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Dean Stroud · Antonius Johannes Schröder · Luca Antonazzo · Clara Behrend · Valentina Colla · Aitor Goti · Martin Weinel *Editors*

Industry 4.0 and the Road to Sustainable Steelmaking in Europe

Recasting the Future

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The Effects of Industry 4.0 on Steel Workforce: Identifying the Current and Future Skills Requirements of the Steel Sector and Developing a Sectorial Database

Tugce Akyazi, Aitor Goti, and Félix Báyon

1 Introduction

The European steel sector is going through continuous and considerable changes due to the emerging digitalization of steel production and strong demands to put the sector on a more environmentally sustainable footing. The manufacturing models are altering with the adoption of smart technologies such as Internet of things (IoT), Artificial Intelligence (AI), robotics, etc. The use of digital technologies results in a new stage of automation, which enables more efficient and creative processes, products and services (Jagannathan and Maclean 2019; German National Academy of Science and Engineering 2016). Even though the steel industry has been recognized as a matured sector with minor technology updates, the sector is already participating in Industry 4.0 evolving into a smart industry. The steel companies are digitizing their manufacturing processes by integrating the 4.0 technologies into the melting, casting, rolling and finishing sub-processes (European Commission Executive Agency for Small and Medium-sized Enterprises 2019). The interconnected, flexible and complex processes have potential to completely change the organizational structure, job profiles and skills requirements of the steel industry. Nevertheless, most of the workers with experience in metallurgy do not have the required technological skills (European Commission Executive Agency for Small and Medium-sized Enterprises 2019).

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As a result, the steel sector is in urgent need of a multi-skilled workforce which is qualified enough to manage the implementation of the smart technologies, contemporary business models and organizational structures. Building this competent labour force is only possible through upgrading the skills, knowledge and credentials. A workforce with updated skills is key for the steel sector to keep up with the growing digitalization, and to adapt to novel working systems. The initial step of the continuous re-skilling and up-skilling of the workforce is addressing the current skills needs and trends as well as foreseeing the future ones. This chapter aims to accomplish that objective through performing a detailed desk analysis and creating a sectoral occupational database. Once the anticipated evolution of skills needs is identified, a long-term skill implementation methodology may be established for reducing the skills gap between the industry expectations and the current workforce. Such a methodical approach would ideally provide tools for the recruitment of new talents, as well as introduce well-developed education and training programs for the current workforce, and redesign work processes.

Accordingly, the steel sector critically demands a roadmap guiding the sector to identify the current and future skills needed by the workforce and tools to implement them. Additionally, a sectorial guideline is needed for education policy makers to facilitate the relevant education programs, degrees and subject-matter syllabuses being compatible with the industry's skills needs. This chapter is developed in response to these needs.

This chapter describes step-by-step the methodical process applied to the steel sector. Initially, we have performed detailed desk research to identify the current steel sector skill trends. Then, we present the development of a sectorial occupation-skills database, through determining the actual and future competences requirements. To achieve that goal, principally we analyse the strategies for the implementation of competences followed by other sectors (e.g. machine tool, construction) and develop a methodology—adjusted from a broad spectrum of European sectoral and cross-sectoral frameworks, projects and scientific articles—to describe the steel industry requirements related to future skills. During the generation of the database, we identify the current and future competences needed by the steel sector occupations (engineers, operators and managers).

To define the relevant steel sector occupational profiles and identify the competence needs of each profile, we use the database of European Skills, Competences, Credentials and Occupations (ESCO). Then, we create the occupation-skills database in an automated excel format using Visual Basic for Applications (VBA) through the integration of the selected occupations and their current skills needs.

To support the development of future competences, we analyse the occupational profiles which are present in the database one by one and pick the ones that will be transformed through the sector's digitalization. For this purpose, we again utilized notable European references related to the subject: numerous strategic inter-sectoral and sectoral European frameworks and projects. Once the future competence needs of each profile are identified, they are integrated into the database to finalize the update process. Eventually, we generate an automated database incorporating the present and future competences needs of the steel sector job profiles. Finally, in the

last section, the main conclusions are discussed explaining the potential importance of our research for companies, training centres, policymakers and researchers.

We envisage that the sectoral database can serve the steel industry as a fundamental tool for all the future technological and organizational transformations. The target end-users of this database are steel manufacturers, universities, training and education centres who are responsible from the development and delivery of training programs. We believe that this work has a potential to be used as a framework guiding the sector for building a competent and multi-skilled workforce.

