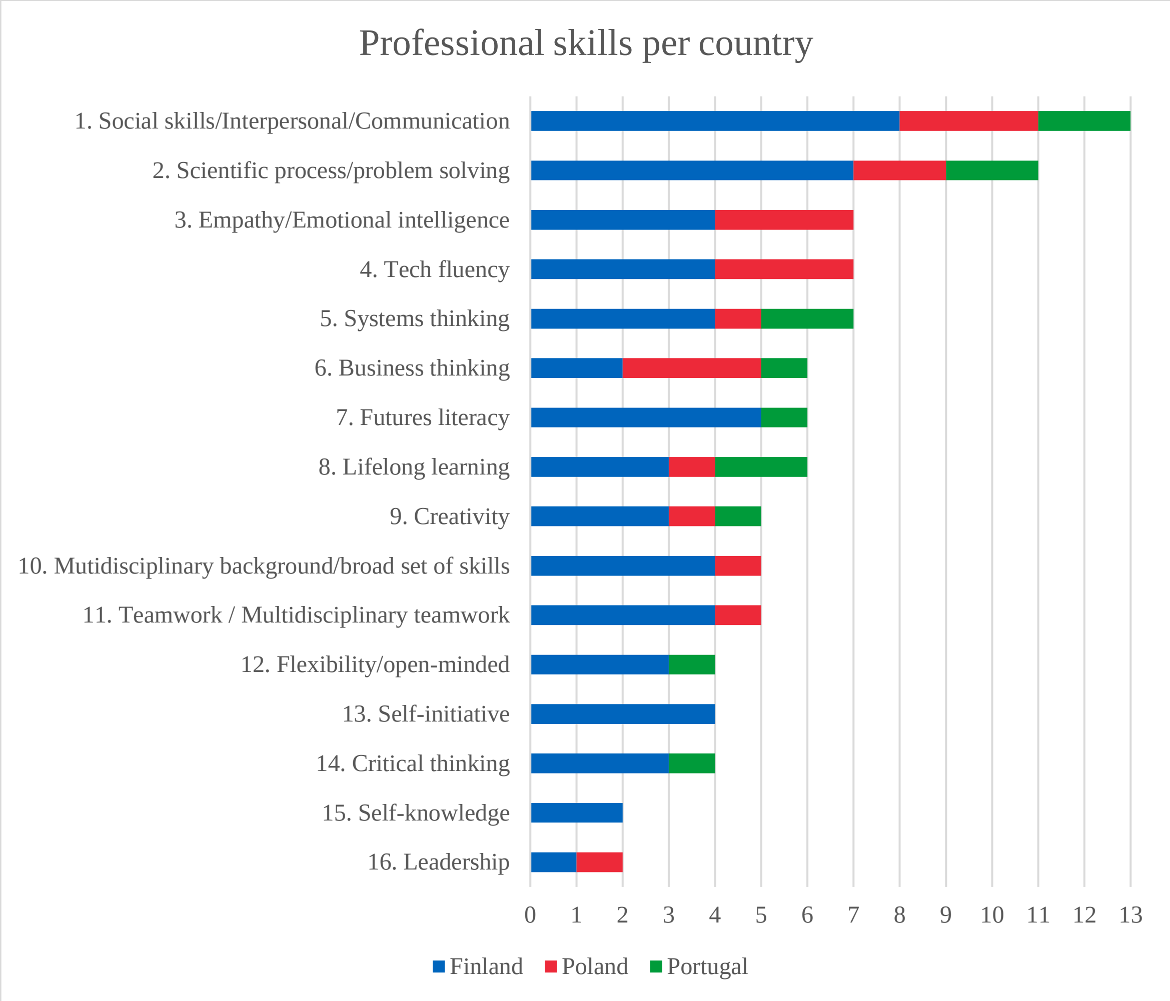
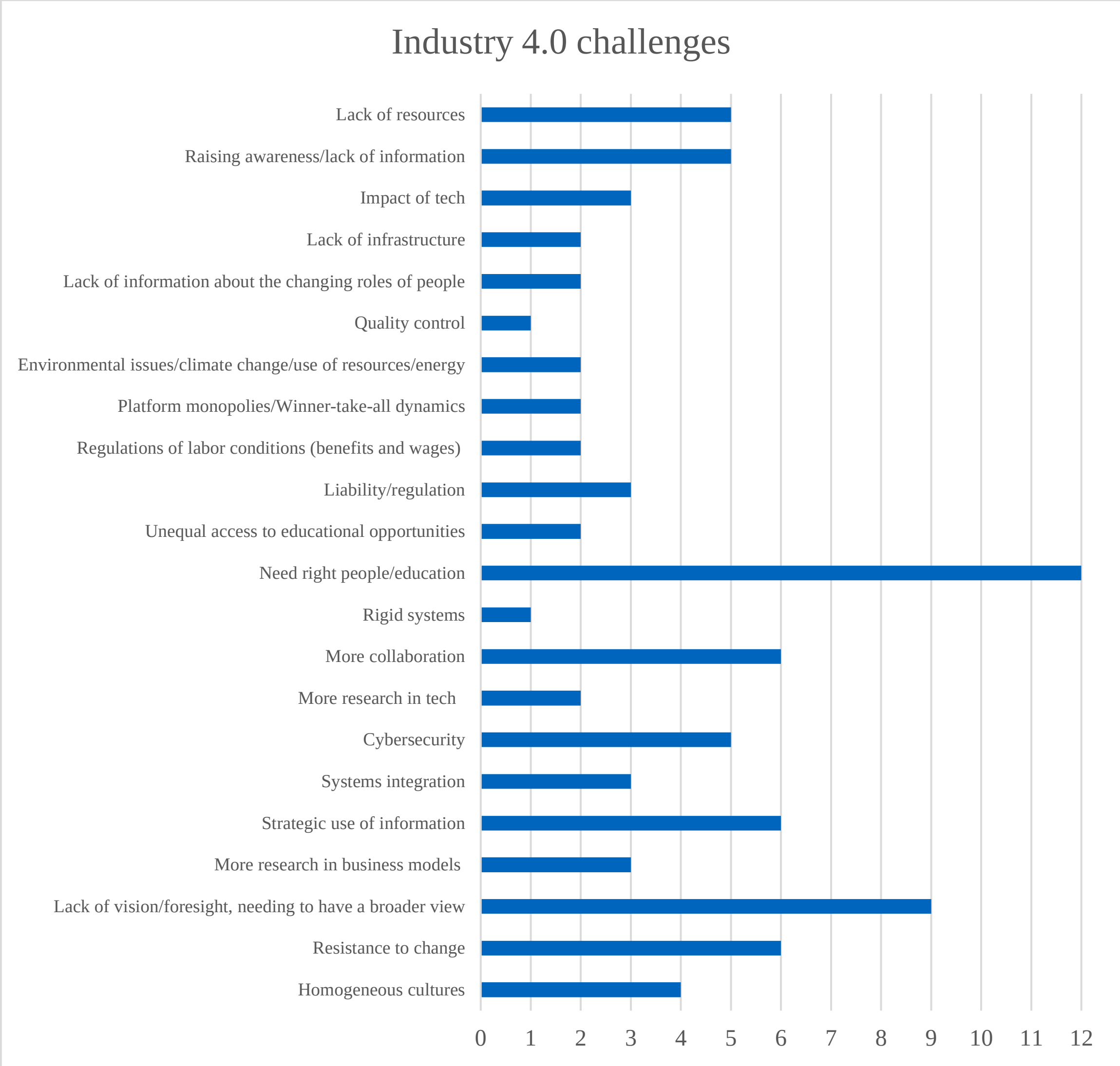
[5] * Industry 4.0 refers to the Fourth Industrial Revolution, in which advanced digitalization technologies (the Internet of Things and Cyber Physical Systems) allow for the creation of "Smart Factories".

