machines

MDPI

Article

Skills Intelligence in the Steel Sector †

Karina Maldonado-Mariscal *, Mathias Cuypers, Adrian Götting and Michael Kohlgrüber

Department of Social Sciences, Social Research Center (sfs), TU Dortmund University, 44339 Dortmund, Germany
* Correspondence: karina.maldonado@tu-dortmund.de

† This paper is an extended version of our paper published in 14th IFAC Workshop on Intelligent Manufacturing Systems IMS (28–30 March 2022, Tel-Aviv and Israel) under the title "Skills Intelligence in the Steel Sector".

Abstract: The ecological and digital transformations of the steel industry intensify already existing skill shortages and create specific skill demands that are currently not being met. One of the main problems in this sector lies in the lack of sufficient information on which skills companies need and which skills trainings are suitable for today's challenges. In addition, more information is needed to provide more and better information for policy-making processes for getting the sector's workforce well-equipped for digitalisation and decarbonisation. This paper uses the framework of skills intelligence in the steel sector, reflecting on theoretical developments and the application of concrete tools in the European projects BEYOND 4.0 and ESSA. The main research questions guiding this work are: To what extent is the concept of skills intelligence useful in the steel sector, and how can it be applied in the steel sector in Europe? This paper provides empirical data based on qualitative and quantitative research carried out in the mentioned projects. The main contribution of this paper is the development of concrete reflections on the concept of skills intelligence based on tools in the steel sector. This work operationalises the skills intelligence approach at sectoral level, namely for the steel industry, and shows how this sector approach can be implemented at the European, national and regional levels. The main findings suggest that skills intelligence in the steel sector is not limited to the preparation and presentation of data but creates a governance structure to mitigate skills imbalances.

Keywords: skills; steel sector; skills intelligence; ecosystems; education; digitalisation; decarbonisation

Citation: Maldonado-Mariscal, K.; Cuypers, M.; Götting, A.; Kohlgrüber, M. Skills Intelligence in the Steel Sector. *Machines* **2023**, *11*, 335. https://doi.org/10.3390/machines11030335

Academic Editors: Marcos de Sales Guerra Tsuzuki, Yuval Cohen and Ahmad Barari

Received: 23 December 2022
Revised: 20 February 2023
Accepted: 21 February 2023
Published: 1 March 2023

1. Introduction

As a result of the rapid digital and ecological transformation, the steel industry has skills shortages and specific skills needs that are currently not being met [1,2]. One of the main problems in the steel sector lies in the lack of sufficient information to know what skills companies need, but also which skills trainings are suitable for the current needs. In order for steel to continue to be produced in Europe, two processes must succeed over the coming years: the decarbonisation of the industry and digitalisation in the steel industry, which are explained in detail in the following section. These two megatrends are associated with numerous challenges, which are also related to emerging skill demands and the supply of green and digital skills. The situation is aggravated by the shortage of skilled workers in the sector, which has been prevalent for years.

In this regard, the concept of skills intelligence has been the subject of debate for decades and, in particular, has been conceptualised by the European Centre for the Development of Vocational Education and Training (CEDEFOP) in recent years. This concept suggests a process of identifying, analysing and presenting data on skills and labour market information to improve decision-making processes. This data should be up-to-date and developed in an expert-driven process so that it is interactive for key stakeholders and can have real impacts on local ecosystems based on the steel industry. Although the concept is gaining prominence, there are currently insufficient theoretical and empirical resources to develop tools for understanding, studying and, especially, implementing skills intelligence

in specific sectors. We argue that the concept of skills intelligence provides an adequate foundation for identifying needs and tailoring skills to a sector as challenged as the steel sector, and this can set a precedent for other sectors. We therefore provide a framework with sectoral skill intelligence tools. This framework provides empirical evidence based on two European projects in the sector and provides reflections on lessons learned.

1.1. Research Problem

The European steel sector has been struggling for years to attract new talent to the industry. The great challenge of recruiting or training the appropriate skills and thus suitable workers is exacerbated by the shortage of skilled workers in the steel industry ([3] (p. 2); [4] (p. 4); [5]). The image of an "old industry" which is not usually perceived as modern and is associated with a harsh working environment, seems to be a major hurdle in attracting talent [6] (p. 94). For example, the steel industry has the image of being a polluter of the environment and local communities [7] (p. 6). At the same time, redundancies and shift work also make working in the steel industry unattractive for skilled workers. Against the backdrop of a pronounced skills shortage, the two megatrends of decarbonisation and digitalisation offer not only major challenges but also opportunities [7] (p.10). For example, if the European steel industry makes the transition to a digital and green sector, the ongoing modernisation and restructuring of the industry can also have a positive impact on its image and on recruitment prospects. Understanding steel as a "permanent material" can make it a pioneer of the circular economy. The implementation of decarbonisation and digitalisation is also accompanied by new and modernised job profiles as well as a modernisation of the organisational structure, i.e., the way companies work internally, which in return could attract skilled workers and modernise the steel sector [7] (p. 10).

Decarbonisation and digitalisation: the duo for the transformation of the steel industry

Steel is a major producer of carbon dioxide, with the steelmaking plants in particular producing emissions on a large scale ([8] (p. 2); [9] (p. 1); [10] (p. 1)). The European steel industry now faces the major challenge of having to significantly reduce its carbon footprint in the coming years and decades. The European Union's goal is to become carbon neutral by 2050—a major challenge for the European steel industry, which entails high costs and efforts ([8]; [11] (p. 2); [12] (p. 4)). The climate targets also affect the competitiveness of European steel producers, as after all, steel continues to be produced in different countries of the world in which costs are lower and no climate restrictions exist [13] (p. 342). Despite the currently limited competitiveness of European steel producers, the assumption is that the direct and indirect costs of carbon dioxide emissions will have a long-term impact on the economic situation of the steel industry in addition to the ecological effects [14] (p. 3). Consequently, decarbonisation has now become the most important transformation issue in the European steel industry and is a top priority, particularly for large steel producers. The green transformation is challenged by investment cycles of 10 to 15 years, with multibillion financing needs and limited supplier capacities [8] (p. 3). One of the main current goals and a heavily debated topic is the use of hydrogen to replace coal as a main energy source ([8] (p. 3); [11] (p. 3)).

Digitalisation is the second major transformation theme in the industry and can also be perceived as an enabler for the green transformation [5] (p. 38). Thereby, further digitalising of the steel sector and making better use of industrial data can enable new business models and optimise steel supply chains [15] (p. 11). Qualitative insights into German steel companies, which were collected in the BEYOND 4.0 project (Beyond 4.0 project is a project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 822296.), show that large steel producers in Europe are driving digital processes forward. Digitalisation is mostly used for process optimisation and also serves to become more effective and efficient ([4] (p. 3); [16]). Furthermore, digital technologies have the potential to "speed up the deployment of breakthrough processes and product innovation" [15] (p. 11).

Transformation must go hand in hand with the adaptation of skills

The current debate on the decarbonisation and digitalisation of the steel industry often focuses primarily on technological aspects, however, having the skills for these transformations is the main bottleneck to their success and implementation [4,5]. The complexity of processes is increasing due to the influence of decarbonisation, while the operation of steel plants using innovative decarbonisation technologies requires new skills [1] (p. 27). A similar picture emerges with regard to digitalisation, a process that is changing skill requirements at all levels of qualification, creating new demands, which are linked to the need for constant updating and supplying of employee skills [15] (p. 11). Consequently, there is an urgent need for new learning and training programmes, since the teaching of additional skills (upskilling) or new skills (reskilling) is becoming more relevant ([1] (p. 27); [17]).

To address the need for new skills, the first step is to identify the skills that are currently needed. In this sense, we argue that skill intelligence has the potential to be a helpful concept for identifying skill demands and developing a proactive strategy to meet the skill needs for a digital and green transformation of the steel sector (see definition of skills intelligence in Section 2). The strategies of the European Union for these challenges also include the development and implementation of an action plan for a competitive and sustainable steel sector (see [15]). This action plan is based on a strategy to offer innovative and high-quality products and thus stay ahead of the technological curve. In addition to the implementation of new technologies (such as intelligent manufacturing systems), one of the main needs is a competitive, well-qualified and adaptable workforce with the right skills to contribute to this strategy.

1.2. Research Questions

There is a gap in the research on skills intelligence, both theoretically and empirically—the concept has been defined, but its mechanisms in concrete contexts remain largely vague and are not highly conceptualised (see Section 2).

Therefore, the main two questions that led this work are: (1) *To what extent is the concept of skill intelligence useful in addressing the two main challenges facing the steel sector?* and (2) *In which ways can the concept of skills intelligence be applied in the steel sector in Europe?*

In order to answer these questions, we analysed the implementation of the concept of skills intelligence in two European projects (BEYOND 4.0 and European Steel Skills Alliance (ESSA) (ESSA project is a project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 600886), which are focused on the steel industry.

1.3. Methodological Approach

In this paper, we have carried out qualitative research to better understand skills intelligence and its dimensions. At the same time, we have studied this concept by applying it in European projects in order to observe the implementation and evaluate tools that lead to the development of skills intelligence.