2 Identifying the Current and Future Skills Requirements for the Steel Sector

This section focuses on identifying the (current and future) competence requirements of the steel workforce. When we talk about the "future" skills, we refer to the foreseen skill needs for the next 10 years (till 2033). To this end, firstly, we evaluate the most recent skills trends affecting the steel industry performing desk research. Secondly, we demonstrate the development of the sectoral occupation-skill database step by step, presenting the methodology and the results (Sect. 3). The key condition for achieving a relatively accurate perception of the evolution of skills is to have a general idea about the future steel industry. This is only possible through examining and determining the outcomes of the ongoing and future industrial changes on the steel workforce.

As for all industries, the steel sector has been tremendously affected by the COVID-19 pandemic. The main consequence of the pandemic from an industrial and business perspective is the accelerated adoption of digital technologies which enable agile and flexible operations. Industrial digitalization has accelerated greatly across the whole manufacturing industry through adopting existing and new technologies related to Industry 4.0 (Naselli 2020; Agrawal et al. 2021). Therefore, the top strategic priorities of the industry have been the integration of smart technologies and the upskilling and reskilling of the workforce accordingly (Agrawal et al. 2021).

On the other hand, during the last decades in the EU, the job loss for workers with low-skilled routine in manufacturing has been observed to increase and it is anticipated to increase further as a result of the automation of the tasks carried out by these job profiles. The upskilling and reskilling of low-profile workers can keep them still useful for the industry (Madl 2021).

Along with digitalization, the steel industry is looking for solutions that make it possible to use resources efficiently and reduce CO_2 emission levels while keeping up competitiveness and economic development. Therefore, both policymakers and companies are constantly integrating the concerns about sustainability into their agendas. Moreover, their strategies focus not only on optimal consumption of resources, sustainability and energy efficiency, but also safety and well-being of employees (Spire-SAIS 2020). Digital technologies facilitate the steel manufacturers

to carry out more energy and resource efficient and less environmentally damaging processes. Sustainability establishes the background for Industry 4.0 (Gajdzik et al. 2020). Even if we cannot separate one from the other as an element in a distinctive way, Industry 4.0 and sustainability are emerging as two main factors that drive the evolution of skills in the steel industry (European Commission Executive Agency for Small and Medium-sized Enterprises 2019). These two drivers result in an acceleration of skill shifts compared with historical trends and also push the sector to improve the quality of skills to fulfil the needs of the industry.

The technological developments are altering the tasks performed by the steel professionals and therefore changing the skills needed to execute these tasks (European Commission Executive Agency for Small and Medium-sized Enterprises 2019; Ellingrud et al. 2020). First of all, the workers will be able to make more informed decisions in shorter periods of time and deal with complicated circumstances due to the real-time data developed by the automated and smart production systems (European Commission Executive Agency for Small and Medium-sized Enterprises 2019; Branca et al. 2020; Schlegel et al. 2018). The majority of the workers will be executing their day-to-day operations beside robots and machines. Collaborative robots will become more autonomous and tackle the plain and repetitive tasks, while operators will perform more complex tasks and make critical decisions (European Commission Executive Agency for Small and Medium-sized Enterprises 2019; Akyazi et al. 2022). Therefore, the importance of decision-making skills will increase substantially.

Additionally, the relationship between machines and humans is being altered by 4.0 technologies (Gajdzik and Wolniak 2021; Tihinen et al. 2017; Ten and St 2015). **New technologies are minimizing physical human work**. Since the high degree of automation will decrease the human intervention in routine production tasks, the workers will be mainly gathered in control rooms operating remotely. Many tasks performed physically by the workers will be operated using computers, monitoring data and providing oversight.

