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Article

Smart Production Workers in Terms of Creativity and Innovation: The Implication for Open Innovation

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Abstract: This paper presents a framework of employee skills and competencies useful for developing occupational profiles for employees of companies transitioning towards Industry 4.0. The paper consists of a discussion of the theoretical and practical parts of case studies. The theoretical portion was created on the basis of a review of scientific literature and research studies regarding the competencies and skills of employees in the ongoing fourth industrial revolution. This part focuses on the skills profile of an Industry 4.0 employee and an Operator 4.0 (O4.0) from a creativity and innovativeness point of view. The link between the theoretical part and the case study analysis was a general framework for building the competencies and skills of the steelworker in the emerging fourth industrial revolution. The case study analysis covered the framework of competencies and skills of a metallurgist in smart manufacturing built into the organization of steel mills. Recruitment offers of a steel company implementing smart manufacturing (SM) projects and educational programmes of technical universities in the field of metallurgy were analysed. The aim of the study was to develop a framework for the profile of an employee working in an innovative company transforming to I4.0. The publication posed the following research questions (purposes/hypotheses): P1. To what extent do Polish companies in the metallurgical sector pay attention to creativity and innovation issues when looking for employees? P2. To what extent do the profile (portfolio) of metallurgy graduates of Polish technical universities turn their attention to the issues related to creativity and innovation?

Keywords: Industry 4.0 (I4.0); skills; education; steel sector; innovativeness; creativity; open innovation

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1. Introduction

With the popularization of the industrial development concept called Industry 4.0 (I4.0), enterprises have begun to build cyber-physical production systems (CPPS), in which the physical (operational) world fuses with cyber technologies and virtual solutions of next-generation technologies. Industry 4.0 technologies create new opportunities for combining IT and operational technologies [1,2]. The changes leading companies towards Industry 4.0 are long-term and may require a radical reorganisation of human resources. Technological changes are implemented both within companies and in entire supply chains. The implemented technologies of Industry 4.0 are based on solutions referred to as "smart" [3]. The smart approach is built on the basis of key technologies of the fourth industrial revolution, which are referred to as Key Enabling Technologies (KETs) or pillars of Industry 4.0 (I4.0). These technologies include: the Internet, Industrial Internet of Things (IIoT), blockchain, big data, edge and cloud computing, autonomous robots, machine learning, work organisation based on human-machine interaction, artificial intelligence (AI), open-source software, etc. [4]. The target direction of change is toward smart factories with smart operations and processes and with smart products and services.

The implementation of Industry 4.0 concepts has an important impact on many traditional areas of organization activities [5,6]. It is, for example, the case of organizational motivation and ethics in a company [7], as well as problems connected with gender diversity are important fields of current research about implementing Industry 4.0 in business environments [6]. We can take into account that the COVID-19 pandemic has changed many aspects of business operations and provide the impulse of movement towards further digitalization of all processes and activities [8].

Companies introduce changes gradually, starting from single installations through technology islands, production nests and production lines, to integrated technologies and autonomous control systems for manufacturing and maintenance processes [9]. The way to I4.0 is defined by companies according to the realized projects of SM [10]. Increasingly better technology is replacing workers in many manual activities, precision activities, activities that are difficult or dangerous for them to perform. At the current stage of change in enterprises, the technology of the fourth industrial revolution is programmed, operated, supervised, taught, and improved by a human being, referred to as operator 4.0 (O4.0) in the changing production systems towards smart manufacturing [11]. Operator 4.0 is a popular nomenclature used to highlight the place of the operator in Industry 4.0. Workers operate with I4.0 technologies to optimise operations and processes [12]. The modern worker must have the technical, IT (digital) and cognitive (intellectual) skills, as well as the physical and mental aptitude to operate Industry 4.0 (I4.0) technologies.

The implementation of Industry 4.0 in a company is aimed, among other things, at improving its innovativeness. An operator should be characterised by the appropriate knowledge and competencies, thus allowing for more innovation and creativity [13–16]. This is necessary for steel companies to develop and establish a competitive rivalry in the global market. The analysis of the literature on the competencies of Operators 4.0 in the steel industry revealed a cognitive gap. There have been no works thus far that have conducted analyses concerning the competency profile of an Operator 4.0 in this industry, in particular in the context of its competency in innovation, which is particularly important in the conditions of Industry 4.0 [17–20].

The relationship between creativity and innovativeness is perceived by most researchers; however, the ways of explaining the mutual relations between the phenomena vary between scholars. According to R.B. Mellor [21], creativity is one of the three (middle) sources of innovation, in addition to the use of invention and dissimilarity. Each of the sources of innovation determines the formation of a different type of innovation [22,23]. To the lowest-ranked "dissimilarity", we owe the so-called incremental innovations, while occupying the very top "invention" is the basis of very rare radical innovations [24–27]. Creativity is recognised by Mellor as the source of both radical and incremental innovations [28,29].

The conception of creativity can be very useful to increase the level of innovativeness within organizations. The cognitive style of thinking and, for example, the curiosity of workers impact the performance of an organization [30,31]. In addition, other important concepts impacting the innovativeness of the organization are connected to employee satisfaction, which leads to better job involvement [32]. Innovations and creativity are based on the level of human resources management level, and to increase it, more diverse and inclusive workplaces are needed, especially in the case of multinational organizations. In addition, the empowerment of workers is needed to boost their engagement in an organization's activities [33]. This empowerment can lead to a high-sociability organization, which is more effective and possesses a better level of innovativeness [34,35].

Conceptual creativity triggers the innovation cycle, as it allows ideas to be created and then participates in the phase of sifting ideas and potential innovations, where operational creativity is activated in parallel [36–38]. Operational creativity, in turn, is necessary for the last phase of the innovation cycle—the innovation implementation phase. While every innovation process must begin with a creative act, not every act of creativity will culminate in the creation of an innovation. Innovation will not be created without creative employees, but in order to use their potential, it is necessary to create appropriate conditions in the company [39–41]. Indeed, creativity is a specific resource of the organization's employees, a particular means of production, while innovation is its effect, the final product [42–46].

It is worth noting that, in particular, the creation of innovations in the open model is based on the simultaneous use of internal and external creativity potential. The innovations created as a result of cooperation with external entities (so-called open innovation) are a manifestation of the co-creativity of all entities involved in the creation of innovation [47,48]. For this reason, it can be considered that the role of creativity in the case of creating open innovation is even greater than in the case of classical innovation [49–51].

The aim of this paper was to develop a framework for the profile of an employee employed in an innovative company transforming to I4.0.

The publication posed the following research questions (Purposes/Hypotheses):

P1. To what extent do Polish companies in the metallurgical industry pay attention to creativity and innovation issues when looking for employees?

P2. To what extent do the profile (portfolio) of metallurgy graduates of Polish technical universities turn their attention to the issues related to creativity and innovation?

The final outputs of the work are a framework of competencies and skills of workers in Industry 4.0, Operators 4.0 (O4.0), and metallurgists for the building environment of smart, innovative metallurgical enterprises.

This paper was based on the review of the literature on requirements for employees in Industry 4.0 and the analysis of recruitment offers of employees of metallurgical enterprises and on the basis of educational programmes of the metallurgical faculties at technical universities in Poland—a graduate profile of metallurgical faculties conducted at technical universities in Poland. While analysing the profiles of graduates, special attention has been paid to the issues related to competencies and skills concerning creativity and innovation.

The paper consists of theoretical and practical parts of case studies. The theoretical part was created on the basis of scientific literature and research studies about the competencies and skills of employees in the ongoing fourth industrial revolution in innovative enterprises. The theoretical part was divided into three parts, respectively, including (i) skills and competencies of Industry 4.0 employees; (ii) requirements for the operators of machines, technological installations, and IT systems in the smart manufacturing (SM) environment, (iii) competency framework of steel industry employees on the basis of EU strategy addressing the skills needs of the steel sector, especially connected with creativity and innovativeness.

The research part has two levels. The first level was the result of a case study based on recruitment offers of a steel company implementing SM projects. On the second level, a case study is presented on the programs in the education field: Metallurgy at the technological universities in Poland. On the basis of recruitment offers of a metallurgical company and educational programmes of technical universities in Poland, a framework of competencies and skills of the metallurgy profession is developed. The paper concludes with a discussion of the relevance of the new competencies and skills framework for industrial innovation toward a creative smart environment.

2. Research Methodology

In this thesis, there is an analysis of the secondary sources, which included three levels of research: (i) it concerned the framework of competencies and skills of employees in the ongoing revolution; (ii) it concerned the general requirements for operators of Industry 4.0 technologies in transforming enterprises; (iii) it concerned the framework of competencies and skills of a steel industry employee. In the empirical part of the paper, the results of the case studies analysis are shared on the basis of the employee recruitment offers of a steel company implementing smart manufacturing projects and the educational programmes of technical scholars in Poland who taught the field of study: metallurgy. The scheme of the research methodology is presented in Figure 1.

