

Article

Challenges and Perspectives in Innovative Projects Focused on Sustainable Industry 4.0—A Case Study on Polish Project Teams

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Abstract: Contemporary project teams are increasingly used to solve problems that are at the crossroads of many disciplines and areas dedicated to Industry 4.0, which is a watershed in the implementation of Sustainable Development Goals (SDGs). Industry 4.0 can serve as a platform for the alignment of SDGs with the ongoing digital transformation. This involves specific challenges for teams, but also allows perspectives that may create innovative and high-quality results. In order to meet these challenges while taking advantage of the opportunities offered by interdisciplinary cooperation, project teams, including the team leader, should have specific competencies. With this in mind, the aim of this article is to identify the challenges and perspectives related to working in interdisciplinary Sustainable Industry 4.0 project teams and to define the competencies necessary to act as a member and leader of these teams. Implementation of this aim will be possible by answering two research questions: (1) What requirements and opportunities are involved with interdisciplinary work amongst members of Sustainable Industry 4.0 project teams; and (2) What are the competencies necessary of members and leaders of such teams to meet these requirements and take advantage of the opportunities for such cooperation? An exploratory case study was conducted among members of interdisciplinary project teams at one of the leading technical universities in Poland. Qualitative data were obtained from many sources: interviews, internal documentation of analyzed projects and managerial notes. The obtained results allow us to state that the most important challenges and perspectives related to the work of interdisciplinary Sustainable Industry 4.0 teams include coordination of individual parts of the project, integrative leadership, establishing a common language, broad views on the issues raised and building a team consisting of specialists with the required competencies. The competencies of the project team that are important for working in the analyzed environment include strategic perspective, communication skills and persuasion, while for leaders, competencies must include the ability to coordinate work, resource management, empowering and motivation.

Keywords: Sustainable Industry 4.0; innovative projects; interdisciplinarity; project team competencies; leadership



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1. Introduction

Over the past centuries, as a result of industrial revolutions, society has experienced significant changes and technological progress [1]. Industry 1.0 was characterized by introducing machines to industrial processes [2]. Industry 2.0 was related to the concept of multi-scale production, reduction of costs and lead time, and the introduction of technical and organizational innovations [3]. The next age, Industry 3.0, was associated with the development of technological information systems [4]. Currently, the fourth stage of industrialization (Industry 4.0) affects the creation of industrial value in the most-developed countries. Industry 4.0 is treated as the beginning of a new era in which industry is becoming more and more “intelligent” thanks to the use of Internet of Things technology, predictive analysis and intensive data exchange [5,6]. Industry 4.0, as many researchers (e.g., ref. [7]) emphasize, also changes the way of performing and controlling tasks related to project

management as projects become more complex, innovative, and implemented at the cross-roads of many areas of the economy. Industry 4.0 is also a sociotechnical concept that can support the entire society and industry in achieving sustainable development [8–11]; hence, this stage of the revolution can be called Sustainable Industry 4.0. Considering the above, it becomes necessary to more deeply understand the challenges and perspectives that project team management brings with it in an environment that is strongly connected to Sustainable Industry 4.0 and to undertake an analysis of the required competencies of members and leaders of such project teams.

Sustainable Industry 4.0 is the new path of organization and control for systems with full added value, and its overriding goal is to satisfy the individual needs of customers with the costs of mass production. On this account, work in an economy based on Sustainable Industry 4.0 means behaviors and skills [12] required from employees, including project team members, must enable them to meet the challenges of Sustainable Industry 4.0. The need for a new approach to human resources management in the era of Industry 4.0 is emphasized by many researchers (e.g., ref. [13]), who point out that Sustainable Industry 4.0 may create a need for a management paradigm shift. Nevertheless, as researchers (e.g., ref. [14,15]) emphasize, analyses in the context of Sustainable Industry 4.0 mostly refer to the new technologies driving this revolution, and the literature on the human factor in the area of Industry 4.0 is still narrow and rare, which necessitates more research in this area.