On the other hand, new skills are expected from the workforce to control the new technologies, to supervise the automated processes and execute more qualified work (Gajdzik and Wolniak 2021) (Romero et al. 2016). For example, thanks to the self-learning productions systems (made possible by AI) **operators will be able to supervise the work** of machines remotely (European Commission Executive Agency for Small and Medium-sized Enterprises 2019; Gajdzik and Wolniak 2021; Bokrantz et al. 2017; Wang et al. 2018). Concurrently, human intervention will become more essential not only during the supervision of the machines but also during maintenance activities (European Commission Executive Agency for Small and Medium-sized Enterprises 2019). Also, capability of online supervising can lead the operators to home office working. The integration of artificial intelligence will cause the organizations to be more **team-oriented** and **top-down hierarchal structures with bureaucracy, collaboration and communication barriers are likely to lose influence** (European Commission Executive Agency for Small and Medium-sized Enterprises 2019; European Centre for the Development of Vocational Training 2009). Teamwork not only between co-workers, but also between the automated

systems and co-workers will become more important (European Commission Executive Agency for Small and Medium-sized Enterprises 2019; European Centre for the Development of Vocational Training 2009).

In general, the job profiles of the steel industry are not expected to be replaced entirely, instead they are expected to **execute more tasks in various departments**. Therefore, workers will be demanded to have a **wider knowledge in different subjects and higher qualification**. Multitasking will become a significant skill for the workers (European Commission Executive Agency for Small and Medium-sized Enterprises 2019; Akyazi et al. 2022).

The major consequence of the aforementioned transformation is the **growing demand for the digital skills** as the steel companies adopt smart technologies (Madl 2021; Deming 2015). Therefore, the workers will be expected to have not merely basic digital competences, but also advanced digital competences related to IoT, AI, robotics, Machine Learning, AR, Big Data Analytics, Cloud Computing, Digital twin, simulations, Predictive Maintenance (European Commission Executive Agency for Small and Medium-sized Enterprises 2019; Branca et al. 2020; Gajdzik and Wolniak 2021; Neef et al. 2018; Fragassa et al. 2019; Hanoglu and Šarler 2019; Colla et al. 2021). Due to this demand, data safety and protection will become crucial to increase the trust in new technologies.

The adoption of digital innovation demands not only digital skills but also require **social and emotional skills**—which machines will not capable of learning in the near future—from the steel sector workers (European Commission Executive Agency for Small and Medium-sized Enterprises 2019; Akyazi et al. 2022). Due to increasing automation, workers will be responsible for more significant tasks which require solid literacy, numeracy, ICT along with some **soft skills** such as collaboration, initiative taking, problem-solving and teamwork (Deming 2015; Industry-driven sustainable European Steel Skills Agenda and Strategy 2019). Flexibility and transferability will become more important as the workers are expected to execute varied tasks (German National Academy of Science and Engineering 2016). Also, because of the growing automation basic cognitive skills will lose importance as higher cognitive ones such as creativity, lifelong learning, teamwork, problem solving, decision making will become more significant (European Commission Executive Agency for Small and Medium-sized Enterprises 2019; Gajdzik et al. 2020; Industry driven sustainable European Steel Skills Agenda and Strategy 2019). Critical thinking, independent problem solving, managing complexity, complex information processing, cross-functional process know-how, interdisciplinary thinking and acting will be crucial in the future industrial environment (Schlegel et al. 2018; Deming 2015). The demand for communication and negotiation skills will also increase (European Commission Executive Agency for Small and Medium-sized Enterprises 2019; Schlegel et al. 2018). Despite of the decreasing demand, manual and physical skills will continue being the largest category of skills (Gajdzik et al. 2020; Schlegel et al. 2018). This category of skills will be updated for each occupation depending on the level of automation of the profile.

Moreover, **green skills** are acknowledged as vital in order to sustain the competitiveness of the European manufacturing industry (including the steel sector) due to

the growing focus on environmental awareness, sustainability and energy efficiency (European Commission Executive Agency for Small and Medium-sized Enterprises 2019; Organisation for Economic Co-operation and Development 2014). The relevance of green skills can also be explained by the fact that EU countries have agreed to reach certain legally binding environmentally targets by 2050 (Spire-SAIS 2020; Organisation for Economic Co-operation and Development 2014). Not only managers, but also operators will be expected to have knowledge in resource efficiency, recycling and material reutilization in the near future (ESSA 2019). Some of the green skills needs relate to environmental awareness, environmental monitoring, sustainability, circular economy, industrial symbiosis basic understanding and methodologies, field experience, waste management, waste reduction and prevention, resource, reuse and recycling, eco-design of product, technology and process, water conservation, sustainable resource management, product life cycle assessment, energy management of equipment and plants, developing and installing analysis systems for energy use, manufacturing principles to reduce energy consumption, monitoring and investigating energy use, selection and use of monitoring equipment for energy consumption, energy data collection and analysis, industry field experience, general regulatory awareness, legislative and compliance requirements, legislation about waste management and CO_2 emissions (Spire-SAIS 2020; Organisation for Economic Co-operation and Development 2014; INSIGHT Industrial Symbiosis Facilitator 2020).