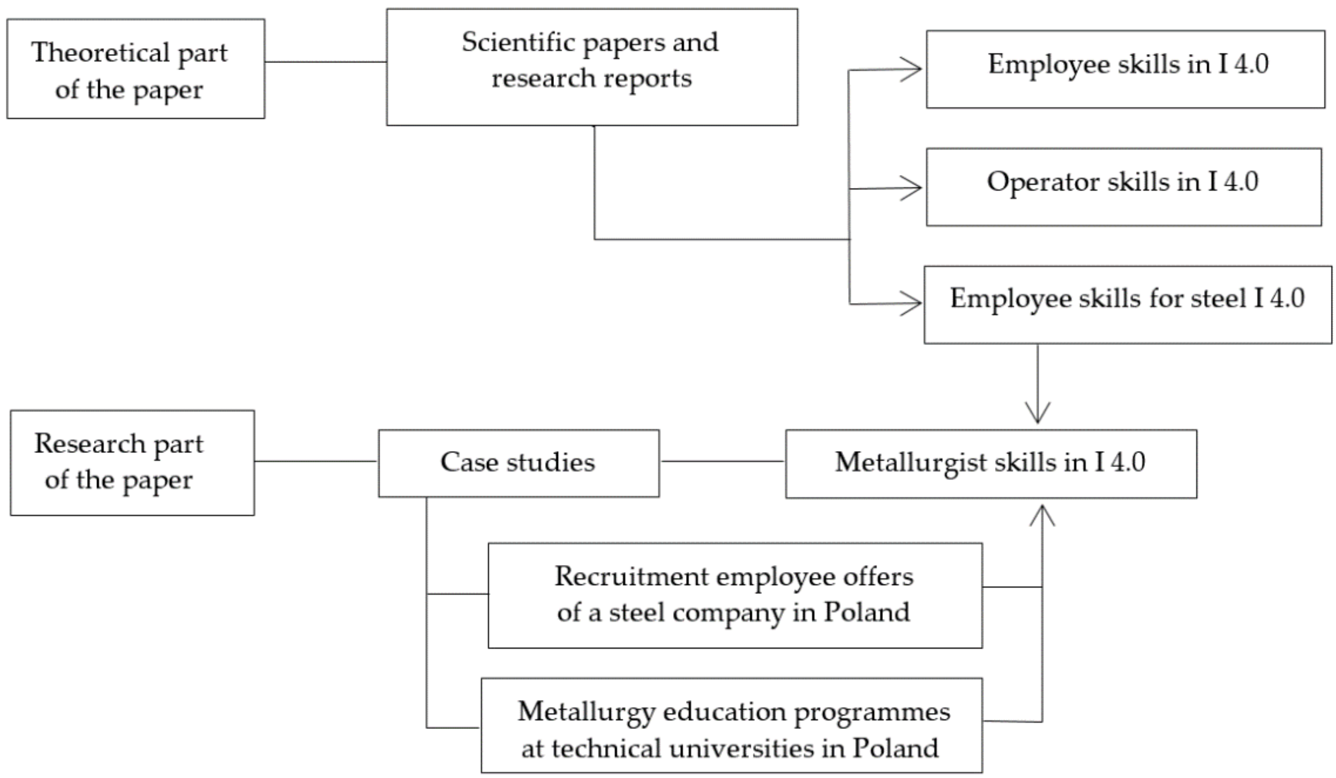

Figure 1. Research methodology in setting the frameworks of employee profiles for smart manufacturing.

3. Industry 4.0 and Employees in Scientific and Research Studies

The concept of Industry 4.0 assumes that operators are needed to operate technologies in a smart environment. New technologies, defined as enabling technologies, need operators so that they can be tested and implemented in smart manufacturing [52]. Authors like Lorenz et al. [53], in their analysis of the relationship between humans and machines, wondered: how will technology transform the industrial workforce through 2025? To answer this question, it is necessary to know the new working conditions in the cyber-physical production systems being created.

Today's production systems are being transformed by the use of the Internet of Things (IoT), the Internet of Services (IoS), robotics, big data, cloud, and cognitive computing, augmented reality (AR), and virtual reality (VR). In Cyber-Physical Production Systems (CPPS), machines are equipped with artificial intelligence algorithms, and machine learning takes place through event memory, simulation, inference, identification, and change recognition. Large data sets, delivered to the machines in real-time, are needed for machine self-learning. Thousands and more internal and external sensors mounted on production line equipment provide data for machine learning and business process optimisation. Modern technology uses various forms of learning, e.g., deep learning based on neural networks and cognitive computing based on artificial intelligence algorithms—computers with associative memory that mimic human thinking. Technological installations in factories are becoming a challenge for machine operators and information system computer scientists. Machines with sensor systems (networks) and learning algorithms are turning into smart technologies, which are technologies with multiple functions and the ability to adapt to change. The information obtained from machines is used to optimise production, and the entire process of controlling production lines is increasingly autonomous and independent of humans [54].

Companies are gradually implementing new technological solutions for Industry 4.0, adopting their own internal development path towards Industry 4.0 [10]. From entries in development strategies through the first smart manufacturing (SM) projects on single installations and workstations to further projects with an increasingly wide range of changes towards smart manufacturing. Technological restructuring is accompanied by a reorganisation of the human factor. Researchers and practitioners are investigating and describing key employee skills that appear to be particularly useful in handling new technologies in manufacturing companies.

3.1. Frameworks of Employee Skills and Competencies in Industry 4.0

The range of competencies and skills frameworks built by researchers and scientists is aligned with their adopted research scope and research objectives. In the Acatech [55] study (a study for the Industrie 4.0 platform), the skill profile of a next-generation technology-enabled worker is the focus in terms of the characteristics of learning the usability of Industry 4.0 technologies and the functions and possibilities of integrating digital and physical solutions in smart manufacturing, as well as understanding business networking. The set of proposed characteristics of an Industry 4.0 worker is closed by the social and environmental requirements to which the worker must constantly adapt, being aware of the changes taking place and the potential for technology to affect changes in the workplace and beyond (Table 1).

Table 1. Sample lists of workforce skills for Industry 4.0 in exemplary academic and research studies.

Reference	Skills/Competencies/Capabilities (Citation According to the Source)
[45]	▪ Learning to think from the use of software ▪ Able to understand network structures ▪ Learn how to master big data technology ▪ Learn how to work with various data formulas ▪ Understand and master the process or implementation of work activities ▪ Learn to take more responsibility in every job ▪ Learn how to be communicative and cooperative workers ▪ Learn how to have high innovation and initiation ▪ Focus on developing sensitivity to the environment and social life through technological developments and innovations
[46]	▪ Knowledge of information and production technology ▪ Knowledge of software structures ▪ Understand the function of Hybrid Exercise ▪ Experience in mechatronic ▪ Sharpening skills in the social field of fellow workers ▪ Sharpening the ability to use software ▪ Able to change programs ▪ Able to execute tasks measurably ▪ Able to make decision ▪ Expert in their field for at least 2 years ▪ Able to use the internet both manually and using data ▪ Broad and directed knowledge ▪ Expert in the process and use of technology ▪ Have an optimistic spirit ▪ Able to read and assess the use of data on the device or the machine used

Table 1. *Cont.*

Reference	Skills/Competencies/Capabilities (Citation According to the Source)
[47]	Levels of industrial engineering model: ▪ Social perception (connected with all fields of knowledge and activities of industrial engineers) ▪ External behavior (industrial engineers are adaptive and proactive in responding to external environment stimulation and forces) ▪ Skills and capabilities: industrial engineers define, design, deploy, and refine conceptual and physical solutions aimed at generating value for Industry ▪ Knowledge fields/disciplines such as: project management, information systems, systems engineering, modelling and simulation, mechatronics and automation, robotics and artificial intelligence, operations research and operations management, facilities management and maintenance systems, quality management systems, and logistics and supply chain management ▪ Value and motivator (application for human benefit is the greatest value and motivator of industrial engineers, and other values include efficiency, human wellbeing, fairness, sustainability, and the application of theory and knowledge) ▪ Thinking style according to the level of industrial development ▪ Core belief (the crux of what makes industrial engineering different and valuable as a discipline is maximising the extraction of value through balanced means) ▪ Fundamental belief (balance is intrinsically valuable, and can be one of the most prominent beliefs
[48,49]	▪ Digital skills in the fields: Industry 4.0 programming and software engineering, data science, data and big data analytics, visualization, Internet of Things, IT architecture, security ▪ Project coordination skills: product management, multi-project management, supply chain and support services, logistic ▪ Soft skills: creativity, design, innovation, leadership, work team The list was adapted from: Subic and Gallagher (2017) based on Prime Minister's Industry 4.0 Taskforce and Skills for Australia
[50]	▪ Workforce readiness, e.g., self-presentation, time management ▪ Soft skills: communication, critical thinking, creative thinking, collaboration, adaptability, initiative, leadership, social-emotional learning, teamwork, self-confidence, empathy, growth mindset, cultural awareness ▪ Technical skills: computer programming, coding, project management, financial management, mechanical functions, scientific tasks, technology-based skills, and others ▪ Entrepreneurship: initiative, innovation, creativity, industriousness, resourcefulness, resilience, ingenuity, curiosity, optimism, risk-taking, courage, business acumen, business execution
[51]	Employees: ▪ Technical skills ▪ Ability to solve problems ▪ Ability to use IT systems ▪ Analytic capacity ▪ Communication ▪ Lifelong learning ▪ Technical and management skills ▪ Ability to work in the team ▪ Openness to changes ▪ Openness to digitalization ▪ Openness to automatization Managerial staff: ▪ Lifelong learning ▪ Social media skills ▪ Connection technical and management skills ▪ Ability to work in a team ▪ Openness to changes ▪ Openness to digitalization ▪ Striving for continuous improvement ▪ Involvement ▪ Openness to automatization ▪ Creativity ▪ Creative thinking ▪ Self-discipline ▪ Self-management