Firstly, we have analysed the concept of skill intelligence and developed a theoretical framework. Secondly, we have analysed two projects (BEYOND 4.0 and ESSA) and their tools under the umbrella of this framework of skills intelligence.

We have selected these two projects because they both address skills shortages in the steel sector and current European challenges, such as digitalisation and decarbonisation, but also because these projects represent a strong effort to mitigate skills imbalances and the development of ecosystems that work together in the modernisation of the steel industry in Europe. An additional rationale for selecting these projects is that they represent the European context, where the concept is particularly relevant and has been developed by a decentralised EU institution.

In the third step, conclusions for the validity of the concept of skills intelligence and its further development and concretisation are drawn. This is done following the research

questions on the basis of the empirical results of the qualitative investigation of the project work and its findings.

1.4. Structure of the Paper

In the following Section 2, we present the theoretical framework of this concept, its origin and the main elements that integrate this concept. In Section 3, we introduce the two projects and the tools selected for this analysis. In Section 4, we present the main findings. Finally, in Section 5, we draw conclusions and provide a discussion.

2. Defining a Framework of Skills Intelligence

In this section, we introduce the concept of skill intelligence as a framework and propose key elements to understand the definition. Selected dimensions of this concept provide the basis for the analysis in this paper and the tools used in the two projects.

The use of data is becoming increasingly important in a modern world characterised by the growing complexity and interconnectedness of information. In terms of the labour market, the question has been raised about how information can be processed in such a way that it actually enables informed skills-related decisions. In labour market and skills statistics, the terms "labour market intelligence" or "skills intelligence" are concepts in use since the late 1980s. They highlight the importance of how relevant data can be used to make informed decisions. In Hasluck's [18] concept of a labour market information systems (LLMIS) the differentiation between data, information and intelligence plays an important role. He sees *data* as simple facts, *information* as "results from the selection and manipulation of data into something more meaningful" and *intelligence as* "a small sub-set of information which relates to key or essential elements of processes" [18] (p. 9). This author recognised the labour market information system as a "complex of people, equipment, and processes which interact", what is supposed to produce information and intelligence from data "to assist in decision-making" [18] (p. 9).

The use of the term "intelligence" to describe a favourable result of data usage has been also used by policymakers. In the United Kingdom, a government initiative defined *labour market intelligence* in 2004 as an "interpretation of labour market information" that "refers to subsets of information that have been subjected to further analysis", whereas *labour market information* refers to "quantitative and qualitative data found in tables, spreadsheets, maps, graphs, charts, reports, newspaper articles or anecdotally" [19] (p. 12). In this way, the term labour market intelligence is differentiated from labour market information, especially in the interpretation of data to inform policymakers in policy-making processes.

Skills intelligence in the European Union and introduction of a Definition

In 1975, the European Union founded a decentralised institution, the European Centre for the Development of Vocational Training (CEDEFOP), with the aim to develop expertise and cooperation in Vocational Education and Training (VET) policy, skills and qualifications between different members of the European Union. CEDEFOP has been working with the concept of labour market and skills intelligence for over a decade [20] (p. 1). This concept, whose short name is skills intelligence, was used to frame the Skills Panorama Platform in 2012 [21] (p. 17), which is now the Skills Intelligence Platform [22]. Recently, this concept was also presented in the European Skills Agenda of the European Commission [23] (p. 8) as a crucial step in creating the foundations for people to acquire the skills needed in their current jobs.

CEDEFOP defines skills intelligence as such:

> *"Skills intelligence is the outcome of an expert-driven process of identifying, analysing, synthesising and presenting quantitative and/or qualitative skills and labour market information. These may be drawn from multiple sources and adjusted to the needs of different users. To remain relevant, skills intelligence must be kept up-to-date and adjusted when user needs change. This requires the expert-driven process to be continuous and iterative."* [24]

We recognised that the skills intelligence perspective has generally been integrated into the EU policy; however, very little research has been done. Therefore, in this paper, we build on this definition and reflect on the need to further develop the concept. Some key elements of this definition are:

- Skills intelligence is the **outcome of processing data**, such as data preparation and presentation (see also [18,19])
- The **data preparation** and **presentation** is to be directed **towards specific target groups**
- The importance of **information up-to-date**
- The important role of **experts** in the process

In the process of building skills intelligence, tools that help to understand the concept should be considered. CEDEFOP has developed such tools (see [24]), and other institutions also developed some tools that contribute to this (see [25]). The classification of tools for the development of skills intelligence is relevant in order to capture the specific contributions of each of them.

We identified two dimensions crucial to the development of skills intelligence: the geographical scope and the purpose of the data, which we present in the following Table 1. These dimensions provide the framework for the analysis of our empirical data and are explained in the following lines.

Table 1. Two dimensions of skills intelligence analysis.

Dimensions for the Development of Skill Intelligence	
Geographical scope	*Purposes*
• national • regional • European	• for company-specific (individual) skills demand and supply • for policy strategy/policy development

Geographical scope: the geographical scope as the name suggests, refers to a geographical area. By studying different examples, we identify tools at the European, national and regional levels that provide cumulative information on the situation for their respective levels. These tools are often designed to support decisions on one of these specific levels, adapted to regional contexts and target groups. Some examples for regional or national tools can be found in the Dutch labour agency ([26], for details see [27]) or in FutureLan in the Basque Country [28].

Purposes: this dimension concerns the aim for the development of skills intelligence. In this dimension, we identify two types of objectives: on the one hand, to identify the supply and demand of skills in companies, and on the other hand, to develop policies.

- For company-specific (individual) skills demand and supply

This dimension is related to the demand and supply of skills, which must always ensure that information on skills is equally available. On the one hand, a company looking for training modules receives information about a possible increase in skills, but can only make a good decision if it also knows what skills the company needs. On the other hand, a training provider may be aware of the skills it provides, but not know which employers need its skills. Therefore, information on both the demand and supply of skills is needed to make good decisions.

- For policy strategy/policy development

The systematisation of the different skill intelligence and skill matching tools means that each of them provides macro-level information to policymakers, associations and the public at large that helps them to better understand the macroeconomic situation of a sector, a region or a country. Some examples of this, which help to shape policy strategies, but do not help to support the skills-related decisions of individual actors, such

as enterprises, employees, job seekers and training providers, can be found in the EU Skills Intelligence Platform [21].

3. Skills Intelligence in Practice

Skills intelligence tools differ in their operating mechanisms, and this has consequences for their target groups. Therefore, one of the main contributions of skills intelligence is to identify needs but also to provide information and evidence for stakeholders to make better informed decisions on skills supply and demand. Skills intelligence is important for the steel sector because this concept helps to identify the status quo in terms of skills needs and skills supply. This section presents the two projects in which this research has been carried out and explains some of the tools based on them. The framework of these two projects reflects a European perspective on the steel industry.

3.1. Introducing Two Projects: BEYOND 4.0 and ESSA

The BEYOND 4.0 [29] project analyses the social and economic impact of digital transformation on jobs, business models and welfare. The main aim is to help shape "an inclusive European future" using a multidisciplinary and innovative research approach. The project explores the extent to which digital technologies have the potential for the inclusion of disadvantaged labour market groups and can thus promote their employment. It is particularly important to provide knowledge for better inclusion of these groups. Additionally, in this context, the project investigates and identifies the skills that workers and managers need to work with new technologies. Within the framework of the project, a categorisation of future skills was developed, which provides information about which concrete skill requirements are gaining in importance or are newly emerging within the framework of digital transformations. Above that, future skill demands of the digital transformation are compared with the supply side of education and training systems and providers, in order to clarify skill gaps and improvements. This article mainly presents the qualitative results of the project, which allow conclusions to be drawn on how the supply of qualifications can take place at a regional level.

The European Steel Skills Alliance (ESSA) [30] is a multi-sectoral and multi-stakeholder cooperation, which was established to support upskilling and reskilling actions in the European steel industry. The project thereby aims to improve the competitiveness of the steel sector through a well and highly skilled workforce. Within a common framework of European and national innovation ecosystems, the project was launched with 24 partners from Poland, Spain, Germany, Italy, the United Kingdom, Belgium, Finland and the Czech Republic. Additionally, different types of organisations are represented, such as steel companies, research institutions, sector associations and also trade unions. The regional level is also taken into account in the project structure, as the project results are presented in the form of a roll-out into different steel regions in Europe. The project partners include key European stakeholders of major importance to the steel sector. Thus, companies, education and training institutions, associations and social partners, as well as research institutions contribute to the project. This core partnership has been complemented by a growing number of partners, so the alliance now has around 40 committed organisations. This provides a solid basis for sustainability, not only during the project but also beyond the funding period. ESSA also provides detailed information on the specific skills needs of the steel sector and their corresponding categorisation. The skills categorised in this project are not only relevant for the digital transformation but also for the green transformation and decarbonisation, a particularly important topic in European industrial sectors.

In the following section, we present two levels of analysis: firstly, a category of skills based on Beyond 4.0, and secondly, examples of tools used in ESSA (see Table 2), which provide a concrete perspective on tools for the development of skills intelligence.

Table 2. Overview of projects.