In conclusion, the future steel workforce is expected to have cognitive and social skills that enables them to work alongside increasingly automated technologies, such as critical thinking, communication, team working and lifelong learning. The steel sector also demands from its labour force to have basic and complex digital skills to handle the digital transformation smoothly and effectively. In addition, green skills present key importance for the workforce to manage European regulations and policies about the sustainability, energy efficiency and environment, which is one of the current focuses of the European steel industry.

3 Generation of the Sectorial Database

This section demonstrates the main objective of the chapter: the generation of the database incorporating competence needs (present and near-future) for the steel sector professional profiles. We firstly explain the development of the methodology (Section "Materials and Methods") and later, present the results (Section "Results and Discussion").

Materials and Methods

The methodology incorporates broad desk research of international publications, inter-sectorial European projects and frameworks, with the opinions of ESSA (Industry-driven sustainable European Steel Skills Agenda and Strategy) subject matter experts about the future skill demands of the steel sector workforce. A similar methodology underpinned previous research on other sectors undertaken by our team (Akyazi et al. 2020a, b, c, d, 2022; Arcelay et al. 2021).

The two main data sources that we used for the generation of our database were: (a) the database of ESCO (created by the European Multilingual Classification of Skills, Competencies, Qualifications and Occupations (ESCO) association—cultivated by the European Commission) and (b) Industry-driven sustainable European Steel Skills Agenda and Strategy (ESSA) project aiming to establish a Blueprint for "New Skills Agenda"—an EU project that we are directly involved in (ESSA 2019). ESCO could be considered a dictionary that classifies skills and professional occupations essential for education, training and labour markets in Europe (European Commission ESCO European Skills/Competences Qualifications and Occupations 2022). It is a European multilingual categorization of occupations, competences and skills. The ESCO database is based on the "International Standard Classification of Occupations" (ISCO-08) framework developed by ILO (International Labour Organization); it enables the ESCO database to be directly linked with a wide range of international occupational group categorizations established by ILO.

The other main source, the ESSA project, has been initiated to develop a Blueprint for a sustainable, steel industry-driven and coordinated European Steel Skills Agenda (ESSA) and to present a strategy for an ongoing and short-termed implementation of new skills demands. The project aims to pilot this by the development of modules and tools for building awareness and implementing new skills for a globally competitive industry, ready to anticipate new skills demands and to develop pro-active and practical activities to meet the future requirements of the evolving job profiles of the steel industry ESSA 2019).

Moreover, the desk research that we executed during the development of Sect. 2 for identifying the general skills trends for the steel sector contributed immensely to the development of the database. The literature was carefully selected from the high impact journal articles, reports published by European Commission and McKinsey consulting.

Furthermore, the "European ICT System of Professional Role Profiles Framework" created by the "Council of European Professional Informatics Societies (CEPIS)" and the "European Committee for Standardization (CEN)" was used as a significant reference to identify ICT-related skills needs of the steel sector. CEPIS is the representative party of national informatics associations in Europe. It is a non-profit organization that not only represents IT professionals in 28 countries but also addresses the development of prominent standards among IT professionals through recognizing the effect of IT on industry, society and labour market (Council of European Professional Informatics Societies 2020).

Furthermore, CEN is the association that combines the National Standardization Entities of 34 European countries supporting standardization activities in a broad range of areas and sectors (European Committee for Standardization 2022). The two aforementioned organizations worked together to develop the "European ICT Professional Role Profiles Framework" supporting the generation of a common European reference for the management, planning and progress of the skill needs related to ICT from a specific perspective (European Committee for Standardization and European e-Competence Framework 2019).

We also benefited from several inter-sectorial strategic projects such as "Skills Alliance for Industrial Symbiosis—a Cross-sectoral Blueprint for a Sustainable Process Industry" (Spire-SAIS 2020), Machine Tool Alliance for Skills (METALS 2016), Digitalization of Small and Medium Enterprises, SMEs (SMeART 2018) and Procedures for Quality Apprenticeships in Educational Organizations (APPRENTICESHIPQ 2018). These projects provided us with a general point of view about the new skills needs in different sectors, related to energy efficiency, industrial symbiosis, digitalization and training.