Table 1. *Cont.*

Reference	Skills/Competencies/Capabilities (Citation According to the Source)
[52]	Students (Machine tools, Robotics, Logistics) ▪ Creativity ▪ Independence ▪ Refinement ▪ Self-discipline ▪ Intellectual curiosity ▪ Spirit of perfection ▪ Perseverance ▪ Empathy ▪ Power on ago ▪ Respect ▪ Personal affirmation ▪ Interpersonal skills
[53]	More focus: ▪ Knowledge about ICT (basic information technology knowledge, ability to use and interact with computers and smart machines like robots, tablets, etc., understanding machine to machine communication, IT security, and data protection) ▪ Ability to work with data (ability to process and analyze data and information obtained from machines, understanding visual data output and making decisions, basic statistical knowledge)
	Less focus: ▪ Technical know-how (inter-disciplinary and generic knowledge about technology, specialised knowledge about manufacturing activities and processes in place, technical know-how of machines to carry out maintenance-related activities) ▪ Personal skills: (adaptability and ability to change, decision-making, working in a team, communication skills, mindset change for lifelong learning)
[54]	▪ Cognitive analytics: cognitive flexibility, creativity, logical reasoning, problem sensitivity, mathematical reasoning, visualization ▪ Physical abilities: physical strength, manual dexterity, manual precision ▪ Basic skills including: connect skills, active learning, oral expression, reading comprehension, written expression, ICT literacy and process skills: active listening, critical thinking, monitoring self and other ▪ Cross-functional skills including: system skills (judgement and decision-making, systems analysis), complex problem-solving skills, technical skills (equipment maintenance, repair, operation and control, programming, quality control, troubleshooting, technology and user experience design), resources management skills (managing financial resources and material resources, people management, time management) and social skills (coordinating with others, emotional intelligence, negotiation, persuasion, service orientation, training and teaching others)

In a scientific study by Ann et al. [56], a team of researchers proposed a skill profile for the Industry 4.0 worker based on IT and mechatronics knowledge and a pledge of skills useful in handling new technology in programming, use of IoT, use of data, understating of process and the function of new technologies. The authors also stressed that employees of Industry 4.0 should have a positive attitude towards working in the smart manufacturing environments created by companies, i.e., "have an optimistic spirit". Employers recruiting employees expect, apart from basic technical knowledge and digital skills, as well as experience in operating given installations and IT systems (for at least 2 years) and expertise in advanced knowledge, in particular, in the field of building smart manufacturing in enterprises (Table 1).

Darwish and van Dyk [57] are the authors of the industrial engineering model (original components of the model prepared by Darwish and van Dyk (2016) were presented in Table 1). On the basis of this model, for the purpose of this publication, key segments of the competency profile of a 4.0 employee were distinguished. The segment of basic technical knowledge of employees in the area of cooperation with Industry 4.0 technologies was extended by management knowledge according to operational processes and technological installations at the particular levels of management in an organization. For an employee to participate in knowledge management, he or she should have conceptual skills, thinking, and perception connected with levels of digital business. Another segment of the competency profile is formed by human wellbeing and awareness according to the level of industrial development.

In the created environment of smart production, the employee must constantly adapt to new situations in the organisation and its smart environment. In addition to hard skills, the model of Darwish and van Dyk [57] also includes social skills and behaviors, and human attitudes to industrial engineering. According to the model, the authors of the paper proposed three segments of employee skills: (i) technical skills in terms of the ability to operate enabling technologies of Industry 4.0; (ii) social and conceptual skills (iii) human attitudes and behaviors suitable for going on technological changes.

The three skill fields were also proposed in reference [58]. According to reference [59], a skill profile is composed of: (i) digital skills in the fields of Industry 4.0 programming and software engineering, data science, data and big data analytics, visualization, Internet of Things, IT architecture, and cybersecurity; (ii) project coordination skills such as product management, multi-project management, supply chain, and support services, logistics, (iii) soft skills including creativity, design, innovation, leadership (the full list is presented in Table 1).

In Deloitte's study [60] four fields of the Industry 4.0 employee profile were presented, including: (i) workforce readiness, e.g., self-presentation, time management, (ii) soft skills including communication, critical thinking, creative thinking, collaboration, adaptability, initiative, leadership, social-emotional learning, teamwork, self-confidence, empathy, growth mindset, cultural awareness; (iii) technical skills, e.g., computer programming, coding, project management, financial management, mechanical functions, scientific tasks, technology-based skills, and other job-specific skills; (iv) entrepreneurship: initiative, innovation, creativity, industriousness, resourcefulness, resilience, ingenuity, curiosity, optimism, risk-taking, courage, business acumen, business execution (Table 1).

According to [61], the required skills for industrial employees in the Industry 4.0 environment are: the ability to solve problems, technical skills, analytic capacity, ability to use IT systems, lifelong learning, communication, ability to work in a team, worker openness to change, technical and management skills, openness to automatization, and openness to digitalization. Skills required for managerial staff in an Industry 4.0 environment are: social media skills, lifelong learning, ability to work in a team, the connection between technical and management skills, openness to change, openness to digitalization, involvement, striving for continuous improvement, creativity, creative thinking, self-discipline, self-management and openness to automation, (Table 1). There is more and more a demand for production engineers who combine managerial knowledge with technical knowledge both in the small and medium-sized enterprises.

Cotet et al. [62] realized the research of students' specializations: Machine-tools, Robotics, Logistics. Researchers have built a profile of the skills of future employees of Industry 4.0. According to Cotet et al. (2017), the characteristics of students are creativity, independence, sophistication, intellectual curiosity, self-discipline, spirit of excellence, perseverance, empathy, empowerment, respect, personal affirmation, interpersonal skills (Table 1).

In his white paper, Roland Berger [63] (2016, p. 35) states there is a division of qualifications and skills into "more focus" and "less focus". The segment of important qualifications and skills for Industry 4.0 was formed by the sub-segments of (i) ICT knowledge (the main knowledge about the usage of information technology, the possibility to interact and use computers and intelligent solutions such as: tablets, robots, etc., understanding the communication system—machine-to-machine, the usage of IT security solutions and careful data protection); (ii) data literacy (ability to analyse and process information and data obtained from technology, understanding of the implementation of visual output and decision-making systems, the usage of basic statistical knowledge). The "lesser" pole includes a sub-segment of technical knowledge, e.g., interdisciplinary and general knowledge of technology, specialised knowledge of production activities and processes, technical knowledge of machines to perform maintenance activities, and a sub-segment of personal skills, e.g., adaptability and capacity for change, decision-making, teamwork, communication skills, changing attitudes towards lifelong learning (Table 1).

The World Economic Forum, based on the O*NET Content Model "Future of Jobs Survey" [64], presented the following skills of Industry 4.0 workers: (i) cognitive analytics, (ii) physical skills, e.g., physical strength, manual dexterity, manual precision (iii) basic skills in two areas: "substantive skills" and "process skills", (iv) cross-functional skills. The list in the last segment is the longest and consists of systems skills, complex problem-solving skills, technical skills, resource management skills, and social skills (Table 1).

Reference [65] pointed out that workers need specific knowledge and a new skill paradigm because the number of jobs with high levels of complexity is increasing significantly. The demand for new skills stems from (1) the increasing need for complex information integration and transparency; (2) the increasing automation and digitalization of production systems, (3) self-management and decision-making by objects (plants and machines), (4) digital communication and the popularization of mobile devices (5) interactive management functions and integration of computer and information systems (ICS), (6) personnel flexibility and multi-site and multi-tasking.

Some of the most important skills that should be needed to implement the Industry 4.0 conception include: computational thinking, (the ability to use the vast amounts of data into useful concepts to understand data-based solutions), technical and digital skills are needed in organization to implement real and virtual collaboration (the ability to collaborate in effective way with new technologies); cognitive load management (the ability to use and filter information according to its importance and this can lead to maximised cognitive functions); adaptive thinking (demonstrating the implementation of thinking and finding new solutions, which leads to the ability to determine the deeper sense of technological functions); design mindset (the ability to develop tasks then focus on the work processes that lead to achieving the desired results); and social intelligence (the possibility to convey new innovative concepts to others people, deeply and directly, and thus stimulates reactions) [66].

In the ongoing revolutions, third and fourth, workers should think industrially, i.e., focus on understanding changes in manufacturing technologies and business processes [67]. Industrial thinking is based on an active work attitude, active machine, and technological cooperation, complex problem solving, coordination with others (teamwork), creativity, critical thinking, judgment and decision-making, project management, self-management, negotiation, and people management. In Industry 4.0, the selections of industrial thinking should be supported by technical skills related to digital, e.g., programming languages, common operating systems, software proficiency, technical writing, data analysis.

The presented list is not exhaustive. Researchers are constantly adding to the skills and qualifications profile of the Industry 4.0 workforce. Companies that transform to Industry 4.0 still need their employees to have specific new skills and knowledge. Comparing the list of employee skills and competencies (Table 1), it was found that authors [55–60,63,64] point to knowledge of Industry 4.0 technologies as a key competency area. Worker knowledge of applied industrial solutions builds their digital skills over time, which are related to operating cyber-physical production systems.