Project Name	Tools and Methods	Contributions for Skills Intelligence	Main Sources
ESSA	• steelHub • Technology and Skills Foresight Survey & Panel • Skills Assessment Template • National and Regional Rollout	Example of tools to develop skills intelligence	cf. [31,32]
BEYOND 4.0	• Systematic literature review on skill demands for the digital age • Interviews with stakeholders in the steel sector Rhine/Ruhr Germany • Regional workshops with steel stakeholders	Skills categorisation	cf. [33] (p. 19); [34]

3.2. Analysis and Tools

1. Skills Categorisation: in the framework of Beyond 4.0, exploratory research was carried out to develop a skills category, which was developed through a systematic review of the skills needs of the digital transformation. Additionally, interviews and workshops were conducted. The interviews took place with stakeholders (company representatives, steel associations, steel-specific training institutes and research institutions) in the steel sector in the Rhine/Ruhr region; they were asked about the skills demands of the digital transformation. Finally, two regional workshops were conducted with steel stakeholders in the same region.

2. Examples of Tools: In the framework of ESSA, different tools that help mitigate skill imbalances were developed. Whereas some of them are more related to the preparation of data (part of a so-called observatory), others present data and play a more important role in the sustainability and project objectives.

3.2.1. Skills Categorisation

Before stakeholders can benefit from skills intelligence, there is the important question of what skills needs to be addressed or what demands employees and companies will face in the future. The importance of developing and using skills classifications is also emphasised by [25] (p. 48). In this context, the BEYOND 4.0 project deals with the social and economic effects of digitalisation, and in order to answer the question of concrete future skill demands of the digital age, a classification for categorising skills was developed in the BEYOND 4.0 project. The category system was developed by systematic literature research on skill needs for the digital transformation (for specific details, see more in [33] (p. 19)).

The category system was developed through a systematic review of skills needs described in these publications [33] (p. 19). The relevance of this categorisation lies in the fact that the skill classification of BEYOND 4.0 makes a distinction between types of skills: transversal skills, also referred to as *general or non-technical skills*, and job-specific skills, also referred to as *technical or professional skills*. Transversal skills are of great importance across different domains and occupations. Job-specific skills, however, are only important in certain domains and within occupations [33] (p. 10). Therefore, the analysis of BEYOND 4.0 focuses on skills that are transversal and relevant across different jobs and disciplines. Due to the huge number of occupations identified, it seems challenging to systematically analyse job-specific skills, which are only relevant within individual jobs. Nevertheless, job-specific skills continue to play a major role against the backdrop of the digital transformation. In this context, digital skills need to be added to job-specific skills, and not vice versa (cf. [34] (p. 20)). Consequently, employees particularly need to combine job-specific skills with digital skills.

BEYOND 4.0 distinguishes between personal, social and methodological skills with regard to transversal skills, as the associated skills were identified as crucial for the digital

transformation ([33] (p. 32); [35–38]). The reason why such cross-cutting skills, which are not directly related to digital technologies, are gaining in importance lies not only in work with digital tools, but also in a changed organisational and work culture, which in turn is often caused by digitalisation. For example, the modern working world is characterised by more—collaborative—project work, which requires increasingly social skills, namely communication skills [39,40].

The following Figure 1 shows a visual representation of the skills categorisation of BEYOND 4.0. At the top level are the four main categories (digital, personal, social and methodological), and at the bottom level are the categories included in each of the skills. In the following paragraphs, we explain in detail each of the skills categories.

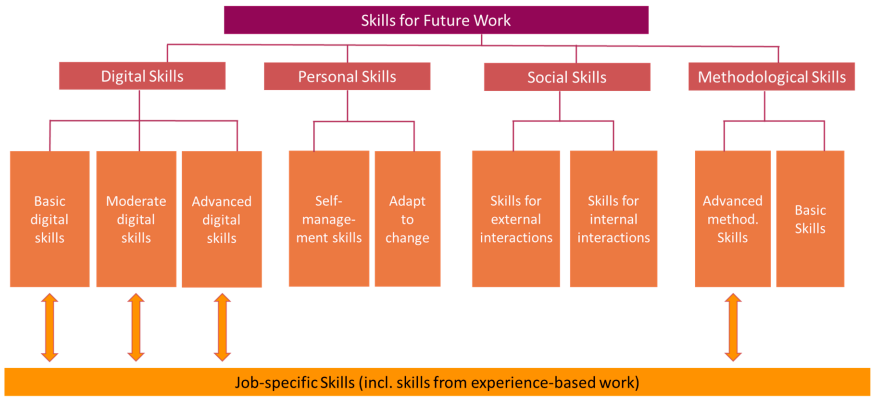

Figure 1. Beyond 4.0 Skills Classification. Source: [34] (p. 9).

Digital skills

Digital skills include, among others, the use of digital devices, cyber security and the secure handling of data, including their analysis and interpretation, as well as the use of complex digital communication tools [33] (p. 33). The central role of digital skills is recognised in all examined studies [33] (p. 35). Within the categorisation, a distinction is made between basic, moderate and advanced digital skills. As various studies show, basic digital skills are already of great importance at practically all skill levels and occupations and will become even more important in the coming years ([33] (p. 35); cf. also [41,42]). Intermediate digital skills, on the other hand, are mainly important in middle-skill occupations, especially in administrative tasks. At higher skill levels, advanced digital skills become necessary. In many cases, these are closely linked to job-specific skills.

Personal skills

Within the frame of the BEYOND 4.0 categorisation, personal skills are understood as those abilities and personality traits that are necessary for people to fulfil their work tasks. Personal skills can be understood as important requirements for succeeding in the modern world of work [33] (p. 35). On the one hand, personal skills include personal attitudes, for example, with regard to openness and values. In addition, self-reflection and motivation as well as a willingness to take risks, integrity and a sense of responsibility are of great importance, especially with regard to work in the digital age [43] (p. 28). A particularly important personal skill against the backdrop of digitalisation is, in close connection with openness, the ability to adapt to change, as well as the continuous learning of new skills. Thus, personal skills are linked to lifelong learning, which will most likely significantly gain importance in the course of digitalisation [44].

Social skills

Social skills include both basic communication skills, such as sharing information, and more complex social interactions, such as teamwork or other forms of cooperation. These complex social interactions comprise, for example, intercultural competencies, conflict resolution strategies, mediation, teaching, negotiation, persuasion and maintaining a polite and

friendly appearance [33] (p. 36). Thus, social skills can be described as skills that have to do with interpersonal interaction. Such skills are becoming increasingly important, especially due to a change in work organisation, which in many cases is a consequence of digitalisation. At the same time, social skills are difficult to automate with digital technologies: another reason to assume that the significance of social skills will increase in the future [45]. Social skills also include leadership and management skills as well as interpersonal skills such as empathy, which are also becoming increasingly important [46,47].

Methodological skills

Basic methodological skills are also seen as important prerequisites for the acquisition of digital skills. These include literacy and numeracy skills as well as basic language skills and cognitive skills, which in turn form the basis for lifelong learning [48]. Basic methodological skills are therefore essential for employability, contribute significantly to the inclusion of people in digitalised work processes and are thus a decisive factor in ensuring that everyone can benefit from the digital transformation [33] (p. 36). Yet, advanced methodological skills also play a crucial role in the digital age and form another sub-category of methodological skills. Such advanced methodological skills comprise problem-solving skills as well as creative thinking and are needed to develop strategic solutions to achieve defined objectives [33] (p. 36).

Job-specific skills

Job-specific skills relate to the respective field of work, the respective domain or occupation. They can be considered a counterpart to transversal skills and refer to the application of specific knowledge within one's own professional field [33] (p. 34). However, due to the multitude of different jobs and occupations, it is almost impossible to get an overview of the underlying and required skills. The exact consideration of job-specific skills, which are assigned to individual fields of work, is therefore hardly feasible (cf. [33] (p. 34)). Accordingly, the focus of the analysis is on transversal skills, which are gaining importance across different professions, such as the above-mentioned categories of digital, social, personal and methodological skills. Nevertheless, job-specific skills continue to play a crucial role in the working world of the future and shall thereby also be considered in the category system, even if these are not analysed in depth. The literature shows that advanced digital skills in particular often go hand in hand with job-specific skills and cannot be clearly separated from each other [39] (p. 99).

Qualitative research conducted in the BEYOND 4.0 project based on interviews confirms that the classification of skills identified mainly by experts is consistent with those identified in the literature, and is reflected accordingly in the skills categorisation. The main results show that the need for the so-called "interacting skills" can be derived from the empirical findings. In practice, it is often not only individual skill categories that are important, but rather the interaction and combination of different skill categories. In particular, the combination of digital and other skill categories is needed by employees in the digital age (e.g., digital and job-specific skills, digital and social skills, digital and personal skills, digital and methodological skills). Such interacting skills are rarely covered by training systems and are also hardly considered in the literature. Against the background of a debate on future skill demands, this finding provides a possible basis for further theory development with regard to interacting skills. In practice, it serves as the basis for a systematic consideration of interacting skills in the education system [34] (p. 3).

The research interviews conducted not only provide information on the demand for qualifications but also show how qualifications are supplied in practice. Through discussions with stakeholders from companies, training providers, steel-specific institutes, social partners and public institutions, as well as chambers and employment agencies, various observations and examples were collected on the topic of skills provision. These data constitute another important contribution to skills information and are of great use for the development of tools for the supply of skills.