Appendix 2: Responses, by country




Industry 4.0 challenges
Lack of resources
Raising awareness/lack of information
Impact of tech
Lack of infrastructure
Lack of information about the changing roles of people
Quality control
Environmental issues/climate change/use of resources/energy
Platform monopolies/Winner-take-all dynamics
Regulations of labor conditions (benefits and wages)
Liability/regulation
Unequal access to educational opportunities
Need right people/education
Rigid systems
More collaboration
More research in tech
Cybersecurity
Systems integration
Strategic use of information
More research in business models
Lack of vision/foresight, needing to have a broader view
Resistance to change
Homogeneous cultures
0 1 2 3 4 5 6 7 8 9 10 11 12

Appendix 3: Competence centres in Poland

Competence centers/DIHs funded by EU projects in Poland in H2020

Project Topic Code	Project Acronym	Project Duration	Project End Date	Participant Legal Name	Participant Role	Participant Short Name	Core Legal Entity Type	Research Organisation?
FoF-09-2015	HORSE	54	30/04/2020	SPOLKA AKCYJNA ODLEWNIE POLSKIE	PARTICIPANT	OPSA	PRIVATE	No
FOF-12-2017	MIDIH	36	30/09/2020	INSTYTUT CHEMII BIOORGANICZNEJ POLSKIEJ AKADEMII NAUK	PARTICIPANT	PSNC	PUBLIC	Yes
FOF-12-2017	L4MS	42	31/03/2021	FUNDINGBOX ACCELERATOR SP ZOO	PARTICIPANT	FBOX	PRIVATE	No
FOF-12-2017	AMable	48	31/08/2021	POLITECHNIKA WROCLAWSKA	PARTICIPANT	PWR	PUBLIC	Yes
FOF-12-2017	CloudiFacturing	42	31/03/2021	SKA POLSKA SP Z O. O.	PARTICIPANT	SKA	PRIVATE	No
ICT-04-2017	TETRAMAX	48	31/08/2021	TECHMO SPOLKA Z OGRANICZONA ODPOWIEDZIALNOSCIA	PARTICIPANT	TECHMO	PRIVATE	No
ICT-04-2017	TETRAMAX	48	31/08/2021	FUNDINGBOX ACCELERATOR SP ZOO	PARTICIPANT	FBOX	PRIVATE	No
FOF-12-2017	I4MS-Go	30	29/02/2020	FUNDINGBOX ACCELERATOR SP ZOO	COORDINATOR	FBOX	PRIVATE	No
609029	FORTISSIMO	42	01-Jul-2013	MICROSCOPEIT SP ZOO	Participant	MIT	Participant	PRC
619205	ACTPHAST	48	01-Nov-2013	POLITECHNIKA WARSZAWSKA	Participant	WUT	Participant	HES
619205	ACTPHAST	48	01-Nov-2013	UNIWERSYTET MARII CURIE-SKLODOWSKIEJ	Participant	UMCS	Participant	HES
619205	ACTPHAST	48	01-Nov-2013	INSTYTUT TECHNOLOGII MATERIALOW ELEKTRONICZNYCH	Participant	ITME	Participant	REC

Image 1(*Digital scoreboard 2016 and other information relevant for decisions about Digital Innovtion Hubs - Poland*, 2016)

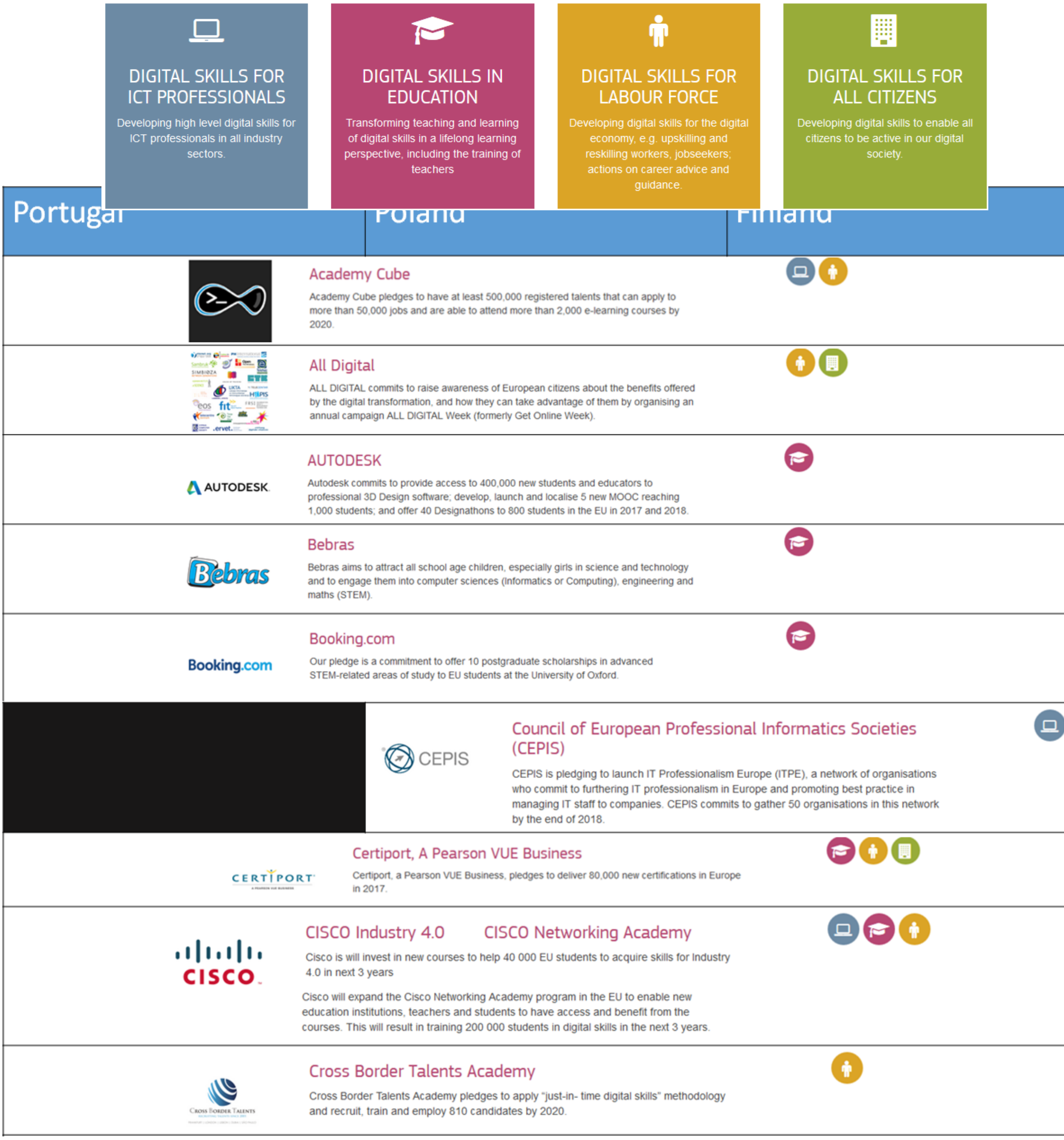
Pilot Lines in Nanotechnology and Advanced Materials