According to reference [61], the digitality of employees is defined by openness to novelty and the acquisition of skills to work with new technologies. Reference [62] analyzes the characteristics of students who, in time, will become employees of companies transposing to Industry 4.0. The characteristics that allow students to adapt to the new smart environment are exposed. In addition to the key skills segment, referred to as digital or technical, another segment is the social and teamwork segment. In references [55,58,59,61,63,64], communication and collaboration are discussed. In Industry 4.0, technology operators exchange knowledge about new solutions and thus become more familiar with the possibilities of new technologies. The third segment is personal skills, where creativity, critical thinking, inquisitiveness, etc. are important characteristics. The three segments of skills and competencies can be considered as the architecture of the Industry 4.0 employee profile. The development of employee skills focuses on digitalization. This digitalization should lead to the improved performance of industrial production systems, the efficiency of manufacturing and supporting processes, and the effectiveness of operative management [68,69]. Highly qualified staff should possess an openness to change, a strong ability to transfer knowledge and teamwork, and the ability to self-manage [70–73].

The responsibility for providing the right workforce for Industry 4.0 rests with education and policy. Nowadays, policymakers and educators can play a key role in organizations, especially in preventing the obsolescence of competence. They should be responsible for knowledge and skill development, and continuously updating all aspects required by the current and future labour market [74]. In the fourth industrial revolution, the demand for computer scientists and digital operations technologists is growing rapidly [65]. Companies need computer scientists, PLC programmers, robot programmers, software engineers, data analysts, cyber security electronics technicians, automation technicians, manufacturing technicians with digital skills, and production engineers to build smart manufacturing. Modern education courses should include subjects in: big data analytics, data science, advanced simulation, data communication, virtual plant modeling, novel human-machine interfaces, networks and system automation, real-time inventory, digital-to-physical transfer technologies (e.g., 3D printing), process quality control, and closed-loop integrated product logistics optimization systems and management systems [75,76]. Reference [61] showed that the greatest demand was for mechatronics and electromechanics (78%) and data analysts and cyber security experts (75%) in the segment of SME under study. Furthermore, there was high demand for logisticians, process engineers, information and communication technology engineers, and machine operators. Generally, employees with technical skills are needed. According to Saniuk et al. (2021) technical skills are the most desirable (91% of respondents). Otherwise, the ability to solve problems (82%), ability to use IT systems (76%), analytic capacity (74%) and communications (72%) are also expected. Moreover, Saniuk noted that respondents also highlighted the need for lifelong learning (71%) [61].

3.2. Frameworks for Skills and Capabilities of Operator 4.0

Another area of research was the competency requirements of Operator 4.0 (O4.0). Quoting from Romero et al., O4.0 as "a smart and skilled operator who performs not only cooperative work with robots but also "work aided" by machines if and as needed" [12,77]. Romero et al. in 2016 presented the first and in-depth analysis of the new concept of 'Operator 4.0', exploring a set of key enabling technologies that can support them. The researchers identified eight typologies of operators: (1) super-strength operator; (2) augmented operator; (3) virtual operator; (4) healthy operator; (5) smarter operator; (6) collaborative operator; (7) social operator; and (8) analytical operator [77]. In terms of the Compass Capabilities of Operator 4.0, four directions of capabilities are proposed: (i) cognitive capabilities, (ii) sensorial capabilities, (iii) physical capabilities, (iv) interaction capabilities [78]. Particular capabilities are assigned technologies with which O4.0 works. In terms of cognitive capabilities, these technologies are: cloud computing, simulation, virtual reality, and artificial intelligence. Technologies that can enhance the worker's sensorial capabilities are: personal activity trackers, health monitoring sensors, Internet of Things (IoT), posture sensors, and other sensors. When an operator uses their physical capabilities in the workplace, they can work with exoskeletons, collaborative robots, control devices, actuators and teleoperated systems. Interaction capabilities are needed in cooperative work with human-machine interfaces, augmented reality, mobile devices, and intelligent personal assistants.

In this publication, there is a proposition as to how to develop final projects in engineering science. Those projects can be used as a form of learning. They can contain the following main skills and scope of knowledge: supervision, advanced automation, robotics, and industrial network communications, including: sensors system integration, computer simulations and modelling of processes, actuators, programming, etc. Di Pasquale et al. [79], also based on the classification developed by Romero and team (2016) [67] analysed the influence of new technologies on operators' work. With the increasing interest of companies in implementing the enabling technologies of I4.0 in maintenance activities, O4.0 needs to continuously develop its skills. Tartora et al. [80] performed a complete literature review in the field of research: Maintenance in I4.0. The authors identified several research topics, and one of them (Topic 3) was: Measuring and Improving Maintenance Operator Performance. In this topic, the authors highlighted maintenance training by using VR in the development of machine operator skills. Industrial training with VR technology is a key form of machine operator skills in the digital factory. The usage of VR can be used for the creation of a useful environment through the use of appropriate computer technology. This usage can lead to the development of the condition in the case of an interactive 3D world. In this environment, objects have a sense of deep spatial presence [81]. The usage of the new training method leads to the situation in which the operator can interact with its prospective work object. This interaction can be done even without the direct presence of the training object. This usage can give the organization the chance to train workers at any desired place. Maintenance and industrial training by the broad usage of VR technology leads to the development of motor skills and cognitive skills for performing a task. In the same publication, Augmented Reality (AR) technology is used in the development of human maintenance operations through a mobile or wearable device to plan and perform maintenance tasks. The work by using enabling technologies is easier efficiently and in an easier way, increasing the productivity of the system. Through simple instructions, the work is easier to understand also for an unskilled operator [82]. This does not mean that in smart factories, unskilled operators will be employed but that enabling technologies of I4.0 will safeguard the process against human error. In modern factories, job rotation of operators is possible (within a given group of I4.0 technologies). Full knowledge of the control principles of the technologies of a given class is required for job-switching. Position crossing, which consists in moving employees on positions forming a production line or a production nest layout, is possible within a given group of I4.0 technologies. Crossing used to be, in a nutshell, "a quick tour of the organization" or, more modernly, "cross-training" [83]. Nowadays, I4.0 technology crossing is a component of knowledge management and skills development programmes for 4.0 operators. Technology crossing helps employees to better understand the I4.0 process technologies used in a given company. Crossing consists of the employee mastering to a satisfactory degree the performance of operations at all or selected positions of the production cycle, both preceding a given (actual) workstation and positions occurring after it [84]. The wide spectrum of support for the 4.0 operator from I4.0 technologies and information and communication systems builds its technological and IT multidisciplinarity [85].

Many technological solutions are applied in smart manufacturing, so I4.0 Operators can be teachers of machines equipped with AI algorithms, mentors of digital solutions, leaders of smart manufacturing projects, technology controllers, robot assistants, information systems programmers, machine learning programmers, managers for mobile robots, cyber-physical systems analysts, machine-to-machine liaisons, artificial intelligence operators, CAD operators, wireless computer network operators, computer application operators, etc. As I4.0 technology develops, operators will perform more and more new functions. Knowledge of enabling technologies of I4.0 and successively acquired knowledge of technological operations management will be useful in this assumption of functions. New technologies have made it possible for operators to access, store and process large amounts of data collected from different complementary sources, both internally and externally, to processes [86].

Industry 4.0 is building demand for many fourth-generation industrial technology operators. Rupper et al. (2018) [52] based on Romero et al. [77], performed a full analysis of the technological cooperation of Operator 4. 0 and identified the following types of operators: analytical operator (works in big data environment), augmented operator (works in AR), collaborative operator (responsible for connectivity, collaboration of technologies), healthy operator (measurement of physiological parameters), smarter operator (Chatbot and AI provide support to operators), social operator (is responsible for Facebook and Social Manufacturing (SocialM), super-strength operator (navigation, safety, etc.), virtual operator (works in HR field). Each of these types of operators must have competencies and skills appropriate to the technological field [87,88]. Gehrke [89] lists three levels for building human–intelligent technology collaborations. The first basic layer is formed by the human-operated technologies together with the organisation and working conditions, as well as forms of cooperation inside and outside the enterprise. The second layer is determined by the tasks to be performed by employees in collaboration with the technology. The third layer is the requirements set for employees to operate a given class (group) of devices in the form of a set of necessary skills and position qualifications.

Operators 4.0 should work in groups (teams) with autonomy to act and space to use talent, creativity, and initiatives in the context of technological innovation. The basic determinant of O4.0 work should be a strong focus on innovation and analytical and conceptual work. The authors of Reference [90] proposed the estimate of operator skills in such categories: basic knowledge, aircraft maintenance workload, other workloads, self-development, problem-solving skill, problem-solving attitude, responsibility, teamwork, work quality, reliability, and attendance rate. Innovation skills include creativity and initiative. Stimulating creativity through the use of creative techniques can help to achieve these competencies. Creative techniques can be a valuable tool to improve operator team performance.

In the smart environment being created, there are many teams of operators within each main category: machine operators, maintenance operators, production operators, process operators. Operators in the smart environment work in teams and communicate using mobile devices. Operators are equipped with mobile devices integrated with machine communication capabilities and computerised data analysis systems. Communication between employees and operational teams takes place remotely. The online form of communication, compared to face-to-face communication, complements and improves the collaboration of machine operators [91]. Many decisions rest on small teams of operators led by highly qualified engineers (operations team leaders). Control teams are located in control rooms or decision-making centres where many process operations are coordinated. Leading operator teams should be characterised by technological expertise with knowledge of such areas as additive manufacturing, 3D modelling, data analysis, computer programming and machine learning [92].

In the development of operators' competencies and skills in companies transforming to Industry 4.0, a holistic approach should be adopted, i.e., a systemic approach with a servant leadership style, inspirational, coaching [93,94]. The leader, e.g., of teams of operators of a given technology or the leader of a given smart manufacturing project, is an authority for the other team members. Strategic thinking, change management, teamwork, and networking are key characteristics of leaders [95–99]. Team leaders of smart manufacturing operators should be authentic, i.e., have advanced knowledge of working with new technologies of Industry 4.0 [100–102].