During the development of the automated sectorial database for the occupation and skills of the steel industry, Visual Basic for Applications (VBA) was used as the programming language in Microsoft Excel Spreadsheet Software. Considering that ESCO database is updated regularly by the organization, our database needs to keep up with these update routines. Therefore, an Application Programming Interface was established in order to automate the updating process of the generated database.

Results and Discussion

The main objective of the methodology is to create an automated skills database for the steel sector job profiles. It includes the current competence needs as well as the near-future ones which are foreseen for the next 10 years.

While identifying the steel sector-associated professional profiles and detecting their current skills and competence needs, the main source of the data was ESCO. Firstly, we analysed the professional profiles connected with the steel sector in ESCO's database. Then, we picked them and integrated them into an excel datasheet. Once all the job profiles were present in the document, we executed the automation process through applying VBA on the datasheet. Therefore, the first edition of the automated database which incorporates solely the current skill and knowledge needs was generated. The following procedure was applied to detect the skill and competence needs for the future and incorporate them into the already-automated database.

ESCO provides us with a very convenient and systematic database used as a reliable reference to gather information related to professional profiles and skills in the EU labour market. However, it does not include satisfactory information related to natural evolution of occupations; its content needs to be updated about the new competence needs arising from the technological developments: namely

digital, transversal and green competences. Therefore we used references other than ESCO to identify the future skills requirements of the steel sector. We carried out desk research about the general skill trends about the future of the steel sector (Sect. 2) and we combined it with the general elements of the methodology which we had developed in ESSA project. Therefore, the main reference used for defining the future competences (digital, personal, social, methodological, green) was the ESSA project. After that, we identified and picked the most relevant skills for the steel sector from the outputs of various EU-level databases and research projects: green competences from the SPIRE-SAIS project, ICT-related competences from the framework of European ICT Professional Role Profiles, and digital and personal, methodological competences from the METALS project.

The final list of future competences was generated through merging the results with the subject matter experts' opinions. This process enabled us to obtain detailed understanding about the additional competences demanded of the steel workforce in order to proceed a successful digital transformation and to achieve a sustainable and competitive steel sector. Tables 1, 2 and 3 show the ultimate list of the identified future competence requirements. They were classified into three groups to be practical: (1) digital competences (2) personal, methodological and social competences and (3) green competences.

Once having identified the future competences, the following step was to determine the profiles that would be transformed as a result of the ongoing digitalization of the steel industry. For this aim, we carried out an analysis on each selected profile present at the database. In order to identify the transformed profiles, we took ESSA project as a basis. At the same time, we also benefited from the above-mentioned (Sect. 2.2.1) European projects executed in a broad range of sectors to detect which occupational profiles were required to be updated through digitalization. Then, we analysed the steel sector occupations including the equivalent work tasks with those in other sectors which had gone through changes due to Industry 4.0 (such as process engineer, industrial manager, etc.). After, we added the future competence needs of these profiles into the database. Particularly, the framework of European ICT Professional Role Profiles provided us with the information of both the altered ICT-related job profiles and their future skills needs. For the rest of the steel sector job profiles, it was our research team who made the decision if their skills required an update or not. When an update was considered essential for a job profile, a detailed analysis based on the subject matter experts' opinion was carried out to select the future competence needs. Then, the identified competence requirements were incorporated manually to the database as "essential" or "optional".

Once we integrated all identified future competences in the database, the skill-updating process for each occupation was finalized. Subsequently, the automated occupation-skills database for the steel sector was generated successfully. Additionally, for the sake of being practical, all current skill and competence requirements demonstrated in ESCO´s database were assumed to be demanded also in the future. In the future, if they become outdated, these skills or competences will be removed both from our and ESCO database. Moreover, during our research, when we identified a competence requirement for the future and it was already present at the database of

Table 1 The list of the detected future digital competence requirements for the steel industry workforce

Future digital competences for the steel sector
Internet of things (IoT)
Machine learning
Big data
Cloud computing
Artificial intelligence (AI)
Business intelligence (BI)
Sensors technology
Collaborative and advanced robots
Customization and personalization of production
Augmented reality (AR)
Cyber-physical systems (CBS)
Human-machine interfaces (HMI)
Cybersecurity
Additive manufacturing
Predictive and proactive maintenance
Computerized maintenance management
Digital twin
Process simulation and integration in manufacturing
Communication among equipment (M2M) and environment
Online equipment and process monitoring systems
Traceability
Basic digital skills
Use of digital communication tools
Basic data input and processing
Advanced data analysis and modelization
Data management-safe storage
E-commerce
Enterprise resource planning (ERP)
Manufacturing execution system (MES)
Financial literacy
Quality procedures related to digital transformation
Project planning and management

ESCO, they were not referred as a ¨¨future competence¨´ anymore. Solely, the new competences that we detected were categorized as ¨future competences¨.