The BEYOND 4.0 skills categorisation provides an important basis for skills intelligence and is systematically tested and applied using the tools presented in the next chapter. At the same time, ESSA skills categorisation was developed in parallel to the BEYOND 4.0 categorisation and has similar skills categories but has added the green skills category, as decarbonisation and its impact on skills is an important theme of the ESSA project.

3.2.2. Examples of Tools

In the following section we present four tools developed in the ESSA project that contribute to the development of skills intelligence and also make use of the ESSA skill categorisation. They are listed and explained in detail below.

(a) steelHub
(b) Technology and Skills Foresight Survey & Panel
(c) Skills Assessment Template
(d) National and Regional Rollout

(a) steelHub

This tool refers to an online platform training ecosystem called steelHub, which was developed under the project of ESSA. In contrast to the skill categorisations developed within other projects, the steelHub is clearly directed to the outside. In the steelHub, previously collected data is compiled. steelHub is suitable for presenting data in such a way that stakeholders derive the largest possible benefit from it. The tool is used to collect and provide various training resources relevant to the steel industry (see [49] (pp. 36–45); [31] (pp. 64–66)). The goal of this platform is to facilitate the matching process between the skill supply of available training materials and skill demands of steel companies. On this platform, both sides are linked via learning outcomes [49] (p. 36), which are defined as "the statements of what a learner knows, understands and is able to do on completion of learning process" [32] (p. 4). This platform is operated by the World Steel Association, a large steel association operating worldwide.

Regarding the skill demands of steel companies, the learning outcomes needed to achieve the required skills can be defined by identifying the tasks of these occupations and the related skill demands. On the supply side, training providers provide training courses and their learning outcomes. This allows steel companies to identify the training courses needed to reduce skills gaps (see [49], pp. 36–39). The platform also addresses other stakeholders such as associations, other blueprints, VET systems, research and development organisations and individuals [49] (pp. 36–39).

The training materials themselves are not developed in the course of the ESSA project, but only the infrastructure for the exchange of these materials is established. With this approach, a connection between a known demand for skills and training resources can be created. Different perspectives are connected, and more informed decisions are enabled. With regard to the multitude of actors and findings that are integrated, it can be seen as a collection point to combine different types of information and actors [31] (p. 64). Finally, the key to a good link between skill demand and supply in the online training ecosystem is a good classification of training materials. This is especially enabled by linking them to existing frameworks, such as the Technology and Skills Foresight Survey & Panel (see section b), European tools such as the European Qualifications Framework (EQF), the ESSA skill classification (see [31] (p. 39)), and the European Skills, Competences, Qualifications and Occupations (ESCO).

(b) Technology and Skills Foresight Survey & Panel

This tool aims to make visible the demand for skills at the level of the European steel sector. It is primarily designed to collect data, but the results will also be presented outside the project partners to inform about the current situation in the sector.

The data collected here concerns skill demands in the sector and make possible to draw a uniform picture of the industry's situation at European level. This tool helps to calibrate larger-scale strategies of political stakeholders and sector associations. This methodology

corresponds to a bottom-up process in which assessments are collected from different perspectives and then cumulated in consensus-based forecasts.

This tool combines a survey of company representatives with a panel discussion of steel sector skills experts [31] (pp. 62–64). Currently, a questionnaire to fill in this tool is active online, and a preliminary version of the questionnaire part has already been tested in 2020 and 2021 (see [33]). The aim of this panel is to record on a regular basis, e.g., every two years, current and future technological developments and skills needs at the European sectoral level. The process is based on a modification of the Delphi approach, which is a social science method focusing on condensing expert knowledge into predictions of the future via group communication processes [50] (p. 587). A two-stage research design is being applied: First, the survey is conducted online in several languages. Second, the central results will serve as a basis for a panel discussion of experts, who will identify a holistic picture of the situation in the European industry. In this adaption of the Delphi approach, two types of experts are included. On the one hand, the representatives of companies who are experts in the skills needs of their company but do not necessarily have a bigger picture of the European steel industry. On the other hand, the panel experts will be more networked and will already have acquired an overview of the situation.

(c) Skills Assessment Template

The Skills Assessment Template [31] (p. 42) will include elements from the questionnaire used for the Technology and Skills Foresight Survey & Panel and will be optimised for company internal usage. The aim is to help company representatives to get an overview of the skills situation in their company and of the future and present skills needs. The tool will work as a guideline, for example, for deciding which occupation will need the most attention regarding further education in the future and which types of skills will be needed. In combination with company-specific knowledge, possible effects can be observed in the areas of further education and training programmes as well as in the recruitment of new staff. As the survey is based on the categorisation of skills, the tool helps the company to prepare and present the data internally.

(d) National and Regional Rollout

In this tool, we refer to national and regional rollouts. This tool is implemented by the ESSA project in the form of a regional rollout in which the aforementioned tools and results of the ESSA project are being transferred to selected steel regions in Spain, the United Kingdom, Poland, the Czech Republic, the Netherlands, Italy, Finland and Germany. The aim of these rollouts is to initiate co-creation processes in the selected countries and regions including strong stakeholder engagement. This is first carried out in the framework of workshops, in which representatives of economy, policy, science and education, and civil society are involved. Collaboration is also one of the main aims among regional stakeholders and companies to expand existing synergies among steel regions in order to implement large-scale upskilling and reskilling strategies. Rollouts are a tool in the sense that they provide interaction at various levels, such as national, regional and inter-regional, thus generating information exchange, synergies and increased stakeholder engagement, which is necessary for skill intelligence to work.

While education policies are created particularly at the national level, it is at the regional level that such skill strategies need to be adapted, facing specific dominant sectors, labour markets, qualification structures, educational infrastructures and regional innovation strategies. As skill shortages are proving to be bottlenecks for digital transformation more and more, regional and sectoral innovation strategies are aligned with skill supply (potential) in the region. Skills intelligence is needed to unfold the full potential of regional skill ecosystems to support both regional and national entrepreneurial innovation strategies. In this sense, the skills ecosystem approach assumes that networks of institutions and actors strongly influence the development, supply, demand and deployment of skills in a given industry or region [51] (p. 117). For example, the steel sector in the Rhine-Ruhr region shows a skills strategy, also in the form of a clear distribution of roles between companies

and relevant actors, and how this is necessary to determine which actor can take on which tasks in the context of skills development and implementation. However, with regard to new topics such as digitalisation and decarbonisation, there is often a lack of such clear skills strategies and a clear distribution of roles in the supply of skills. This is also evident in the steel industry of the Rhine/Ruhr region with regard to hydrogen technology: new skills needs and new training needs for employees arise, which particularly have to be supplied at the national and regional levels through the cooperation of various stakeholders. As a consequence, a rollout workshop dedicated to hydrogen qualification measures in the steel sector was conducted in the Rhein/Ruhr area. The workshop proved to be an effective means of bringing stakeholders into dialogue, clearly identifying challenges and initiating cooperation in the area of skills supply. At the same time, the workshop provided an opportunity to exchange concrete information on existing initiatives for hydrogen qualification measures and to harmonise activities.

When conducting and planning such rollout workshops, special emphasis is placed on bringing together significant stakeholder groups. For example, in the Galati region in Romania, network ties were initiated with actors who are not directly related to the steel sector but who nonetheless perform an important function in supplying skills and for general problem-solving strategies regarding image and recruitment at the regional and national levels. The cooperation is then to be increasingly refined and concretised in the individual countries and regions within the framework of further concrete workshops.

In the following Table 3, we introduce the analysed tools and present them graphically based on the two dimensions identified above (geographical scope and purpose). This table shows on the left side the geographical scope, which includes the tools developed in the framework of the ESSA project at the European level and at the national or regional level of the participating countries. On the right side, we add the purpose dimension, which refers to the demand for specific skills and the supply of specific skills. Additionally, we have identified in the literature the purpose of the policy strategy/policy development, we do not yet have specific tools in this dimension that can be added to the framework of the ESSA project. However, it is an important tool for disseminating results and allows for the consolidation of skills intelligence.

Table 3. Overview of the Analysed Tools.

Geographical Scope	**Purpose**	
	For Company-Specific (Individual) Skills Demand and Supply	**For Policy Strategy/Policy Development**
European level	**steelHub***: online training ecosystem (training offers and learning arrangements)	
		Technology and Skills Foresight Survey & Panel*: a tool that combines a survey of company representatives with a panel discussion of steel sector skills experts
	Skills Assessment Template*: defining steel job profiles, evaluate their current and future skills levels and identify their skills demands	
National and regional levels	**National and Regional Rollout*:** The attempt to initiate processes of a training ecosystem (training offers and learning arrangements) in the individual member states at regional or national levels, and to network and involve the most important stakeholder groups. The focus is mostly on the supply side; but findings on demand are also collected (mostly with regard to image/recruiting/retention, but also with regard to skills).	

Source: Author's illustration. * They correspond to the original names of the tools used in the projects.