In operator relationships with Industry 4.0 technologies, trust is gradually built between team members, and the exchange of knowledge and experience gained from working with advanced technological installations and information systems grows [103–105]. Operators of new technologies must break down any barriers that may arise when using new technologies. The whole process of holistic learning in the cyber-physical systems being created is designed to comprehensively develop operators' skills at every level of operating new technologies and prepare operators to think independently, as well as to overcome possible adversities (problems) [106]. On the one hand, automation facilitates operators' work; on the other hand, it requires them to continuously learn how to co-operate with I4.0 technologies [107]. In Industry 4.0, human–machine integration is stronger than up to now [107]. Operators of I4.0 technologies are increasingly taking on independent managerial roles for smart production, operation of information and communication systems, data processing, and others [88,105]. On the operational level of production and technology, Industry 4.0 is blurring the distinction between technical and managerial positions through new technology functions, e.g., hazard prediction, selection of optimal operating parameters by the machine.

Operators are subjected to tests to assess their psychophysical characteristics before working with a given technology. The results of the tests provide an answer to the question of a person's ability to cooperate with increasingly intelligent machines and devices. Smart manufacturing technology operators are required to have perceptiveness and accuracy in action, analytical skills, the ability to assess the situation in relation to the problem, divisibility and concentration of attention, responsibility, good eye-hand coordination, having and developing technical interests, and above all, readiness to work in a smart work environment and smart space [106–109]. Operators have to move in the area of many knowledge fields—knowledge-related fields—such as computer science, automation, electrical engineering, electronics, mechanics, robotics, optics and photonics, sensorics and engineering, e.g., quality engineering, information technology engineering, precision engineering, and automation and robotics, as well as management and decision-making techniques [16,110]. This means that operators must continuously improve their skills [110,111]. The list of competencies and skills of O4.0 is open, although key components of the profile can be identified (Table 2).

Table 2. Key skills and competencies in the O4.0 portfolio.

knowledge	▪ Core technical knowledge, including knowledge about technologies I4.0 and understanding functions of new technologies ▪ Core engineering knowledge, including knowledge about production engineering, reengineering, and production processes ▪ Core knowledge about production management, including knowledge about lean manufacturing, knowledge about productivity, and methods of quality management ▪ Core IT knowledge: computer programs, programming, programming languages, software applications, common operating systems, software proficiency, technical writing, data analysis, computer design, computer visualization of processes, computer modeling and virtual simulation, etc.
	▪ Knowledge of creating innovative solutions and improvements to the organization's processes ▪ Other knowledge according to operating fields of organization and involvement of processes in an enterprise

Table 2. *Cont.*

	▪ Cyber skills: mastery of multimedia techniques, cooperation with intelligent environments, human-intellectual interaction in control and optimisation functions of processes ▪ Specific digital skills: project management (budget planning, risk management, project planning, PM tools, tasks management), product management (SCRUM methodology, agile methodology, product roadmaps, user experience design, programming skills, product lifecycle management, QA testing), software development (coding, debugging, implantation, testing, design, application, IOS/Android, language, security, algorithms, modeling, documentation), design (HTML, interactive media, adobe creative apps, wireframing, UX research, prototyping, user modeling, responsible design, etc.), marketing (marketing methods and tools, digital media, social media, automated marketing software, Internet analytics, marketing analytics tools, visual creation tools, product positioning tools, etc.
	▪ Decision-making—able to control the situation, able to analyze the situation and reason out possible solutions, able to follow instructions and production schedules, able to act quickly when a problem arises, able to choose the most efficient machine to work with, understand the limits and capabilities of the machine, coordinate several machines working together, able to analyse processes data, able to study the potential of operations management—OM continuously, able to adapt to a flexible, dynamic and decentralised transformation process, able to improve delivery if real-time data were collected and fed to the decision process.
skills	▪ Organization skills—able to organise jobs, able to realise multiple tasks, able to monitor and control the machine work, able to care for high productivity of the machine, able to focus on total productive maintenance TPM—the ability to identify and perform necessary maintenance, active learning—operator should always look out for new information needed for solving problems and making decisions, computer skills—understand and use computer-aided technologies like CAD, or other programs, able to lead the smart manufacturing projects, understand the smart environment, able to operate with industrial robots, cobots, etc.
	▪ Expert skills: funkcje opiniodawcze i doradcze w zakresie użytkowanych technologii, posiadanie i rozwijanie zainteresowań technicznych, ciągła edukacja w technologiach IT ▪ Attitudes: motivation to work in an intelligent environment, responsibility for decisions taken, concentration on tasks, attention to detail, communication in collaborative teamwork—able to communicate clearly, able to communicate efficiently, teamwork—able to coordinate teamwork, able to build trust to perform work efficiently without the need for constant supervision and guidance, critical thinking, problem-solving, able to identify the complex problem, able to find the solution and implement the change, attention to detail in the smart manufacturing field, communication with other machine operators or coordinators or supervisors of processes, good listener, honest to themselves and others—integrity skills. ▪ Thinking about customer's needs and competitors' supply—able to customer operations by e-invoice, EDI, CRM), cooperate with customer in personalised product process and servitisation (CAD, industrial communication by platform, IIoT, IIoS), networking, etc. ▪ Creative skills. Creative skills are indispensable to creating a new solution in the organization's business activities

3.3. Frameworks for Skills of Employee in Steel Industry on the Way to I4.0

In the fourth industrial revolution, modular and multi-profile competencies of steel industry employees are needed. The steel industry is transforming from level 3.0 to 4.0 by realising an increasing scope of digitalisation and implementing Industry 4.0 technologies [112–114]. The profile of a metallurgical technology operator should be specialised and, at the same time, flexible in order to be able to freely operate a given technological installation. According to the document of the European Commission [92], the shaped skills concept for a steel industry worker takes the shape of the letter "T". The arrangement of "T" competencies includes: technical skills (base of the letter "T", digital and soft skills (arms of the letter "T"). A metallurgical engineer must be familiar with new technical and technological solutions taking into account computerisation of processes, automation and robotisation of activities. The adopted concept of the letter "T" for the competencies of a steelworker refers to people with specialised skills in one specific area and general skills in other areas. The European Commission has engaged in a number of initiatives to bridge the gap between the needs of Industry 4.0 and the availability of a skilled workforce. The European Steel Skills Agenda (abbreviation: ESSA), which was launched in January 2019, proposes a competency profile for the Industry 4.0 worker. Part of the programme is a market study of the steel industry workforce. The participants of the research were from seven countries: Finland, France, Germany, Italy, the Netherlands, Poland, and Spain. On the basis of interviews with experts, scientists, steel mill workers, and social organisations, a new profile of the steel industry worker was developed. The research analysed current and future workforce skills needs. The research resulted in the pilot development of modules and tools to build awareness and implementation of new workforce skills for a globally competitive steel industry—more information about the project is at: https://www.estep.eu/essa/essa-project/ (accessed on 15 February 2022) [115].

The competencies of a metallurgist are built up by individual areas of specialisation within metallurgical skills, which can be grouped as follows: (i) a package of basic knowledge in metallurgy, physics, chemistry, mechanics and other scientific disciplines related to metallurgy; (ii) information and computer technology skills, computer programming, use of open data and data analysis (iii) understanding of statistical coefficients, statistical models, statistical prediction, (iv) collaboration with technologies I 4. 0, which are increasingly equipped with artificial intelligence (AI) algorithms, (v) cognitive skills, such as: critical thinking, creativity, logical reasoning, inquiry, knowledge compilation, problem recognition, problem solving and decision-making, (vi) social skills, such as: interpersonal communication, teamwork skills, leadership and employee management, effective teamwork, emotional intelligence, entrepreneurship and others, (vii) knowledge of cyber security procedures for in-service systems and digital industrial technologies.

Steel industry workers should be able to adapt to changing technological and process conditions in the ongoing fourth revolution. Employees of steel mills, apart from general knowledge of metallurgy, material science, physics, chemistry, and other related fields, are required to know the technologies supporting steel production, such as: mechatronics, metrology, computer science, electrical engineering, micro- and nanoelectronics, nanotechnology, industrial biotechnology, photonics. Basic knowledge shall include: steel melting techniques, steel melting temperatures, steel enrichment processes, deoxidation and desulphurisation processes, hydrogen and nitrogen removal processes, decarbonisation, etc. The knowledge package of a steelworker is referred to as STEM, i.e., Science, Technology, Engineering, and Mathematics [116].

A very important skill of a modern engineer in the conditions of Industry 4.0 is creativity. This trait is necessary for the engineer to create new and innovative solutions. Creativity is a creative attitude; innovative, a mental process involving the generation of new ideas, concepts or new associations, connections to existing ideas and concepts. Creative thinking is thinking that leads to original and innovative solutions. An alternative, more everyday definition of creativity states that it is simply the ability to create something new [109,117,118]. Creativity consists of many subskills such as making connections, making observations, asking questions, experimenting, and networking [119–122]. On the basis of the European ESSA document [115], a list of key competencies and skills of a steelworker was prepared, which is presented in the form of Table 3.

Table 3. Key skills and competencies of employees in the steel industry towards I4.0.