European Commission

Project Number	Project Acronym	Project Title	Project Start Date	Project End Date	Participant Legal Name	Participant Short Name	Sectors	Pilot line
646307	PLATFORM	Open access pilot plants for sustainable industrial scale nanocomposites manufacturing based on buckypapers, doped veils and prepregs	01/02/2015	31/01/2018	FUNDACJA PARTNERSTWA TECHNOLOGICZNEGO TECHNOLOGY PARTNERS	FUNDACJA PARTNERSTWA TECHNOLOGICZNEGO TECHNOLOGY PARTNERS	Aerospace, Defence industry, Automotive industry, Chemical Industry, Energy storage, Textile Industry, Power Generation Industry, Oil and Gas Industry , Security Industry, Construction Industry	Continuous melt blown filaments
646307	PLATFORM	Open access pilot plants for sustainable industrial scale nanocomposites manufacturing based on buckypapers, doped veils and prepregs	01/02/2015	31/01/2018	TOMASZ MARIAN KOSMIDER	TMBK Partners		
646364	NANOFACTURING	The Development of Medium- and Large-Scale Sustainable Manufacturing Process Platforms for Clinically Compliant Solid Core Nanopharmaceuticals	01/02/2015	31/01/2019	PROCHIMIA SURFACES SP. Z O.O.	PROCHIMIA		
646397	NANOLEAP	"Nanocomposite for building constructions and civil infraestructures: European network pilot production line to promote industrial application cases."	01/01/2015	30/06/2018	PURINOVA Sp. z o.o.	PUR		

Image 2: (*Digital scoreboard 2016 and other information relevant for decisions about Digital Innovtion Hubs - Poland*, 2016)

Appendix 4: Educational initiatives for digitalization in Finland, Poland and Portugal



DIGITAL SKILLS FOR ICT PROFESSIONALS
Developing high level digital skills for ICT professionals in all industry sectors.

DIGITAL SKILLS IN EDUCATION
Transforming teaching and learning of digital skills in a lifelong learning perspective, including the training of teachers

DIGITAL SKILLS FOR LABOUR FORCE
Developing digital skills for the digital economy, e.g. upskilling and reskilling workers, jobseekers; actions on career advice and guidance.

DIGITAL SKILLS FOR ALL CITIZENS
Developing digital skills to enable all citizens to be active in our digital society.

Portugal | Poland | Finland

Academy Cube
Academy Cube pledges to have at least 500,000 registered talents that can apply to more than 50,000 jobs and are able to attend more than 2,000 e-learning courses by 2020.