4. Results

The main results suggest that the concept of skills intelligence is applicable to the steel sector, providing transparency on the skills needs arising from the double transition of

digitalisation and decarbonisation. The concept of skills intelligence applied to the steel sector requires some adaptations, as it is not only limited to data preparation and reporting, but also requires a governance structure that facilitates coordinated actions to mitigate skills imbalances. We provide here an overview of the findings answering the research questions.

Answer to RQ1: To what extent is the concept of skills intelligence useful in the steel sector?

Challenges in the steel sector require timely adjustment of skills supply and demand

We found that the transformation of skills needs due to digitalisation and decarbonisation can be assigned to a categorisation of digital skills, non-digital skills, green skills and job-specific skills. Accordingly, training and education measures provided by the supply side (VET, HE, training providers, company-specific trainings) can be assigned to those categories, enabling the match-making of skills demand and supply.

Standardisation of data with the help of categorisations/taxonomies of skills is a good starting point

Skills categorisation is an important prerequisite for the comparison of the skills demand and supply information.

Some of the main aspects on which we base the design of skills intelligence tools (see Table 1) for a specific sector are:

- Which categories of skills should be used?
- What are the target groups?
- At which geographical levels do they operate?
- What decision do they need to make?
- What data do they need to make this decision (demand and supply information)?
- How can this data be provided (expert-driven or digital technologies driven)?

We found that the categorisation of skills represents a relevant step in providing information on skills demand and supply, as we observed in the BEYOND 4.0 project. At the same time, skills intelligence fosters an ecosystem approach to solving needs. Therefore, the use of geographical scope in the development of skills intelligence seems appropriate. More detailed explanations are given in the following paragraphs.

Current knowledge of skills intelligence does not provide guidance on sectoral decisions

We found out that the interaction of different stakeholders has to be taken into account in order to make informed decisions on education and training and to achieve a certain level of skills intelligence. Our research shows how CEDEFOP's understanding of skills intelligence is very useful for a first analysis as it is mainly characterised by quantitative data. The general understanding of skills intelligence as an enabler for informed skills-related decisions [12] is the main driver for the framework presented here to raise information on skill needs and on how to cope with them. However, this article shows that skills intelligence has to address the specific needs of different users from the steel sector. This is based on the reflection that current skills intelligence tools do not support sectoral decisions by companies, associations or regional policymakers. They often contain data that refer to the whole European economy or to very broad sectors, such as the "manufacturing industry".

We identified that skills intelligence and the skills matching tools of Rentzsch and Staneva [13], which highlight the importance of a taxonomy of skills, provide a good basis for the analysis and development of skills intelligence accompanied by sector-wide research. Using this taxonomy proved very helpful for a systematic analysis of needed skills and corresponding education and training.

Answer to RQ2: In which ways can the concept of skills intelligence be applied in the steel sector in Europe?

Skills intelligence fosters an ecosystem approach

Skills intelligence encourages ecosystem-specific solutions taking the specific needs of a context, initial situation and framework conditions in their region into account when it comes to defining appropriate training and education measures. For the practical implementation of skills intelligence in the steel sector, an ecosystem approach is of great importance, both on the EU level and on regional and national levels. In essence, such an approach relates to the involvement of stakeholders from different sectors of society, for example in the sense of a quadruple helix; involving economy, policy, research and education, and civil society. Therefore, it is important to integrate the various stakeholder groups not only in terms of their competencies but also to formulate binding responsibilities, for the successful development of training programs and thus to skills supply. Ideally, the communication and collaboration of different stakeholder groups are initiated through a co-creation process, taking into account different stakeholder perspectives [38].

On the one hand, collaboration processes at specific regional levels are often company-driven, as skills needs ultimately become apparent within the company, and companies have a strong interest in covering their skills demands. Likewise, corporate interests are closely linked to the interests of stakeholders in the region in which companies are running their businesses. They are dependent on available skilled people in the region, offers by training and education providers, political support, measures of employment offices and other regional support.

On the other hand, the region needs companies for upskilling people leading to a higher skill level in the region. Integrating the different actors, skills intelligence addresses both skill gaps: those of the companies and those of the regions.

Therefore, the ecosystem approach often focuses on the regional level and the spatial proximity of actors. However, as an initial step, it is crucial to involve stakeholder groups also at a European level. Practical insights from the steel sector show that implementation at a regional level is more successful when European umbrella organisations and institutions are already involved in processes. Furthermore, experiences from projects on skills intelligence show that it is primarily individuals who initiate processes and take responsibility at the European and regional levels. At the same time, an overarching platform in which results and concrete strategies of the regional ecosystems can be discussed is needed. In this way, the stakeholders involved can inspire each other and exchange ideas. When actors contribute their competencies and take on responsibilities, ecosystems can be understood as communities with clearly divided responsibilities, with stakeholders who drive each other.

Summarising the tools of two projects towards skills intelligence development

Here we provide a comparison between the different tools of ESSA and BEYOND4.0 with the concept of Skills Intelligence.

The **Skills Categorisation** is a very basic example of a tool developed in BEYOND4.0 and adapted within the ESSA project, that structures the understanding of different types of skills and thereby builds an important basis for a number of further tools. This is fully in line with the need for skill taxonomies emphasised by Rentzsch & Staneva [25].

The BEYOND 4.0 project conducted qualitative research in the regional steel industry of the Rhine/Ruhr area in Germany, making another important contribution to skills intelligence. Thereby, stakeholders and experts were interviewed about future skill demands in the steel industry. The estimations provided information about the quality of the skill categorisation. The results showed that all the skills mentioned by the experts could be classified in the BEYOND4.0 skills categorisation. In addition, the interviews also provided information about concrete processes in skills supply. Various qualitative examples and observations showed concretely how skills are taught in practice, which in turn is an important prerequisite for skills intelligence and also plays an important role in the development of skills intelligence tools.

Some examples of tools that build on this skill categorisation are the **Technology and Skills Foresight Survey & Panel** as well as the **Skills Assessment Template**. The survey

uses the categorisation to ask for the most demanded current and future skills. The assessment tool uses skills categorisation to provide a template that company representatives can use to receive feedback on their own skills demands. Both tools form also one pillar of the projects' contribution to the establishment of skills intelligence in the steel industry. Even though the concrete functioning and embedding of the tools are still being worked out, it is also clear that they contribute to both preparing data and presenting it to stakeholders.

The platform **steelHub** is the second pillar that contributes to skills intelligence. It also connects to the skill categorisation as well as to other structuration realised in the project, e.g., on relevant job profiles. It provides an easily accessible access point to different training contents and thereby helps to saturate individual and company-specific skill demands. Thereby, it also takes up qualitative results from the BEYOND4.0 project, which identified needs for specific combinations of skills [34]. These needs are considered for developing train-the-trainer concepts, which are becoming part of the steelHub. It is also being considered to connect other tools to the steelHub, for example, a matrix of VET programmes developed for the project, as well as the already mentioned Technology and Skills Foresight Survey and the Skills Assessment Template. It is foreseen that the platform will continue to operate after the end of the project. The platform is therefore becoming a platform for skills intelligence tools and is clearly linked to the presentation of relevant data.

The **rollout tool** is therefore a pillar to implementing skills intelligence in practice. Its basic idea is that in order to establish and maintain structures, the right stakeholders must be involved. In this way, it is possible to move from data to decisions and, in subsequent steps, to concrete actions. Thereby, the application of skills intelligence to the steel sector does no longer limited to the preparation and presentation of data, but creates governance that facilitates coordinated actions to mitigating skill imbalances.

Through the rollout, skills intelligence tools can also be tailored specifically to regional and national challenges, again through dialogue with stakeholders and experts in the respective regions. Consequently, it is also important that the quality of skills intelligence tools goes through such a rollout process, so that the respective services are tailored to the end-user and provide real added value and the necessary data for companies, training providers and other actors in the education system that are ultimately involved in the provision of skills. The rollout has so far led to better networking of stakeholders in selected steel regions. However, in order to systematically implement skills intelligence in these regions and to address concrete skills needs, long-term cooperation between these stakeholders is necessary. The stakeholder groups must thereby not only contribute their competences but also with their responsibility to develop measures for skills supply. After the project's end, the rollout activities will be framed by the European Community of Practice (ECoP).

Categorisation of skills represents a relevant step in providing information on skills demand and supply

Transformation of skill needs, due to digitalisation and decarbonisation can be assigned to a categorisation of digital skills, digital-complementary skills, green skills and job-specific skills. Accordingly, training and education measures provided by the supply side (VET, HE, training providers, company-specific trainings) can be assigned to those categories enabling a match-making of skill demand and supply.

The categorisation of skills provides a framework that allows all stakeholders in the ecosystem to refer to the same skill categories and to come to a common understanding of skill gaps and measures to be taken. A broad literature review and an empirical testing in a regional steel ecosystem shows the increasing demand not only for digital skills, but also for digital-complementary skills. However, one of the most important findings of the empirical evaluations on skill demands in the Beyond 4.0 project is that it is not only individual skill categories in high demand (such as digital skills or social skills). Rather, combinations of digital skills and another non-digital skill category, so to speak, "*digital skills plus X*" demands. This article refers to these as interacting skills or an interaction of skill categories. In this sense, different combinations of the various skill categories must be interwoven in order for workers to perform single tasks within their jobs. For instance, problem-solving

with big data or other digital tools requires both digital skills and methodological skills just for one task. This is really different from the other approaches in literature, which analyse the demand and supply in terms of individual skill categories.