Specialised technical skills	▪ Scientific and operational skills are necessary for the performance of tasks requiring specific knowledge of metallurgical operations and processes (e.g., melting, welding, rolling, machining, agglomeration) and the materials used (e.g., iron ore, pig iron, steel, steel scrap, coke)
Basic procedural skills	▪ Understood as the knowledge of the steps that occur before and after a specific task in the production process, based on knowledge of manufacturing techniques and technologies, reinforced by specialised knowledge of metallurgy
Advanced technological skills	▪ Operating steelmaking and steelmaking technologies and auxiliary technologies such as electronics, computer science, robotics, optics, photonics, sensorics
Digital skills and basic knowledge of IT	▪ Proficiency in the use of mobile devices, knowledge of information systems and their compilation, mathematical and statistical knowledge of data analysis and presentation
Skills in using Big Data and Open Data	▪ Data monitoring, data understanding, data usability assessment, prediction; cloud computing
The ability to build a collaborative Intelligent Machine Environment (I2M)	▪ Tracking optimisation of production processes and efficient use of resources through increased connectivity between sensor networks used at different stages of steel production, knowledge of process control and conversation methods, ability to follow processes
Manual dexterity	▪ Ability to perform manual operations (speed and dexterity in handling equipment), handling of mobile devices
Leadership and decision-making skills	▪ Critical thinking, problem-solving, decision-making, leadership skills, co-operation with computers in autonomous decision-making systems
R&D skills	▪ Creativity, perceptiveness, ability to see opportunities for change, innovative courage, presentation or "influencing" or presenting and "selling" ideas, contextual awareness in identifying factors influencing the production process
Soft skills	▪ Communication (oral and written expression), interpersonal skills (ability to interact and cooperate in a team, build trust in a team, quick decision-making
Customer orientation	▪ Understanding of customer needs, ability to sell products
Technological awareness	▪ Openness to and cooperation with new technologies, acceptance of change, promotion of technological change

Table 3. *Cont.*

Understanding of business	▪ Knowledge of basic entrepreneurial principles, management economics, lean manufacturing
Environmental knowledge ("Green Economy")	▪ About environmental aspects of the steel industry and the principles of resource optimisation and reuse, as well as awareness of sustainability and health and safety
Lifelong learning (continuous improvement: CPD and lifelong learning: LLL)	▪ Assimilation of formal and informal knowledge, curiosity about the world, adaptability to different environments (flexibility of skills and work competencies)
Creativity	▪ Creativity is the ability of the person to think about a particular task or problem in a different and new way. It is also the ability to use a person's imagination to create new ideas or solutions. Creativity can enable the possibility to solve complex problems or find new and interesting ways to resolve the problem or conduct the task.

The list is not exhaustive and closed because the rapidly changing environment requires steelworkers to have dynamic competencies with characteristics that enable them to adapt to change. The term dynamic competency was used in 1997 by D.J. Teece et al. [123] and denotes an employee who is able to comfortably navigate through multiple tasks, respond to problems and implement change. The hallmarks of a dynamic competency are [124] the ability to understand the environment ('sense') and the ability to seize opportunities ('seize'). To meet the demands of rapidly evolving industrial technologies, metallurgical companies recruit engineers in many specialties, ranging from metallurgical engineers to high technology engineers. In addition to traditional metallurgical occupations such as metallurgist, welder, locksmith, electrician, mechanic, steel industry employers demand: programmers, IT specialists, designers, analysts, mechatronic engineers, laboratory technicians, machine operators, production operators, IC system operators, etc. At higher levels of specialisation, the most sought-after digital skills include 3D design, computer modelling, machine learning, computer simulation, data analytics [11,12,52,77]. Table 4 summarises the occupational skills of the steel industry workforce, divided into focused technical manufacturing competencies and digital competencies. The technological solutions used increasingly rely on synergies between the different competencies of individual workers and teams of operators and IT specialists [125].

Table 4. Examples of occupations in the steel industry.

Focused on Production Processes	Focused on Digital Service Processes
Metallurgical engineer, R&D specialist, manufacturing and product quality control engineer or technician, materials science engineer or technician, metallurgist, metallurgical engineer or technician, metallurgical plant electrical engineer or technician, maintenance engineer (UR) welder, structural steel technician, industrial laboratory technician, metallurgical equipment mechanic, process design engineer, manufacturing process engineer, furnace and steel plant operator, metallurgical production manager	IT application specialist, data management specialist, industrial data analyst, system application manager, automation engineer, industrial robotics engineer, industrial robot operator, IT programmer, manufacturing support information systems operator, industrial cyber security specialist

Source: Own work.

Workers' knowledge of cyber-physical production systems can be named "digital knowledge", and we can also think about competencies in this area as a conception of "digital competencies" [69]. The analysis of this knowledge can include the following areas: assembly, production, logistics, quality management, as also auxiliary areas, which can include, for example: production planning, production preparation, and production maintenance. Therefore, we can observe a growing demand in the industry for engineers who have the ability to combine information technology with automation robotics in new technology conception like mechatronics. It can be observed that engineers are preferred in organizations implementing Industry 4.0 due to the high importance of production and the high importance of securing its development technically. According to this, an engineer 4.0 (Industry 4.0 engineer) can be named as someone who moves without a problem at the interface between two conceptions: cyber and physical. Furthermore, engineers 4.0 should combine the knowledge of a specific manufacturing process in the industry, such as tuning a machine and working with robots. In addition, it is useful to have high IT skills ranging from the basic level (e.g., using operating interfaces and spreadsheets) to the advanced level (e.g., advanced analysis and programming skills) [85,87,109].

In particular, it is highly beneficial for organisations to combine digital knowledge with employee creativity. Creativity is going beyond what is known, common, and obvious; breaking down or reorganizing one's thoughts on a topic, undertaken to gain new and deeper insights into its nature; "escaping from stagnant thinking"; a way of thinking that involves finding particular relationships between elements and combining them in unprecedented ways resulting in breaking down a learned pattern of thinking and using the knowledge held to generate new ideas. An employee who is creative can create new solutions in terms of the processes they are involved in or the IT solutions they use [126,127]. He/she will be able to improve production processes in an innovative way, e.g., in terms of using new technologies, digitalization of processes, robotics, etc.

4. Case Studies—The Metallurgical Profession in Company Requirements and Educational Programmes

4.1. Analysis of Steel Company Recruitment Offers

Recruitment offers from a steel company operating in the Polish steel market were used as a case study. Job offers were posted on the recruitment Internet website under the tab, Industry 4.0 Engineer. The analysis of recruitment offers was carried out on the basis of publicly available job search offers posted on a popular website in Poland. A search was applied according to the following criteria: industry: steel industry, area: metallurgical enterprises, type of work: engineer or metallurgist or IT specialist. Applying these criteria, the following offers were found: IT specialist in metallurgy and metallurgical engineer. The offers came from the same steel company, a key producer of steel products in the Polish steel market (its production potential is estimated at 70% of the Polish steel market). The steel company used as a case study implements Industry 4.0 projects, including: centres of digital excellence, data collection, drones, automation, Artificial Intelligence (AI), digital twinning, and virtual reality (VR). The first stage of recruitment was to recruit employees for teams involved in designing and implementing innovative solutions in the metallurgical environment. The second stage was to recruit employees for teams operating new technologies of Industry 4.0.

For design and implementation teams, we recruited employees with experience in the area of design and who were highly creative. The new employees participate in the development of smart manufacturing projects by initiating new organisational ideas and technological solutions, as well as by constant research, initiating changes and providing relevant data for designing and optimising processes for the created smart environment. From among the newly recruited employees, leaders were selected for pilot projects conducted by the company in its preparation for operation in Industry 4.0. Project team leaders work with other teams to maintain design standards and business rules to support the overall data strategy. The company also recruited product engineers who are responsible for product innovation and building VR spaces for products. Newly recruited employees should motivate other employees to participate in the smart steelmaking systems at the steelworks with their active basis towards change. In addition to members of the design and implementation teams, the company was recruiting operators of production control IT systems, and IT specialists for many fields of the built smart environment. Based on the recruitment offers, key requirements and skills for the candidates were prepared (Table 5).

Table 5. Portfolio of professional qualifications of employees in a steel company.

Technical knowledge	▪ Understanding of usage of the Industry 4.0 concept in organizations ▪ Knowledge of IoT solutions implementation and the specifics of the usage of this conception in the steel industry ▪ Experience in developing the concepts of Augmented Reality and / or Virtual Reality ▪ Experience in developing the technology of image processing, 3D scanning applications and computer vision algorithms ▪ Strong knowledge about usage of mobile application and its development ▪ The usage of object-oriented programming and also software engineering in steel production organization, the solid knowledge of data structures and the usage of Big data analysis, ▪ Experience in the usage of 2D/3D motion tracking systems ▪ Knowledge of machine learning, artificial intelligence, and the usage of neural networks in organizations, ▪ Interest in data analytics and the usage of Big Data
Skills	▪ Assertiveness, visionary thinking, problem-solving ▪ Ability to transform organizational needs into new projects that can confirm the implementation of concept of Industry 4.0 ▪ Ability to implement and initiate industrial innovations, the usage of technical and non-technical innovations in organization ▪ Strong communication skills of the people especially including the ability to persuade in technical problems to workers ▪ Ability to adapt and learn about new technologies and knowledge about programming ▪ Workers' passion for learning new things about production systems and advanced technology
Education	▪ Engineer/master's degree in computer science or field related to it, for example manufacturing engineering ▪ Engineer/master's degree from a technical university especially with majors in fields like: Industrial Informatics, Production Engineering ▪ In the field of Industry 4.0, we should concentrate on training specialist in postgraduate studies
Foreign language	▪ Fluency in English
Attitudes	▪ Caution ▪ Self-work organization ▪ Curiosity ▪ Insight ▪ Commitment ▪ Responsibly ▪ Creativity

4.2. Metallurgy 4.0 in Educational Programmes of Technical Universities

Education at the faculty of metallurgy is implemented at a few universities in Poland (only four universities). According to the historical state, it was conducted at four technical universities (previous four academic years, studies of a student's last six or seven semesters). On the governmental website in the tab, Education—Higher Education, the name of the field of study was entered into the search engine: metallurgy. A preview of all four metallurgical faculties conducted by universities in Poland was obtained. Each of these majors had an attached study programme. On the basis of the programmmes, Table 6 was prepared.