Sustainable Industry 4.0 is an excellent opportunity to take a real step towards better performance and strategic value creation by organizations [16]. For this reason, more and more references related to Sustainable Industry 4.0 can be found in various citation databases today [17]. These considerations focus on the concept of Sustainable Industry 4.0 in the context of project management. Ref. [18] points out, the role of project management is crucial for the success of Sustainable Industry 4.0 and vice versa. Therefore, many researchers emphasize the need for further work in this area to provide a more in-depth analysis of the use of project management during the 4th Industrial Revolution. Ref. [19], on the basis of their analysis of the main research areas in project management and activities covered by the 4th Industrial Revolution, identified human resource management as one of the common themes for future analysis in this area. The relevance of this topic from the point of view of the discussed issues is also indicated by other researchers. For example, ref. [20,21] emphasize that Sustainable Industry 4.0 influences project management and makes it necessary to change the way projects are implemented and the interaction between team members. It also forces project teams to develop new competencies necessary for activities within the 4th Industrial Revolution. Similarly, ref. [22] points out that project managers and teams will require higher soft and hard skills than needed in the past, and more autonomy in handling Sustainable Industry 4.0 projects. Ref. [23] adds that Sustainable Industry 4.0 challenges the project managers in different ways.

Moreover, it should be noted that 4.0 projects are characterized by higher complexity and uncertainty, which requires a flexible approach to solved problems and interdisciplinary work. Ref. [7] draws attention to that, also pointing out that the two main theoretical attributes of project management—uncertainty and complexity—also play a significant role in Sustainable Industry 4.0 projects because they shape and define the necessary features to support the workload and are associated with increasing project complexity. Therefore, as [24] indicates, project teams in Sustainable Industry 4.0 must be self-organizing, interdisciplinary, real-time and autonomously optimized. This is also emphasized by the authors of [25], who state that project management in Sustainable Industry 4.0 is characterized by digitization, virtualization, transnationality, professionalization, the transition from Waterfall to Agile, focus on the project–organization relationship and organization maturity in project management. The complex problems that characterize Sustainable Industry 4.0 projects, as many authors emphasize (e.g., ref. [24]) and is also emphasized above, require interdisciplinary cooperation. However, based on analysis of the literature, it can be concluded that analyses related to interdisciplinary cooperation of teams operating in the 4.0 environment are rare.

The motivation for this article was to identify ways in which the changes accompanying the 4th Industrial Revolution affect the new requirements for workers from many industries and sectors, and the aim of this article is to develop a theoretical and empirical understanding of how the changes caused by the 4th Industrial Revolution affect the competencies of project teams. Although research and practice show that in order to achieve the sustainable implementation of technologies supporting Sustainable Industry 4.0, a new approach to human resource management will be necessary, including, in particular, the acquisition and improvement of appropriate competencies by employees, including members of project teams. However, streams of literature connecting management projects and human resource management have not been largely integrated into Sustainable Industry 4.0 literature. The absence should be seen as a problem, because research of various disciplines suggests (e.g., ref. [2]), that, in the face of future trends of the 4th Industrial Revolution, it is necessary to develop a new management paradigm, which will be largely based on the interdisciplinary cooperation of competent teams, and their lack is seen as the main threat to economic growth and should be a top priority in the agendas of enterprises and policy makers. Further, management literature indicates that the development of employee competencies is necessary in rapidly changing industries and sectors, as is the case in industries and sectors of Sustainable Industry 4.0, so that companies can adapt to changing conditions [26]. Taking into account the above, a case study of project team members at one of the leading technical universities in Poland between February 2019 and September 2020 was conducted in this article. The obtained results fill the research gap concerning the requirements of Sustainable Industry 4.0 for members of project teams, and are some of the first to indicate the necessary competencies in this area. What is more, the inclusion of interdisciplinary project teams in the analysis of the interdisciplinary context makes these considerations original, as they are overlooked or considered in a very narrow scope and can provide a basis for shaping and improving the selection process of interdisciplinary teams in the area of Sustainable Industry 4.0.