All Digital
ALL DIGITAL commits to raise awareness of European citizens about the benefits offered by the digital transformation, and how they can take advantage of them by organising an annual campaign ALL DIGITAL Week (formerly Get Online Week).

AUTODESK
Autodesk commits to provide access to 400,000 new students and educators to professional 3D Design software; develop, launch and localise 5 new MOOC reaching 1,000 students; and offer 40 Designathons to 800 students in the EU in 2017 and 2018.

Bebras
Bebras aims to attract all school age children, especially girls in science and technology and to engage them into computer sciences (Informatics or Computing), engineering and maths (STEM).

Booking.com
Our pledge is a commitment to offer 10 postgraduate scholarships in advanced STEM-related areas of study to EU students at the University of Oxford.

Council of European Professional Informatics Societies (CEPIS)
CEPIS is pledging to launch IT Professionalism Europe (ITPE), a network of organisations who commit to furthering IT professionalism in Europe and promoting best practice in managing IT staff to companies. CEPIS commits to gather 50 organisations in this network by the end of 2018.

Certiport, A Pearson VUE Business
Certiport, a Pearson VUE Business, pledges to deliver 80,000 new certifications in Europe in 2017.

CISCO Industry 4.0 | **CISCO Networking Academy**
Cisco is will invest in new courses to help 40 000 EU students to acquire skills for Industry 4.0 in next 3 years

Cisco will expand the Cisco Networking Academy program in the EU to enable new education institutions, teachers and students to have access and benefit from the courses. This will result in training 200 000 students in digital skills in the next 3 years.

Cross Border Talents Academy
Cross Border Talents Academy pledges to apply "just-in- time digital skills" methodology and recruit, train and employ 810 candidates by 2020.

Dell EMC

Dell EMC will expand its Academic Alliance program to offer ICT skills to a greater number of students in Europe and help them prepare for successful careers in a transforming IT industry.

Department of Computer Sciences, University of Alcalá

The Department of Computer Sciences, University of Alcalá pledges to offer open tools and training to guide IT professionals and beginners towards the best employability in the ICT profession through the most relevant competence framework, e-Competence Framework (e-CF EN16234), and the new labor classification ESCO.

Digital Leadership Institute

The Digital Leadership Institute pledges to promote greater participation of girls and women in ESTEAM (entrepreneurship, science, technology, engineering, arts and mathematics) sectors.

Digital Skills Academy

Digital Skills Academy pledges is to increase the number of digitally-skilled employees across Europe by reskilling 1,600 job-seekers in Ireland, with the goal of 92% graduate employment, and upskilling 8,400 working professionals across Ireland, France, Germany, Greece, Spain, Portugal and the UK by 2020.

ECDL Certifications / Digital Marketing / Pilot Computing Module

ECDL Foundation pledges that by the end of 2018, 2 million digital skills assessments leading to certification under ECDL standards will be taken in the EU. This will contribute to reducing the share of Europeans (45%) who lack basic digital skills and increase their employability and mobility in the labour market.

ECDL Foundation pledges to implement the Digital Marketing module developed and piloted as pledge for the Grand Coalition for Digital Jobs in 2015 in at least 5 EU countries by the end of 2017. This pledge is aimed to tackle the problem of a small share of SMEs who sell online (16%) and across borders (7.5%).

ECDL Foundation pledges to launch an ECDL Computing module which will cover all elements of computing and to pilot it in Europe. The module will be aimed at students aged 12 to 16 years, who wish to start learning about computational thinking and coding.

eSkills for Volunteers

Eskills for volunteers pledges to develop a certification tool and courses to help 200 young volunteers acquire digital literacy.

ESRI

ESRI is pledging to establish a "GIS School Program" offering free access to and use of the ArcGIS Online platform -a Cloud-based package, which allows the visualisation and analysis of geospatial data- to 300 primary and secondary schools and vocational institutions in 10 EU Member States by the end of 2017.

European Digital Learning Network / Communication campaign / Survey second edition

European Digital Learning Network pledges to carry out a pan-European survey to gather qualitative data about current trends and future developments in education related to digital skills. The pledge will take place between May and October, when results will be published in a final report. The survey will tackle all educational sectors: School education, Vocational Education, Higher Education and Adult education with a lifelong learning approach.

European Digital Learning Network pledges to carry out an informative and regular campaign to inform EU citizens, organisations, National Institutions and other relevant stakeholders about digitization, which is radically transforming the economy and the workforce.