Table 6. Profile of a metallurgy graduate case study based on educational programmes in Poland.

Category: exact sciences	
Mathematics	Mathematical description of phenomena, formulation of mathematical models and their solution
Physics	Measurement of basic physical quantities, analysis of physical phenomena, solving technical problems based on the laws of physics
Chemistry	Understanding of chemical transformations and their significance in industrial processes, in particular metallurgical processes
Mathematical Statistics	Understanding and application of statistical methods for data handling and econometric modelling
Category: technical sciences	
Raw material preparation and extraction metallurgy	Understanding of metallurgical processes, knowledge of preparation of raw materials for steelmaking
Ferrous and non-ferrous metallurgy	Selection of metal alloys for technical applications, design of processes for shaping the properties of metals and their alloys
Processing of metals and alloys	Design of metallurgical technologies and their application to the manufacture of engineering materials
Materials science and engineering materials	Selection of materials for technical applications in order to shape their structure and properties
Crystallography	Ability to describe metallic structures
Shaping, testing the structure and properties of materials	Designing technological processes, shaping the structure and properties of materials and products, studying the influence of technological processes on the structure and properties of materials and products
Metal casting	Understanding of casting processes, knowledge of casting methods and techniques
Plastics for foundry moulds	Selection of plastics for casting moulds
Thermal techniques	Application of the principles of thermodynamics to describe physical phenomena and mathematical modelling of thermal processes, knowledge of the principles of thermal technology, design and operation of energy devices
Materials testing methods	Application of analytical methods in materials testing—mainly in metallurgy; use of testing apparatus; assessment of the structure and properties of metals and metal alloys
Theory of elasticity and plasticity	Modelling of technological processes
Technical mechanics	Application of computer techniques in technical mechanics; solving technical problems based on the laws of classical mechanics; modelling of mechanical phenomena and systems

Table 6. *Cont.*

Category: information technology sciences	
Basic informatics	Fundamentals of programming, internet applications, operating systems, advanced information technologies, theory of algorithms, data structure
Industrial informatics	Use computer-aided technology to solve technical tasks
Engineering graphics and design	Design and execution of strength calculations; graphic representation of machine elements and mechanical systems using computer aided design of machinery
Computer science and programming techniques	Application of the basics of industrial computing, use of computer programs, programming: programming techniques, knowledge of programming languages
Electrotechnology and electronics	Knowledge about electrics and electronics in manufacturing
Basics of industrial automation and robotics	Use of automation and automatic control systems in engineering knowledge of advanced technologies in mechanical engineering, ability to design technological of lines
Engineering design	Fundamentals of engineering design, project management (PM), design in CAD systems, introduction to rapid prototyping, "C" programming
Modelling and computer-aided engineering	Basics of design and modelling of metallurgical technological processes
Computer network, computer technical support	Use of computer networks and network applications; use of computer-aided metallurgy
Automatics and robotics	Fundamentals of automation and robotics, machine learning, advanced technologies in mechanical engineering, process line design
Category: engineering sciences	
Manufacturing technology and production engineering	Knowledge about: production systems, manufacturing processes, metallurgical manufacturing technologies, organisation (design) of technological lines, technology and process control, information systems: CAM, optimisation, task scheduling, etc.
Additive manufacturing	Understanding of the importance of additive manufacturing in metallurgy, operation of 3D printers based on metal powders, 3D printing of metal products
Manufacturing management/production management systems	Knowledge about: process control, quality control (quality management methods and techniques, quality standards, TQM, statistical quality control), organization of production systems, computer systems (ERP, CRM, etc.)
Work organisation and economics	Consideration of principles of work organisation, fundamentals of ergonomics and occupational health and safety in various forms of activity (including: ergonomics in metallurgy, working conditions in metallurgy, occupational risk assessment in metallurgy, safety standards in metallurgy)
Simulation methods used to solve engineering problems and tasks	Use of computer simulation for solving engineering problems, computer simulation of manufacturing processes

Table 6. *Cont.*

Metal recycling and treatment of process waste	Understanding of the principles of metallurgical waste management (recycling, treatment, utilization), knowledge of metallurgical waste, metallurgical environmental aspects, classification of metallurgical waste, product life cycle analysis: ALC, understanding of the importance of sustainable production for ecology and environment protection
Management/entrepreneurship	Understanding entrepreneurship, measuring and evaluating productivity (KPIs), management methods, lean manufacturing
Protection of intellectual property	Copyright law, patent law, data protection, basics of cyber security
Category: social sciences and ethics	
Business ethics and social responsibility (SR)	Ethical business principles, SR areas, humanisation of work, employee involvement
Communication and work team	Forms of communication in organization, techniques, communication in group, work in teams
Category: foreign languages (foreign language in business)	

On the basis of the review of the curricula, it was established that in the basic curriculum, students learn: mathematics, including mathematical statistics, physics, including the physics of metals and chemistry in the scope of chemical transformations and their significance in industrial–metallurgical processes, material science, including engineering materials. The directional contents include, among others, subjects such as: metallurgy and metal processing together with mechanization and automation of metallurgical processes, thermal thermodynamics and thermal technology, including design and operation of power equipment, methodology of materials research in metallurgy, operation of industrial research apparatus, evaluation of the structure and properties of metals and metal alloys, technical mechanics with strength of materials, with an emphasis on the use of computer techniques in technical mechanics and solving technical problems based on the laws of classical mechanics, modelling of mechanical phenomena and systems, engineering graphics and design, including computer-aided design (CAD) and machine design, electrical engineering and electronics in metallurgy, automation and robotics—applications of automation and robotics in metallurgy, work organization and management, including TQM quality management, ergonomics, ecology—metallurgical waste recycling LCA analysis computer science and computer-aided engineering.

After completing the basic degree, students extend their knowledge at further educational levels within the metallurgical specialisation. Students develop their knowledge in such areas as: shaping, structure and properties of materials, metallurgical processes, including design of metallurgical technological processes, metallography of ferrous and non-ferrous alloys including computer aided materials design (CAMD), design of processes of shaping properties of metals and their alloys, elasticity and plasticity tests, modelling of technological processes, computer aided engineering, computer networks including AI. Graduates are skilled in using the knowledge of: extractive metallurgy, processing of metals and alloys, material science, recycling of metals, utilisation of technological waste, thermal technology, computer science, basics of automatics and ecology and ergonomics (Table 6). A modern metallurgist has metallurgical and IT knowledge. He or she must be able to deal with computer modelling, materials testing, machine programming. A metallurgy graduate also has knowledge of incremental manufacturing, i.e., 3D printing from metal.

Graduates of metallurgy in Poland can specialise in a selected field of metallurgy, e.g., engineering materials, metallurgical engineering, plastics for casting forms, crystallography, environmental protection in metallurgical industry, conducting research on metal content in various ores, conducting research on physical properties of various alloys, designing processes in metallurgical industry, metal quality, selection of metals with specific properties for given applications. After completing their studies with a specialization in metallurgy, they can work in the following departments: technological (as technologists, calculators, instrumentation constructors), production planning, design and repair, industrial laboratories, design offices. Graduates of metallurgy can work in small, medium and large metallurgical and metal alloying enterprises and related industries, including design and consulting units and other economic and administrative units where technical knowledge is required. In Industry 4.0, studies complementary to metallurgy are IT studies, including industrial informatics. Graduates of the metallurgy program can complement their technical knowledge with the knowledge of information technology by taking advantage of the offer of education programmes in the fields of information technology or industrial informatics.

5. Discussion

The implementation of Industry 4.0 in metallurgical enterprises has as one of its objectives the improvement of innovativeness of enterprises in this industry. For this reason, the curricula of metallurgical engineers' education should take into account issues concerning innovation as well as those related to innovation [128–134]. Innovation issues should be one of the important elements of the education programme as well as their elements should be included in the programme of other engineering and social subjects.

In order for an engineer to be able to create new and innovative solutions, he or she must have a high level of creativity [135–138]. This creativity is based on industrial knowledge. Knowledge about manufacturing processes in particular companies are a key component of an employee's portfolio [139,140]. The componential theory of creativity developed by T.M. Amabile [141] assumes that creativity can take different forms—from everyday creative activities to important scientific inventions shaping the development of entire civilizations, while the level of creativity displayed by individuals, even within the same tasks can change because it is the result of the influence of different time-varying components, concerning both the person and their environment.

The first component of creativity includes: domain-specific skills; expert knowledge; technical skills; and intelligence and talent corresponding to the domain. The second component consists of factors relating to the creative process, including cognitive and personality processes that lead to new results; cognitive style; risk-taking; taking a new perspective on a problem; and the ability to generate new ideas and tolerate diverse, contradictory solutions. The third component of creativity is intrinsic motivation to undertake tasks resulting from interests, perceived level of pleasure, sense of challenge and passion. The last (fourth) component of creativity is created by the environment, primarily the social environment, and especially external motivators.