The high relevance of interacting skills has an effect on skills intelligence. It is no longer sufficient for employers and training providers to offer training for digital skills or methodological skills. Rather, providers of education and training need to be able to deliver interacting skills. So far, this is very much limited to large companies that offer project-based, problem-based or work-based learning approaches that teach these interacting skills. There are only single regional ecosystems that provide interacting skills. One of the conclusions of this article is that skills intelligence in the steel sector needs to pay more attention to this challenge.

Skills intelligence fosters an ecosystem approach

Skills intelligence encourages ecosystem-specific solutions taking the specific needs of a context, initial situation and framework conditions in their region into account when it comes to defining appropriate training and education measures. For the practical implementation of skills intelligence in the steel sector, an ecosystem approach is of great importance, both on EU level and on regional and national level. In essence, such an approach relates to the involvement of stakeholders from different sectors of society, for example in the sense of a quadruple helix; involving economy, policy, research and education, and civil society.

On the one hand, collaboration processes at specific regional levels are often company-driven, as skills needs ultimately become apparent within the company and, companies have a strong interest in covering their skills demands. Likewise, corporate interests are closely linked to the interests of stakeholders in the region companies are running their business. They are dependent on available skilled people in the region, offers by training and education providers, political support, measures of employment offices and other regional support. On the other hand, the region needs companies for upskilling people leading to a higher skill level in the region. Integrating the different actors, skills intelligence addresses both skill gaps, those of the companies and those of the regions.

Therefore, the ecosystem approach often focuses on the regional level and the spatial proximity of actors. However, as an initial step, it is crucial to involve stakeholder groups also at the European level. Practical insights from the steel sector show that implementation at the regional level is more successful when European umbrella organisations and institutions are already involved in processes. Furthermore, experiences from projects on skills intelligence show that it is primarily individuals who initiate processes and take responsibility at European and regional level. At the same time, an overarching platform is needed where results and concrete strategies of the regional ecosystems can be discussed. In this way, the stakeholders involved can inspire each other and exchange ideas. When actors contribute their competencies and take on responsibilities, ecosystems can be understood as communities with clearly divided responsibilities, with stakeholders who drive each other.

As discussed in Section 1, the European steel industry is undergoing a double transformation affecting both digitalisation and decarbonisation. This transformation will create changing skill demands. To meet these demands, companies in the steel industry rely on other stakeholders, such as policymakers, training providers and the workforce. To mitigate skills imbalances, all relevant actors need to work together.

In this context, the skills intelligence concept provides both an orientation for this goal and some broad guidelines for implementation. Going back to the definition of the concept (see Section 2), the general idea of skills intelligence is to create transparency for all stakeholders through data so that better skills-related decisions can be made. Furthermore, a distinction is made between data preparation and data presentation, and there is also an emphasis on the updating of data for expert use.

The experiences of BEYOND4.0 and ESSA have shown that the right match between skills demand and supply requires the collaboration of stakeholders to make well-coordinated decisions.

Although the steelHub e-learning system, which operates at the European level, already addresses a European skills ecosystem, regional and national deployment of alliances and skills strategies is needed to establish skills and training ecosystems, in order to make better skills decisions.

Coming back to the definition of skills intelligence, it is striking that this element of the project, the rollout, is most likely not to be found in the understanding of skills intelligence. It is not easily related to the two process elements of data preparation and data presentation, but rather seems to combine the two and link them to the concern for sustainability and stakeholder involvement. However, there is no concrete template for the regional rollout processes. They are rather open communication processes with project leaders and relevant regional stakeholders, which should lead to sustainable use of the developed tools. It is a work in progress that can be translated into models that can be used in another sector or context once the project is completed.

5. Discussion

Some of the main findings suggest that the concept of skill intelligence is applicable to the steel sector, providing clarity on current and future skill needs arising from the twin transitions of digitalisation and decarbonisation. However, the adoption of the theoretical concept of skills intelligence by the steel sector requires some adaptations. The concept of skills intelligence applied to the steel sector is not limited to the preparation and presentation of data; instead, it facilitates a governance structure that allows for coordinated actions to mitigate skills imbalances.

In this paper, we contributed on two different levels. Firstly, a theoretical level based on the concept of skills intelligence to analyse skills needs in the steel sector. Secondly, an empirical level, where two projects provide evidence on how skills needs can be identified in the European steel sector and at a national level and how the demand for skills is met. Although the concept of skills intelligence offers several contributions, some of the limitations we identified are that this concept can be difficult to interpret in different industry contexts.

The concept

Our research shows how CEDEFOP's understanding of skills intelligence is very useful for a first analysis as it is mainly characterised by quantitative data. The general understanding of skills intelligence as an enabler for informed skills-related decisions [24] is the main driver for the framework presented here to raise information on skill needs and on how to cope with them.

We identified that skills intelligence and the skills matching tools of Rentzsch and Staneva [25] provide a good basis for the analysis and development of skills intelligence accompanied by sector-wide research. However, this article shows that skills intelligence has to address the specific needs of different users from the steel sector. This is based on the reflection that current skills intelligence tools do not support sectoral decisions by companies, associations or regional policymakers. They often contain data that refer to the whole European economy or to very broad sectors, such as the "manufacturing industry".

From a theoretical point of view, the claim of skills intelligence is that skills-related data enables better decision-making. However, Rentzsch & Staneva [25] and also CEDEFOP [24] focus on the preparation and presentation of data, the step from data presentation to decision-making and, later on, to actions omitted in this logic. While the theoretical approach to skills intelligence focuses on the preparation and presentation of data, the application to the steel sector requires additional measures for skills intelligence to be of real use. Given that skills intelligence is designed to make better skills decisions, the right decision-makers need to be targeted. This article on a sectoral approach to skills intelligence has shown that to fill this gap, data provision needs to be integrated into skills ecosystems.

Dimensions

We have identified two main dimensions that can be analysed for the development of skills intelligence in the steel sector: (a) geographical scope and (b) for company-specific skills demand and supply (see Table 1). First, we consider these two dimensions to be relevant for the steel sector, as the first one provides relevant information in specific geographical contexts, not only on skills but also for stakeholders in the steel sector. Second, for company-specific skills demand and supply helps to identify information of needs and gaps of skill. Third, policy strategy is very relevant in the case of the steel sector, as modernisation strategies in the steel sector are closely linked to an EU strategy. At the regional level, the link between the skills demand and skills supply becomes most concrete: it is not only companies and training institutes but also employment agencies, chambers of industry and commerce, business development agencies, political actors and research institutions that have to work together on policy strategies to adapt skills supply to skills demand in the best possible way.

Ecosystem and Tools

In the ecosystem approach, it is important to integrate the various stakeholder groups not only in terms of their competencies but also to formulate binding responsibilities, for the successful development of training programs and thus to skills supply. Ideally, the communication and collaboration of different stakeholder groups are initiated through a co-creation process taking into account different stakeholder perspectives [52].

The involvement of business representatives and other stakeholders is necessary for skills intelligence to really work. Based on the research of Beyond4.0 and ESSA, we suggest further developing the skills intelligence approach by integrating the ecosystem perspective and considering specific regional particularities when it comes to regional and national rollouts of skill strategies and alliances to the extent that the concept of skills intelligence needs customisation when it is applied to the steel sector.

From a practical point of view, the current status of skills intelligence in the steel sector shows structures, platforms (steelHub) and processes of how skills intelligence can happen in the steel industry. Currently, these are pilots whose rollout has to be continued to obtain feedback and process experiences in order to create a running system on a regular base. The steelHub as a platform for skills intelligence including data on skill demand and supply has to be fed with more data to enable stakeholders to make better decisions.

A gap identified between the theoretical approach and practical experience is that skills intelligence claims to consider both, quantitative and qualitative data. In practice, however, skills intelligence is rather focused on quantitative data, whereas the approach presented here shows that in the Beyond4.0 project, qualitative data have also been raised as highly relevant to explore skills needs and current ways of providing them. Therefore, qualitative data should be explicitly included in a skills intelligence approach to explore the specific situation in the steel sector before collecting and analysing quantitative data.

Outlook

Regarding **practical implications**, there are still further challenges with regard to the sustainable implementation of skills intelligence tools developed in the ESSA project. As already described, the rollout and development of regional skills ecosystems is an important pillar for the implementation and adaptation of tools such as the steelHub, which will be further developed in collaboration and communication with stakeholders and continuously tailored to concrete needs. This process has been initiated and launched during the ESSA project. However, it is important that selected stakeholders continue and coordinate the rollout in the respective steel regions, also after the project's duration. For example, the Focus Group People of the European Steel Technology Platform (ESTEP), through which ESSA-relevant activities are to be further coordinated, is particularly important in this respect after the end of ESSA. Thereby, the formation of a European community of practice (ECOP) is planned, establishing interrelated alliances and leadership on the European, national and regional levels.

Ensuring the **sustainability of the skills intelligence** tools developed in the project beyond the duration of ESSA is currently one of the main focal points. A continuous operation of the steelHub platform is targeted so that it can be established as an important contact point for steel-related qualification, while other tools of the Skills Observatory, such as the Technology and Skills Foresight Survey & Panel, will also feed into the steelHub.