Table 4 demonstrates an example data sheet of the created steel sector database. In this table, the “casting machine operator” is taken as an example. The initial four rows represent the hierarchical organization of the occupation groups: The “casting

Table 2 The list of the detected future personal, social and methodological competence requirements for the steel industry workforce

Future personal, social and methodological competences for the steel sector
Personal competences
Critical thinking and decision making
Strategic and systematic thinking
Interdisciplinary thinking and acting
Continuous learning
Adaptability and adapt to change
Work autonomously
Ethical skills
Personal experience
Appropriate linguistic skills
Methodological competences
Creativity
Cross-functional process know-how
Complex problem solving
Opportunity assessment
Risk management
Customer relationship management
Creativity
Cross-functional process know-how
Basic numeracy and communication
Quantitative and statistical skills
Complex information processing and interpretation
Advanced literacy
Social competences
Entrepreneurship and initiative taking
Interpersonal skills and empathy
Cultural empathy
Active listening
Effective communication and negotiation skills
Teamwork skills
Leadership and managing others
Conflict resolution
Networking
Teaching and training others

Table 3 The list of the detected future green competence requirements for the steel industry workforce

Future green competences for the steel sector
Environmental awareness
Understanding circular economy and industrial symbiosis concepts
Waste reduction and prevention
Waste management
Resource re-use and recycling
Sustainable resource management
Product life cycle thinking assessment
Eco-design of product, technology and processes
Understanding energy efficiency concept
Understanding energy use and costs
Energy management of equipment and plants
System optimization and process analysis
Energy data collection and analysis
Platforms for energy management of equipment and plants
Manufacturing principles to reduce energy consumption
Selection and use of monitoring equipment for energy consumption
General regulatory awareness (incl. legislation, compliance)
Legislation on waste management and CO_2 emissions

machine operator" professional profile is a part of the "metal processing plant operators" occupation group, which belongs to the broader group of "metal processing and finishing plant operators" and so on. The table incorporates a direct web link to the website of ESCO where all the presented data related to the profile is accessible. Moreover, the database demonstrates the ISCO number (the international occupation code) and the alternative labels for the presented professional profile. In addition, the table describes both the essential and optional skill, competence and knowledge requirements for the "casting machine operator" job profile. The current skill and knowledge requirements extracted from ESCO's database are shown in black font while the future competence needs that were identified in this research are demonstrated in red font.

The table is regarded as a "smart table" due to the automation process executed on the database. Therefore, when we alter "casting machine operator" professional profile with another one, all the data about the new profile comes into sight automatically on the spreadsheet replacing the information related to "casting machine operator". This capability enables us to display the competences of any professional profile instantly using the database. Hence, the database can be used as a very effective and convenient tool for the implementation of competencies.

Table 4 An example sheet extracted from the automated occupation-skills database created for the steel sector

8—Plant and machine operators and assemblers
81—Stationary plant and machine operators
812—Metal processing and finishing plant operators
8121—Metal processing plant operators
Professional Job Profile: 8121.1 Casting Machine Operator
ESCO link: http://data.europa.eu/esco/occupation/25206eaa-04da-4fd6-bac7-173d7eb142dc
mold casting worker // metal molder // foundry operator // molding and casting worker // metal moulder // ladleman // metal caster // pourer and caster // foundryman // mould casting worker // ladleperson/
Casting machine operators operate casting machines to manipulate metal substances into shape. They set up and tend casting machines to process molten ferrous and non-ferrous metals to manufacture metal materials. They conduct the flow of molten metals into casts, taking care to create the exact right circumstances to obtain the highest quality metal. They observe the flow of metal to identify faults. In case of a fault, they notify the authorised personnel and participate in the removal of the fault
ISCO number: 8121
Essential
Knowledge
Casting processes
Manufacturing of metal assembly products
Metal joining technologies
Skill/competence
Admit basic metals to furnace
Assemble metal parts
Maintain mould parts
Use tools for castings repair
Optional
Knowledge
Precious metal processing
Types of metal
Skill/competence
Assess suitability of metal types for specific application
Cut metal products
Follow manufacturing work schedule
Future competences
Essential
Collaborative and advanced robots
Basic digital skills
Artificial intelligence (AI)