It is worth paying attention to all components of the creativity process by analysing the case studies presented in this publication. In particular, the first three factors are important from the point of view of educating Engineers 4.0 for the metallurgical industry, i.e., possession by a given person of appropriate technical skills, appropriate personality traits and proper motivation to create new, innovative solutions. The fourth component is also important, but it can be created directly in the company itself and not in the process of education.

Table 5 presents the profile of professional qualifications of a 4.0 employee for steel companies operating in Poland. Starting from the presented concept of 4 creativity components, the analysis of the table allows us to state that particular attention is paid to Component 1—technical knowledge. There are also elements of component 2, as the attention is drawn to the fact that an employee should be characterised by visionary thinking, assertiveness, ability to solve problems—these are undoubtedly elements of being creative and very important features from the point of view of innovativeness of a given employee. Component 3 of creativity is represented by issues concerning passion for learning new things and advanced technology. An employee who easily adapts to new technologies and is able to use them becomes a creative engineer who is able to use such technological tools in new and innovative ways. Among the features of the professional profile listed in the table, direct attention is also paid to the issue of innovation, in particular in terms of the ability to initiate and implement industrial innovations, both technical and non-technical, e.g., organisational innovations. The presented requirements are undoubtedly high, as they require from the future Engineer 4.0 very solid technical knowledge, including knowledge in the field of new IT solutions, and social skills such as creativity and communication skills. On the basis of the conducted analysis, it may be stated that in the recruitment offers of Polish companies operating in the metallurgical sector under the conditions of Industry 4.0, the issues concerning creativity and innovativeness of future employees are very strongly emphasised directly or indirectly. This phenomenon may be assessed positively, as it gives a chance to recruit good employees who will be able to bring value to the enterprise. The presented analyses provide an answer to the first research question P1.

The importance of the issue of innovation in the processes of implementing Industry 4.0 is also emphasised in the studies of other scholars such as Lekan [142] or Hizam-Hanafiah [143]. The particular importance of creating open innovation in the conditions of Industry 4.0 is emphasised by Osorno-Hinojosa [144]. In order for employees in industry to be able to create this kind of innovation, they need to be characterised by appropriate creative skills [145,146]. An analysis of the competencies taught at universities suggests that programmes focus mainly on technical and engineering competencies. Thus, it can be concluded that only the first of the four components of creativity is present in the analysed graduate profiles. This should be considered far from conclusive, but on a knowledge basis, graduates in metallurgy can develop creativity in a specific working environment. Creativity is also learned during internships and apprenticeships, which are added to education programmes in Poland. Industry 4.0 needs engineers who will be able to cope well in the conditions of advanced technologies, in particular, their competencies concerning creativity and ability to create innovative solutions are important.

The presented analyses allow answering research question P2. It seems that on the basis of the conducted analysis of study curricula, it is possible to recommend the introduction of two subjects to the curricula of technical studies educating engineers in the conditions of Industry 4.0: creativity (or design thinking) and innovation management. The first of these subjects will allow the student to understand the principles of creative thinking, creation of creative projects in technical problems and practical application of such solutions. The second subject will allow the student to understand the importance of innovations, methods of their creation and tools that can be used in practice to create new, innovative solutions, such as the TRIZ method, etc. Analysing the curricula of metal studies in Poland in more detail, one can find the basis for building creativity in each of the areas of knowledge, as students participate not only in lectures, but also perform many practical, laboratory and project exercises. Moreover, in the area of engineering sciences there are subjects in the field of organisational management, including entrepreneurship, which in itself teaches creativity. This is particularly important because nowadays, more and more companies operating in Industry 4.0 conditions are based on a new paradigm of innovation creation—open innovation [147–150]. In this case, the role of creativity is even greater than in classical innovation. For this reason, failure to equip young engineers with this kind of skills may hinder their functioning on the contemporary labour market under Industry 4.0 conditions.

In particular, the importance of creativity in the process of education under Industry 4.0 conditions and the impact of this kind of education on the innovativeness of employees is emphasised by Rozmirez-Montoya [36]. According to Eliot et. al. [146], the emphasis in education should be on the external frame of reference in terms of building professional identity. Authors realized the importance of research in terms of the student portfolio—they researched the internal and external framework of the portfolio (engineering undergraduate students). Based on the research, the authors concluded that components of the internal frame of reference are more important than the external. The internal frame of reference, which accounted for twice as many responses as the external frame coding, focused on students' emerging realizations of their own values and interests as professional engineers. Industry 4.0 needs students to have opportunities to engage the internal frame of reference with which our participants were particularly concerned. Such analyses confirm the presented recommendations for modifying engineering curricula.

In the case of innovations, the important part for current business practices is called the open innovation concept [147]. According to this concept, if an organization does not manage the concept of inheritance, it can use external sources of innovation, but can manage substitute services with other entities [148–151]. Because many organization from the steel industry use the external sources when they are working on new, innovative solutions, it is important for potential workers, managers and students to have knowledge about the open innovation concept and its implementation in the organization [152–155]. It is not possible to find direct information about open innovation in the analyzed job proposal or university curricula, but there are some indirect mentions about it. In our proposed two subjects, especially in terms of innovation, knowledge about open innovation should have an important role in the syllabus. It gives technical university students the very useful knowledge from a business point of view and can provide them a comparative advantage in the recruitment process in industry organizations [156–164].

6. Conclusions

This paper provides an analysis about the smart production workers in terms of creativity and innovation. According to the analysis, we can observe that the expectation of Polish metallurgical organizations is to account for innovativeness and creativity as an important part of managers and workers skills in Industry 4.0. Organizations see that the innovativeness and the knowledge as to how to create and manage innovative solutions within an organization are important skills needed by workers. Of course, this kind of knowledge should be linked with technical and communication sources but is a very important part of today's Industry 4.0 operator portfolio. The Polish steel industry's recruitment offers refer directly or indirectly about the issues connected with innovativeness and creativity.

The situation is slightly worse in the case of university programs, as technical university programs mainly concentrated on technical and engineering competencies, not soft skills connected with creativity. Some analyzed university programs have connected issues of innovativeness and creativity, but rather nondirectly.

On the basis of the conducted analysis, we have recommended the introduction of two subjects to the curricula of technical studies based on our research and the experience with Industry 4.0 implementation in various industries. Those subjects are creative thinking and innovativeness. In the discussion, we presented a more detailed conception of these subjects and to achieve them, it is important to engage with the university staff to consider changes in the students' curriculum [165–167].

Our paper has some limitations connected with the data and its analysis. Firstly, in the case of smart worker recruitment, we conducted our analysis on some case studies of recruitment offers from Polish steel companies. Our sample of case studies was limited, and it is possible to conduct a more detailed analysis on a statistically significant sample of recruitment offers from an organization.

The study about university programmers was conducted from a group of metallurgy graduates. It would be useful to compare the results with other industry-related programs in Polish universities—especially in the case of industrial management and mechanical engineering, which are strictly connected with Industry 4.0 industry organizations.

The authors are aware of the limitations of the prepared work, which are narrow in scope and area of research. The research was conducted for one country—Poland—and the research focused on one profession—metallurgist. In the future, it is possible to conduct the analysis on the basis of other industries, not only the steel industry. For example, in Poland, there is an advanced automotive industry using many Industry 4.0-connected solutions and tools. It would be worthwhile to conduct a similar analysis on this industry. In the case of university curricula, it would be interesting to conduct the research on other European Union countries to compare the realization of university curricula in technical universities in the case of creativity and innovativeness in various countries.

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Institutional Review Board Statement: According to our University Ethical Statement, the following shall be regarded as research requiring a favourable opinion from the Ethics Commission in the case of human research (based on document in Polish: https://prawo.polsl.pl/Lists/Monitor/Attachments/7291/M.2021.501.Z.107.pdf (accessed on 15 February 2022)): research in which persons with limited capacity to give informed or research on persons whose capacity to give informed or free consent to participate in research and who have a limited ability to refuse research before or during their implementation, in particular: children and adolescents under 12 years of age, persons with intellectual disabilities persons whose consent to participate in the research may not be fully voluntary prisoners, soldiers, police officers, employees of companies (when the survey is conducted at their workplace), persons who agree to participate in the research on the basis of false information about the purpose and course of the research (masking instructions, i.e., deception) or do not know at all that they are subjects (in so-called natural experiments); research in which persons particularly susceptible to psychological trauma and mental health disorders are to participate mental health, in particular: mentally ill persons, victims of disasters, war trauma, etc., patients receiving treatment for psychotic disorders, family members of terminally or chronically ill patients; research involving active interference with human behaviour aimed at changing it; research involving active intervention in human behaviour aimed at changing that behaviour without direct intervention in the functioning of the brain, e.g., cognitive training, psychotherapy psychocorrection, etc. (this also applies when the intended intervention is to benefit the subject, e.g., to improve his/her memory); research concerning controversial issues (e.g., abortion, in vitro fertilization, death penalty) or requiring particular delicacy and caution (e.g., concerning religious beliefs or attitudes towards minority groups); research that is prolonged, tiring, physically or mentally exhausting. Our research was not done on people meeting the mentioned conditions. Any of the researched people: did not have a limited capacity to be informed, were not susceptible to psychological trauma and mental health disorders, the controversial issues above were not mentioned, and the research was not prolonged, tiring, physically or mentally exhausting.

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