In order to ensure the practical implementation of the theoretical concept of skill intelligence, it is important, from the authors' perspective, to provide stakeholders with **recommendations for action** for the establishment of corresponding structures. Only through the proper involvement of all relevant actors at different levels of action (regional, national, European) stakeholders in the skills market can recognise the individual benefits of skills intelligence and corresponding tools. This concerns the creation of own tools and the use of third-party tools, their adaptation to the specific needs of a sector, increased cooperation and also the integration of qualitative data in decision-making processes.

Therefore, for skills intelligence to continue to develop successfully, it is crucial that it remains a concept that provides a foundation for the development of tools at the theoretical level. At the same time, it must be consistent with the real needs of the relevant actors and sectors in the application and development of tools.

From a theoretical point of view, concepts such as ecosystem and multi-level perspective are relevant to engage these stakeholders and should be further investigated in the context of skills intelligence in the steel sector.

Author Contributions: Conceptualization, K.M.-M., M.C., A.G. and M.K.; methodology, K.M.-M., M.C., A.G. and M.K.; formal analysis, K.M.-M., M.C., A.G. and M.K.; investigation, K.M.-M., M.C., A.G. and M.K.; resources M.C. and A.G.; writing—original draft preparation, K.M.-M., M.C., A.G. and M.K.; writing—review and editing, K.M.-M. and M.C.; project administration, M.K.; funding acquisition, M.K. All authors have read and agreed to the published version of the manuscript.

Funding: The insights of this article are based on the projects BEYOND 4.0 (grant agreement No. 822296) and ESSA (grant agreement No. 600886). The Social Research Centre/TU Dortmund University received funding from the European Commission for participating in these projects. This research was undertaken within the BEYOND4.0 project. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 822296. We acknowledge financial support from the BEYOND 4.0 Project for the publication of this paper.

Data Availability Statement: Data is contained within the article. Some of the data presented in this study are available in [Behrend, C.; Götting, A.; Kohlgrüber, M.; Wright, S.; Pomares, E. Understanding Future Skills and Enriching the Skills Debate, BEYOND 4.0 Deliverable 6.1—3rd Report. 2022. Available online: https://beyond4-0.eu/storage/publications/D6.1%20Understanding%20future%20skills%20and%20enriching%20the%20skills%20debate/BEY4.0_WP06_Task_6.1-%203rd%20Update%2008.2022.pdf (accessed on 22 December 2022)] and in [Schröder, A.; Stroud, D.; Antonazzo, L.; Weinel, M.; Bayón, F.; Akyazi, T.; Murri, M.; Tropeoli, A.; Muract, J.; Eitner, C. Mid-term Report. ESSA Deliverable 1.4. 2020. Available online: https://www.estep.eu/assets/Uploads/ESSA-Deliverable-D1-4-Mid-term-Report-2020-12-31.pdf (accessed on 22 December 2022)].

Acknowledgments: We thank all BEYOND 4.0 and ESSA project partners who contributed to data collection and analysis in the framework of the projects. We especially thank Antonius Schröder for previous discussions and valuable comments for our article. We also thank three anonymous reviewers for their comments to improve this manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Vu, H.; Cecchin, F. *Climate-Neutral Steelmaking in Europe: Decarbonisation Pathways-Investment Needs-Policy Conditions-Recommendations*; Publications Office of the European Union: Luxembourg City, Luxembourg, 2022. [CrossRef]
2. Branca, T.A.; Fornai, B.; Colla, V.; Murri, M.M.; Streppa, E.; Schröder, A.J. The Challenge of Digitalization in the Steel Sector. *Metals* **2020**, *10*, 288. [CrossRef]

3. Antonazzo, L.; Stroud, D.; Weinel, M.; Dearden, K.; Mowbray, A. *Preparing for a Just Transition: Meeting Green Skill Needs for a Sustainable Steel Industry*; Cardiff University: Cardiff, Wales, 2021. Available online: https://orca.cardiff.ac.uk/id/eprint/145353/1/RGB_Meeting_Green_Skills_Needs_A4_booklet_singlepages.pdf (accessed on 9 February 2023).
4. Branca, T.A.; Fornai, B.; Colla, V.; Murri, M.M.; Streppa, E.; Schröder, A.J. Current and future aspects of the digital transformation in the European Steel Industry. *Mater Magistra* **2020**, *108*, 508. [CrossRef]
5. Murri, M.; Colla, V.; Branca, T.A. Digital Transformation in European Steel Industry: State of the Art and Future Scenario. ESSA Deliverable 2.1, Version 2. 2021. Available online: https://www.estep.eu/assets/Uploads/ESSA-D2.1-Technological-and-Economic-Development-in-the-Steel-Industry-Version-2.pdf (accessed on 9 February 2023).
6. Peaslee, K.D. Opportunities and Challenges in Steel Manufacturing: Engineering a Brighter Future. *Iron Steel. Technol.* **2008**, 91–102.
7. Echterhoff, V.; Schelkle, P.; Cassel, S. Attracting Talents to the Steel Industry: Recommendation Paper. European Steel Technology Platform. 2020. Available online: https://www.estep.eu/assets/Uploads/20200302-attracting-talents-to-the-steel-industry.pdf (accessed on 22 December 2022).
8. Hoffmann, C.; Van Hoey, M.; Zeumer, B. Decarbonization Challenge for Steel. Our Insights, McKinsey & Company. 3 June 2020. Available online: https://www.mckinsey.com/industries/metals-and-mining/our-insights/decarbonization-challenge-for-steel (accessed on 22 December 2022).
9. Medarac, H.; Moya Rivera, J.A.; Somers, J. *Production Costs from Iron and Steel Industry in the EU and Third Countries*; Publications Office of the European Union: Luxembourg, 2022. [CrossRef]
10. Fourquet, R.; Hippe, R. Twin transitions of decarbonisation and digitalisation: A historical perspective on energy and information in European economies. *Energy Res. Soc. Sci.* **2022**, *91*, 102736. [CrossRef]
11. Skoczkowski, T.; Verdolini, E.; Bielecki, S.; Kochański, M.; Korczak, K.; Węglarz, A. Technology innovation system analysis of decarbonisation options in the EU steel industry. *Energy* **2020**, *212*, 118688. [CrossRef] [PubMed]
12. EUROFER. Low Carbon Roadmap: Pathways to a CO_2-Neutral European Steel Industry. 2019. Available online: https://www.eurofer.eu/assets/Uploads/EUROFER-Low-Carbon-Roadmap-Pathways-to-a-CO2-neutral-European-Steel-Industry.pdf (accessed on 9 February 2023).
13. Glushchenko, A.M. Decarbonization of the Steel Industry: The Role of State Economic Policy. *Probl. Econ.* **2020**, *43*, 340–347. [CrossRef]
14. Wörtler, M.; Schuler, F.; Voigt, N.; Schmidt, T.; Dahlmann, P.; Lüngen, H.B.; Ghenda, J.-T. Steel's Contribution to a Low-Carbon Europe 2050: Technical and Economic Analysis of the Sector's CO_2 Abatement Potential. Boston Consulting Group. 4 June 2013. Available online: https://www.bcg.com/publications/2013/metals-mining-environment-steels-contribution-low-carbon-europe-2050 (accessed on 22 December 2022).
15. European Commission. Towards Competetive and Clean European Steel. Accompanying the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Updating the 2020 New Industrial Strategy: Building a stronger Single Market for Europe's Recovery. European Commission, 2021. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021SC0353&from=EN (accessed on 24 February 2023).
16. PricewaterhouseCoopers. Agility in Metals: Digital Transformation in the Steel and Aluminium Industry. 2019. Available online: https://www.strategyand.pwc.com/de/en/industries/energy-utilities-resources/agility-in-metals/agility-in-metals.pdf (accessed on 9 February 2023).
17. Worldsteel Assocation. Working in the Steel Industry: Fact Sheet. 2021. Available online: https://worldsteel.org/wp-content/uploads/Fact-sheet-Working-in-the-steel-industry.pdf (accessed on 9 February 2023).
18. Hasluck, C. An information framework for a local labour market. *Local. Econ.* **1989**, *5*, 15–25. [CrossRef]
19. Learning + Skills Council. LMI Matters! Understanding Labour Market Information: A Toolkit for People who Give Advice and Guidance on Education and Employment. 2004. Available online: https://warwick.ac.uk/fac/soc/ier/ngrf/effectiveguidance/improvingpractice/lmi/lmi_matters_lsc.pdf (accessed on 22 December 2022).
20. Cedefop. Conference Concept Note. 2021. Available online: https://www.cedefop.europa.eu/files/getting_the_future_right_-_cedefop_conference_april_13_-_concept_note.pdf (accessed on 9 February 2023).
21. Cedefop. *Work Programme 2012*; Publications Office of the European Union: Luxembourg, 2012. [CrossRef]
22. Cedefop. Skills Intelligence. Available online: https://www.cedefop.europa.eu/en/tools/skills-intelligence (accessed on 9 February 2023).
23. European Commission. *European Skills Agenda for Sustainable Competitiveness, Social Fairness and Resilience*; European Commission: Brussels, Belgium, 2020. Available online: https://ec.europa.eu/social/BlobServlet?docId=22832&langId=en (accessed on 22 December 2022).
24. Cedefop. Crafting Skills Intelligence. Blog, Cedefop. 25 September 2019. Available online: https://skillspanorama.cedefop.europa.eu/en/blog/crafting-skills-intelligence (accessed on 22 December 2022).
25. Rentzsch, R.; Staneva, M. Skill-Matching and Skills Intelligence through curated and data-driven ontologies: Usage scenarios, practical examples and the question: Who annotates education? In *Proceedings of the DELFI Workshops 2020, Heidelberg, Germany, 14 September 2020*; Schumacher, C., Ed.; Gesellschaft für Informatik e.V.: Bonn, Germany, 2020; pp. 1–11. [CrossRef]
26. Uitvoeringsinstituut Werknemersverzekeringen. Arbeidsmarktinformatie. Available online: https://www.werk.nl/arbeidsmarktinformatie?dmn=2H (accessed on 9 February 2023).