2. Literature Review

2.1. Sustainable Industry 4.0

Industry 4.0 is treated as the 4th Industrial Revolution [27]. It includes a number of new technologies influencing new digital value chain creation as well as the digitization and automation of the production environment. The 4th Industrial Revolution is based on development of intelligent systems that enable system monitoring and decision making in real time [28]. A new paradigm appears here, focused on modern enterprise management based on new technologies enabling integrated optimization of processes [7]. This paradigm results from the combination of production systems, which on the one hand are vertically connected to the company's business processes, and, on the other hand, horizontally connected to other points in the value chain in order to increase efficiency and response time to each request, with the customer being the main target [29–31]. It can therefore be concluded that the transition to Sustainable Industry 4.0 and the development of cyber-physical systems introduces technical, organizational and human changes in various organizational layers of enterprises [32,33].

Although the 3rd Industrial Revolution was marked by simple digitization, the 4th Industrial Revolution has an inexorable shift in this simple digitization, where the rush of innovation comes from many combinations of technology in new forms. The 4th Industrial Revolution can be distinguished from others for three reasons: (1) Speed—the interconnectivity of the world increases at an exponential rate, and the emergence of new technologies generates further innovation. (2) Breadth and Depth—taking the 3rd Industrial Revolution as a reference, the 4th Industrial Revolution integrates and expands various technologies. (3) Systemic Impact—entire systems are transformed within countries, companies, value creation networks or in society in general [24]. Therefore, despite the many advantages of Sustainable Industry 4.0, this new era of industry is also associated with a number of challenges for many organizations. Examples of such challenges are technology integration,

data security, organizational transformation [34], acquisition and implementation of appropriate information technologies, distribution of decisions, encouragement to experiment with new ideas in the workplace [35] and greater complexity of projects [36]. Consequently, these challenges are reflected in new requirements for employees, changing professional profiles of employees and employment structures. The change of professional profiles especially is characterized by a change in the required competencies of employees. Examples of such desirable competencies include abstract and analytical skills, openness to changes and knowledge in the field of data processing [37]). Much emphasis is also placed on active individual development.

In their research, ref. [38] divided professional profiles into two groups: 4.0 and non-4.0 profiles, and then assessed the differences between the skills of these profiles, dividing the skills into three groups: everyday execution, operational abilities and functional abilities. The operational skills consisted of hard and transversal skills. The everyday skills cluster included eight abilities (e.g., business acumen, project management, change management and problem solving). All of them were of a cross-sectional character, and many of them also had a methodological character (e.g., project management and change management). On the other hand, the functional cluster included 28 skills, both hard and cross-sectional. The results of these studies show that the average level of vertical skills, such as operational and functional, turn out to be the same for both 4.0 and non-4.0 profiles. Transversal skills, in turn, prove to be much more appropriate for 4.0 profiles. This indicates that there is an important soft component to manage and face the introduction of new technologies [39]. The importance of soft skills in the digital age is also emphasized in many other studies, e.g., ref. [40–42], where they are indicated as resistant to change and a vital new component of the workforce of the future, not just the key to differentiate people from machines.

Ref. [43] pointed out that the main skills that can best influence the context of Sustainable Industry 4.0 are based on three skill groups: cognitive skills, interpersonal skills and strategic skills. In the interpersonal leadership group, the most outstanding competencies are negotiation, persuasion and social perception. In the case of the strategic leadership group, the most significant competencies are vision, identification of key requirements and system and solution assessment. For the cognitive group, the important competencies are communicative skills, active listening, learning and critical thinking. Ref. [44], in turn, identified two sets of leadership skills necessary in Sustainable Industry 4.0: one related to human relationships and the other related to knowledge about the use of technology. The main leadership skills were listening, teamwork, stakeholder relations, team member relations, use of digital tools and ability to deal with change.

Moreover, ref. [38] proved that significantly important competencies for 4.0 professions are abilities such as business acumen, project management and change management, in which the difference between 4.0 and non-4.0 profiles is substantial, and which play a key role in the context of renewal.

2.2. Project Management in Sustainable Industry 4.0

In Sustainable Industry 4.0, a faster and more dynamic flow of information is expected. Working groups will cover very different areas of knowledge and will be varied. There will be development and use of more predictive and faster management tools. The use of Big Data tools will enable rapid flow of huge amounts of information with a wide spectrum. Robotization of the industry will increase its efficiency, but under certain circumstances it can also remove the human factor [45]. All these factors will cause significant changes in the form of management, and thus also in project management [7].