(continued)

Table 4 (continued)

8—Plant and machine operators and assemblers
Predictive and proactive maintenance
Augmented reality (AR)
Digital twin
Critical thinking and decision making
Strategic and systematic thinking
Effective communication skills
Teamwork skills
Advanced literacy
Understanding energy use and costs
Use of monitoring equipment for energy consumption
Waste reduction and prevention
Resource re-use and recycling
Optional
Cybersecurity
Quality procedures related to digital transformation
Creativity
Interpersonal skills and empathy
Cultural empathy
Complex information processing and interpretation

The main differences between our database and conventional ones, such as ESCO, are that (1) our database includes the anticipated skill requirements for each job profile and (2) ours is a steel sector-specific database. Our work aimed to fill the gap of a sectorial database including future skills emerging from sector-specific industrial changes, innovations and sustainability requirements. Therefore, the research findings aim to contribute to the continuous updating and development of ESCO, thus reaching more effectively to the end-users thanks to our interaction with ESCO experts. The findings are intended to be consistent with ESCO framework, which is a significant and common reference among the European labour market, training and education centres.

Moreover, the results of the research were validated by Sidenor Aceros Especiales SLU which is an international company and leader in the European steel industry for the production of special steel long products. Sidenor is also involved in the ESSA project as an industrial partner. They aim to implement the necessary skills on their workforce so that the workers can handle the current and upcoming technological developments and sustainability requirements properly. They are in the process of upskilling and reskilling of their workforce through identifying the skill gaps and looking for required training programmes. Therefore, they are using our automated and sector-specific database effectively. Our database provides Sidenor and other

companies with easy access to information on foreseen skill requirements for each steel sector job profile. Through this information, they can analyze and identify suitable and well-developed training programmes for each job profile in the company. Therefore, after confirming the validity of the database, Sidenor is actively using it during the implementation of the new skills by the human resource department.

4 Conclusion

The steel sector faces constant and profound transformations of its manufacturing models because of Industry 4.0 and sustainability demands. The sector is already participating in the digitalization converting into a smart industry. The application of the smart technologies leads to more efficient and reliable manufacturing processes as well as higher quality products and services. Therefore, Industry 4.0 is recognized as a good opportunity for the sector. Furthermore, these flexible, complementary and complex smart processes are altering the organizational structure and competences of the steel industry. On the other hand, the steel industry is seeking solutions for an efficient use of resources and the reduction of CO_2 emission levels while maintaining their competitiveness. The industry is also working towards the implementation of solutions to ensure that they operate with respect to energy efficiency, workforce that can handle the implementation of new business models compatible with IS & EE and technological developments. Thus, it also creates a challenge for the sector. For this reason, the steel industry urgently needs to generate a multi-skilled labour force which is capable of managing the implementation of newly introduced business models compatible with smart technologies and environmental imperatives/sustainability requirements.

This competent workforce can only be created by up-skilling and re-skilling of the current one through the development of well-established training programs. Identifying the skill mismatch between the workforce and the industry's expectations is the key for the development of the high quality training and it is only possible through defining the current and anticipated skill needs for the steel industry. Our work responds to this need for addressing the current skill and competence requirements and foreseeing the future ones.

In this chapter, after evaluating the current skill requirements and defining the foreseen evolution of competences for the steel sector, we generated a structured and automated skills database for the steel industry professional profiles. We believe that the created sectorial database is an essential tool that could guide the steel industry through the implementation of new skills during digitalization. Indeed, the results of the research and the utility of the sectorial database for the skills implementation were validated by Sidenor Aceros Especiales SLU.

It is our belief that our research could be adopted as a guidance not only for companies but also for training centres, universities and policy makers throughout the development of well-designed training programs which are designed to minimize the skill gap between the workforce and job profiles. We strongly believe that in the

lead of the ESSA project, the steel sector will be seeking more sectorial frameworks for the implementation of new skills in the steel industry. Our research would also serve them as a roadmap.

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