27. Van Smoorenburg, M. Customising LMI to Different User Groups—The Approach of the Dutch Public Employment Service. Cedefop, 2021. Available online: https://www.cedefop.europa.eu/files/cedefop_m._van_smooorenburg_uwv.pdf (accessed on 22 December 2022).
28. Euskal Enplegu Zerbitzua Servicio Vasco de Empleo. FUTURELan. Available online: https://futurelan.eus/es/ (accessed on 9 February 2023).
29. Beyond 4.0 Home Page. Available online: https://beyond4-0.eu/ (accessed on 9 February 2023).
30. ESSA Home Page. Available online: https://www.estep.eu/essa/ (accessed on 9 February 2023).
31. Schröder, A.; Stroud, D.; Antonazzo, L.; Weinel, M.; Bayón, F.; Akyazi, T.; Murri, M.; Tropeoli, A.; Muract, J.; Eitner, C. Mid-term Report. ESSA Deliverable 1.4. 2020. Available online: https://www.estep.eu/assets/Uploads/ESSA-Deliverable-D1-4-Mid-term-Report-2020-12-31.pdf (accessed on 22 December 2022).
32. European Parliament & European Council. Recommendation of the European Parliamentand of the Council of 23 April 2008 on the Establishment of the European Qualifications Framework for Lifelong Learning. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008H0506(01) (accessed on 22 December 2022).
33. Kohlgrüber, M.; Behrend, C.; Götting, A.; Cuypers, M.; Warhurst, C.; Wright, S. Understanding Future Skills and Enriching the Skills Debate; BEYOND 4.0 Deliverable 6.1—Version 3.0—Second report. 2021. Available online: https://beyond4-0.eu/storage/publications/D6.1%20Understanding%20future%20skills%20and%20enriching%20the%20skills%20debate.%20Full%20version./BEY4.0_WP06_Task_6.1_Report%20overview%20new%20skills.pdf (accessed on 22 December 2022).
34. Behrend, C.; Götting, A.; Kohlgrüber, M.; Wright, S.; Pomares, E. Understanding Future Skills and Enriching the Skills Debate, BEYOND 4.0 Deliverable 6.1—3rd Report. 2022. Available online: https://beyond4-0.eu/storage/publications/D6.1%20Understanding%20future%20skills%20and%20enriching%20the%20skills%20debate/BEY4.0_WP06_Task_6.1-%203rd%20Update%2008.2022.pdf (accessed on 22 December 2022).
35. Berger, T.; Frey, C.B. Digitalization, Jobs, and Convergence in Europe: Strategies for Closing the Skills Gap. European Union, 2016. Available online: https://www.oxfordmartin.ox.ac.uk/downloads/reports/SCALE_Digitalisation_Final.pdf (accessed on 22 December 2022).
36. Deming, D.J. The Growing Importance of Social Skills in the Labor Market. National Bureau of Economic Research, 2017. Available online: https://www.nber.org/papers/w21473.pdf (accessed on 22 December 2022).
37. Kirchherr, J.; Klier, J.; Lehmann-Brauns, C.; Winde, M.; Future Skills: Welche Kompetenzen in Deutschland Fehlen. Stifterverband. 2019. Available online: https://www.stifterverband.org/download/file/fid/6360 (accessed on 22 December 2022).
38. Probst, L.; Pedersen, B.; Bohn, N.; Verzijl, D. Skills for Smart Industrial Specialisation and Digital Transformation: Interim Report. Publications Office of the European Union: Luxembourg, 2018. [CrossRef]
39. Dhondt, S.; van der Zee, F.; Preenen, P.; Kraan, K.; Oeij, P.R.A. Dominant technology and organization: Impacts of digital technology on skills. In *International Perspective and Research on the "Future of work"*; Frauenhofer IAO: Stuttgart, Germany, 2019; pp. 186–205. Available online: https://wp.workplaceinnovation.org/wp-content/uploads/sites/2/2021/01/Dhondt-Zee-Preenen-et-al-2019-Dominant-tech-and-organization-Fraunhofer-book-003.pdf (accessed on 24 February 2023).
40. Fernández-Macías, E.; Hurley, J.; Bisello, M. *What do Europeans do at Work? A Task-Based Analysis: European Jobs Monitor*; Publications Office of the European Union: Luxembourg, 2016. [CrossRef]
41. Cedefop. The Great Divide: Digitalisation and Digital Skill Gaps in the EU Workforce. 2016. Available online: https://www.cedefop.europa.eu/files/esj_insight_9_digital_skills_final.pdf (accessed on 22 December 2022).
42. Vazquez, I.G.; Milasi, S.; Gomez, S.C.; Napierala, J.; Bottcher, N.R.; Jonkers, K.; Beldarrain, X.G.; Pabollet, E.A.; Bacigalupo, M.; Biagi, F.; et al. The Changing Nature of Work and Skills in the Digital Age. Publications Office of the European Union: Luxembourg, 2019. [CrossRef]
43. Abel, J. *Kompetenzentwicklungsbedarf Für Die Digitalisierte Arbeitswelt*; Forschungsinstitut Für Gesellschaftliche Weiterentwicklung: Düsseldorf, Germany, 2018. Available online: https://www.fgw-nrw.de/fileadmin/user_upload/FGW-Studie-I40-09-Abel-komplett-web.pdf (accessed on 22 December 2022).
44. Janis, I.; Alias, M.A. Systematic Literature Review: Human Roles, Competencies And Skills In Technology & Society: A Multidisciplinary Pathway for Sustainable Development. In *Proceedings of the Asia International Multidisciplinary Conference (AIMC 2017), Johor Bharu, Malaysia, 1–2 May 2017*; Qureshi, M.I., Ed.; Future Academy: London, UK, 2018; pp. 186–205. [CrossRef]
45. Publications Office of the European Union. *Skills Forecast: Trends and Challenges to 2030*; Publications Office of the European Union: Luxemburg, 2018. [CrossRef]
46. Bughin, J.; Hazan, E.; Lund, S.; Dahlström, P.; Wiesinger, A.; Subramaniam, A. Skill Shift. Automation and the Future of the Workforce. McKinsey & Company. Available online: https://www.mckinsey.com/~/media/mckinsey/industries/public%20and%20social%20sector/our%20insights/skill%20shift%20automation%20and%20the%20future%20of%20the%20workforce/mgi-skill-shift-automation-and-future-of-the-workforce-may-2018.pdf (accessed on 22 December 2022).
47. DRIVES. Skill Needs and Gaps. DRIVES Deliverable 2.8. 2020. Available online: https://www.project-drives.eu/Media/Publications/19/Publications_19_20200323_215437.pdf (accessed on 22 December 2022).
48. Organisation for Economic Co-operation and Development. *Skills Matter: Additional Results from the Survey of Adult Skills*; OECD Publishing: Paris, France, 2019. [CrossRef]

49. Bayón, F.; Goti, A.; Akyazi, T.; Cuypers, M.; Muract, J. Company Skills Requirements and Foresight. ESSA Deliverable 3.2. 2021. Available online: https://www.estep.eu/assets/Uploads/ESSA-D3.2-Industry-Skills-Requirements-Version-2.pdf (accessed on 22 December 2022).
50. Häder, M.; Häder, S. DELPHI-Befragung. In *Handbuch Methoden der Empirischen Sozialforschung*; Baur, N., Blasius, J., Eds.; Springer: Wiesbaden, Germany; pp. 587–592. [CrossRef]
51. Anderson, P.; Warhurst, C. Lost in translation? Skills policy and the shift to skill ecosystems. In *Complex New World: Translating New Economic Thinking into Public Policy*; Dolphin, T., Nash, D., Eds.; IPPR: London, UK, 2012; pp. 109–120. Available online: https://pure.strath.ac.uk/ws/portalfiles/portal/31767989/complex_new_world_Aug2012_web_9499.pdf (accessed on 22 December 2022).
52. Kohlgrüber, M.; Maldonado-Mariscal, K.; Schröder, A. Mutual Learning in Innovation and Co-Creation Processes: Integrating Technological and Social Innovation. *Front. Educ.* **2021**, *6*, 498661. [CrossRef]