The contribution of the human factor in project activities related to Industry 3.0 is visible and observed in all processes that make up project management. The tasks carried out within the project are defined here, timed and used as a project management and control instrument covering all activities ranging from initiation to completion of the project. Initiating, planning, implementing, monitoring and controlling the project, as well as the

processes related to closing the project, are subprocesses of the classic approach to project management [45] and are implemented in Industry 3.0 projects. In contrast, Sustainable Industry 4.0 projects are individual-customer driven. For this reason, order management applies to all areas, such as research and development, production, commissioning, delivery and recycling of manufactured products. It is also particularly noticeable in the production sector, which today is pioneering Sustainable Industry 4.0, and in which the human factor is gradually replaced by machines, and the subprocesses of applying, monitoring and controlling are fully automated. In this case, initiation and planning processes take on more importance than in the classic approach to project management, and identification of the human factor involved in project initiation and planning requires restructuring to include its functions during the implementation, monitoring and control of the project [25]. This is also emphasized by [46], who indicate that, unlike “classic” projects, sustainable Industry 4.0 projects are characterized by an unclear purpose and/or unclear solution, therefore an important aspect here is the phase of gathering and identifying information that is missing in the implementation of “classic” projects.

In addition, in the era of Sustainable Industry 4.0, new opportunities are the digitization of production using base, cyber–physical production systems. This is why resources, such as all employees, products, resources and systems, must additionally be integrated as intelligent, self-organizing, interdisciplinary, real-time and autonomously optimized. This is also pointed out by [46], who emphasize that 4.0 projects are increasingly becoming interdisciplinary projects that combine various project grounds that can no longer be clearly separated from each other. Moreover, as the authors point out, management of 4.0 projects encounters barriers related to such issues as: insufficient change management, corporate culture inhibiting innovation, insufficient support and quality of decision making by managers, or the lack or inadequately planned project characteristics.

Project management in Sustainable Industry 4.0, through manifestation of its characteristic elements, will have a significant impact on the planning and implementation of projects in various areas of activity. For example, the new function of project management in Sustainable Industry 4.0 projects will be as follows: In the area of time management—real-time monitoring of project execution and eliminating gaps in progress reports; In the area of team management—generalize the use of virtual teams and collective intelligence; In the area of communication management—accelerate communication processes within projects, remove physical communication support and increase connectivity [7]. These changes can also be emphasized in the soft and hard skills of project managers and their team members. In Sustainable Industry 4.0, the soft skills of project managers will undergo a significant transformation mainly related to new ways of interacting with project stakeholders. There will be important soft skills such as [22]: communication skills, power, team management, management of unforeseen events and negotiating skills. Therefore, the project manager should build their authority on the basis of 360-degree knowledge of the project and the related field. In order for the team to operate effectively, communication should be carried out in a transparent and responsible manner.

2.3. Interdisciplinary Project Teams

Working in interdisciplinary project teams is becoming increasingly popular [47–50] due to their increasing use in the development of the new processes and products [51] required by Sustainable Industry 4.0. This also affects the composition of project teams, as team members should be highly qualified and have diverse competencies. Therefore, a very important issue, already at the stage of defining the resources necessary for project implementation, is the proper selection of employees for the project team [52].

The work of project teams in an environment such as Sustainable Industry 4.0—which, therefore, is subject to constant innovation—requires team members not only to develop technical knowledge and hard skills, but also necessitates changes in behavior and development of soft skills, among which interdisciplinarity is emphasized [53]. Ref. [54], analyzing the new skills of teams necessary for Sustainable Industry 4.0, indicates that the most

frequently mentioned skills include interdisciplinary thinking, problem solving, flexibility and creativity, and adds that the need for interdisciplinary thinking is a consequence of the high complexity of knowledge (tacit and explicit) in companies. In this context, ref. [55] also emphasizes education of team members must be adapted to new teaching and learning models that focus on developing interdisciplinary competencies and increasing employees' ability to solve problems and face the challenges resulting from the 4th Industrial Revolution. This is also emphasized by [56], pointing out that it is important for organizations to remodel the learning process and develop interdisciplinary competencies that will increase the capacity of team members in problem solving, creativity, and innovation.