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European Digital SME Alliance

European Digital SME Alliance is pledging to reach 5000 people by 2019 with its #digitalSMEs4skills campaign. The campaign will enroll hundreds of digital SMEs, such as software developers and tech integrators, which will transfer digital skills to people by offering them internships.

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European Schoolnet

European Schoolnet will train 15 000 teachers in innovative teaching and pedagogical use of technology between 2016 and 2020 through European Schoolnet Academy.

Google — Grow with Google

Google is pledging to continue to support European to gain digital skills through the following initiatives: Digital Workshop (online training hub); engaging young job seekers; helping small businesses to grow; funding 10,000 Android scholarships via Udacity and in partnership with Bertelsmann for EU mobile developers.

Google pledges to help 1 million Europeans to find a job or grow their business by 2020 as a part of its ongoing initiative Grow with Google.

Instituto Politécnico de Santarém

The #Picking Winners (Course ecosystem - job training, digital literacy and Labour Mediation) project will develop the necessary networking activities, resources and materials in order to address the needs of VET students with disabilities.

K2 Partnering Solutions

K2 Partnering Solutions, through K2 University, is pledging to help close the digital skills gap in Europe by training 800 IT professionals, 1,000 students and 400 Workforce Professionals in the key technology growth areas of SAP and Salesforce, to become SAP consultants and Salesforce professionals.

Kaspersky Lab

Kaspersky Lab pledges to scale up cooperation with universities and reach more students with Futureproofing Cybersecurity campaign.

Liberty Global

Liberty Global pledges to create digital solutions to boost the digital skills of Europeans through its Digital Imagination program.

Microsoft

Microsoft will increase access to computer science education and digital skills training for 5 million youth across 2 years in all 28 EU member states. This will be accomplished through a holistic approach that directly empowers both educators and youth. Furthermore, we are refocusing our non-profit-led training efforts in 21 EU member states by aiming to reach at least 50% girls.

ORACLE ACADEMY

Oracle

Oracle, through its Oracle Academy, is pledging to invest US $1.4 billion in direct and in-kind support for computer science education in the EU member states over the next 3 years, reaching students in 1,000 additional EU educational institutions, nearly doubling its current EU Oracle Academy membership.

paloalto

Palo Alto Networks - Academy Programme

The Palo Alto Networks Academy will provide cybersecurity courseware, certifications, faculty training, instructional resources, and enterprise security platform lab technology at no cost to qualified European academic institutions. We will also be actively involved in sponsoring and supporting collegiate and secondary cybersecurity competitions in Europe.

WePROMIS®

PROMIS@Service & Millennia2025

Millennia2025 and PROMIS@Service are pledging to expand their alliance with the goal of advising women and men concerned by gender equality in particular through eMentoring, transfer of knowledge and eSkills, doubling by 2020 the Millennia2025 community of international voluntary researchers which at present counts 10.717 contacts and 4.419 members in 141 countries.

SAP

SAP Next Generation

SAP Next Generation pledges to open 24 SAP Next-Gen Labs and start 180 SAP Next-Gen Consulting projects by 2020. SAP Next Generation is an open innovation platform connecting students, researches, thought leaders, start-ups, accelerators with corporates and venture capitalist to seed in disruptive innovation and accelerate the digital transformation and digital futures of the economy.

Telefónica

Telefónica Educación Digital

Telefónica Educación Digital pledges its support to the Digital Skills and Jobs Coalition by offering free access for all citizens to three online platforms with educational resources.

Transformify

Cross Border Talents

Transformify

Transformify #GoRemote program commits to collect data about the digital skills demanded by the business and the digital skills possessed by the people registered with Transformify platform. Based on the report, Transformify will offer e -learning opportunities jointly with partners to help bridge the digital skills gap. At least 5000 targeted remote jobs will be offered via the Transformify platform.

Transformify & Cross Border Talents Academy

Transformify and Cross Border Talents Academy jointly commit to provide targeted e-learning courses and digital jobs to more than 100 job seekers by the end of 2018.

Ubiqum Code Academy

Ubiqum Code Academy and its partners pledge to increase the number of digitally-skilled employees in Europe, and to help tackle youth unemployment, by reskilling 3,000 jobseekers by 2020.

ubiqum

YouRock.Jobs

YouRock

YouRock.Jobs is an online employability site allowing users to create dynamic skills personality profiles in support to young people (16-30) with little or no work history. Its pledge is to reach 15,000 new users and connect with 20 National Coalitions by the end of 2018.