Moreover, in the case of 4.0 projects that are realized in a dynamic environment that is constantly changing and for which the goals cannot be clearly defined at the beginning, agile approaches to project management become important [57]. Agile project management is characterized by an iterative and adaptive approach, consisting of short, customer-oriented feedback loops, formal and informal communication, and enabling self-organization in interdisciplinary teams [58]. In addition, the agile approach allows project teams to respond to emerging needs in a timely manner [59–61], which is extremely important in the context of the 4th Industrial Revolution, which is aimed at meeting rapidly changing preferences, customers and available technologies.

The interdisciplinary teams behind [62] are those in which the team uses the information, data, techniques, tools, perspectives, concepts and/or theories available within different disciplines or groups of expertise to solve an issue that goes beyond the scope of one discipline or area of research. Of course, the project team itself has, by definition, distributed roles and expertise [63], but in the case of interdisciplinary project teams, we deal with a different type of skills and highly specialized knowledge from several disciplines, professions, organizations or nations. Moreover, it should be noted that degrees of distributed knowledge and expertise likely vary according to project team type; therefore, when considering an interdisciplinary project team, we are dealing with integrated project teams that have multiple varied goals that must be clarified across their heterogeneous membership and multiple work cycles. Furthermore, such a team must integrate extremely large amounts of information, as processes and routines must be adapted or created for managing and executing projects [63].

The main challenge in interdisciplinary team cooperation is overcoming the disciplinary gap, but often, also, the form of cooperation itself. Interdisciplinary project teams vary in configuration in terms of how they perform their work. An interdisciplinary project team may include members who each have expertise in a different area—i.e., the diversity of disciplines is “interpersonal” at the team level [64]—or include members who each have experience in all the different aspects present in the team—i.e., the interdisciplinarity is “intra-personal”. In addition, interdisciplinary teams may be dispersed or partially dispersed, come from one or more organizations, or cooperate within one organization or with many external institutions [65].

2.4. Challenges of Interdisciplinary Work

Interdisciplinary teams try to integrate their diverse knowledge so that their collective knowledge is greater than the sum of the knowledge of individual members [66,67]. This provides better-quality problem solving and a broader view of the analyzed problem [68]. On the other hand, the researchers in [69–71] emphasize that the integration of knowledge of team members, especially in situations novel to Industry 4.0 projects, is a challenge. In this context, ref. [72] believes that interdisciplinary projects can be more complex and require more bureaucracy or other efforts to organize and coordinate individual contributions. Others researchers, e.g., ref. [72,73], emphasize members of interdisciplinary teams speak different “languages”, which influences the direct cooperation in these teams, creates reasons for conflict and makes them tend to share tasks more strongly. In addition, the literature, e.g., ref. [51,74], points out the difficulty of integrating the various knowledge bases of interdisciplinary teams, emphasizing that closer interaction between team

members is necessary. Ref. [75] stresses that “interdisciplinarity requires more than just complementarity”, it requires “new types of empirical approaches” as well as “integrated analyses”. Similarly, ref. [76] points to the importance of close communication and co-operation between team members in interdisciplinary projects. They argue that frequent direct interactions facilitate knowledge integration but also contribute to building trust and common understanding of the research problem, which improves the quality of results and reduces coordination costs over time. In this context, ref. [77] identified five practices that project teams can use to integrate their knowledge to cocreate a solution. Moreover, the researchers confirm the key role of active communication in the process of knowledge transformation and integration, especially when the tasks are of innovative nature, i.e., as it is the case with projects implemented at the intersection of different disciplines and in the area of Sustainable Industry 4.0.

Refs. [78,79] emphasize that the more diverse the disciplines are, as presented by team members with little common experience, the greater the differences between their tasks may be. Each team member, who represents a different specialization of knowledge, comes to the team with a different “world of thought” and understands problems, critical elements and problem-solving steps differently than other team members [77,80]. Therefore, it is important that each interdisciplinary team includes leaders who, through their integration skills, will support interaction and discussion between team members to generate the trust and common understanding necessary for knowledge integration [81].

Ref. [82] treats team-leader behavior as the key input that shapes the knowledge development process, and suggests that this behavior is key to ensuring that the unique knowledge of team members can be used by the entire interdisciplinary team. Ref. [83] points out that coordination in interdisciplinary teams can be improved if the team uses members’ individual leadership strengths. This is also emphasized by [84], emphasizing that interdisciplinary projects can increase the probability of scientific breakthroughs by bringing together ideas, tools and specialists from different research and practice areas. Moreover, the importance of leadership is also emphasized for projects in Sustainable Industry 4.0 and referred to as Leadership 4.0 [85,86]. Ref. [87] emphasizes that implementing Leadership 4.0 requires investment and openness to cultural change. Leadership 4.0 styles must be open, leading to a learning- and innovation-oriented culture focused on improving and integrating knowledge and thinking outside the box [88]. Ref. [89] indicates that in order to improve coordination in interdisciplinary teams, it is appropriate to adopt a common leadership structure focused on the team. Ref. [84] indicates that an integrative approach to team leadership is necessary for successful interdisciplinary projects. The goal of integrative leadership is to achieve team creativity through a process of integrating the experiences, perspectives and ideas of both team leaders and their members [90,91]. Leadership is, therefore, another element that influences the effective cooperation of an interdisciplinary Sustainable Industry 4.0 project team.

According to the analysis, the challenges related to the work of interdisciplinary Sustainable Industry 4.0 project teams involve many aspects. The most frequently stressed is the need to agree on a “common language”, close coordination of individual parts of the project, and communication and cooperation between team members. Moreover, leadership and selection of a team with specific competencies is indicated as an important factor for the success of such projects. However, from the results of the conducted analyses and what has already been emphasized, it is difficult to find in the literature research that would treat the issue of interdisciplinary competencies of project teams solving problems for Sustainable Industry 4.0 as a whole, and to indicate the competencies of members and leaders of such teams. Therefore, the research questions referred to in this article are: (1) What requirements and opportunities are set before members of project teams undertaking interdisciplinary Sustainable Industry 4.0 work? and, therefore (2) What are the competencies of members of such teams and their leaders to meet these requirements and take advantage of the opportunities for such cooperation?

3. Materials and Methods

Due to the lack of previous systematic research on the competencies of members of project teams carrying out interdisciplinary projects in Sustainable Industry 4.0, we decided to conduct an exploratory case study among members of interdisciplinary teams at one of the leading technical universities in Poland. The case study is a valuable research project in exploratory research because it is possible to obtain extensive data that allows researchers to investigate specific managerial problems in existing application areas, which extends the existing state of research [92,93]. In addition, case studies have been successfully used elsewhere to identify necessary competencies [94], including studies dedicated to Sustainable Industry 4.0 [95].

Qualitative data came from many sources: interviews, internal documentation on analyzed projects and reflective notes of project managers. In order to establish the reliability of the analysis, the sources used were triangulated [96,97].

The study started with finding a representative sample [92,93]. Subsequently, the interviews were conducted, which were partially structured and consisted of guidelines representing the research questions posed in the article. The interviews were conducted in person. Each of the interviews lasted between 30 and 60 min, depending on the respondent's statements. With the consent of the interviewees, the interviews were recorded and then transcribed from audio files to text. In addition, internal documentation of the analyzed projects provided by the technical university was used as a secondary source for triangulation [92,98,99]. All the collected data were arranged in a spreadsheet, and qualitative analysis of their content was performed [100]. During qualitative content analysis, requirements and perspectives were defined in an inductive way according to the description of [101,102] and adjusted to existing research, enabling the emergence of new knowledge [103]. The coding process started by "plunging" into the data by repeatedly reading interview transcripts to achieve a high level of data knowledge. Then, an initial code list related to the perspectives and challenges of 4.0 teams was generated and organized. In the next step, these codes were used to search for emerging categories by frequency analysis [104]. Subsequently, categories were refined by further searching for data that supported or rejected the proposed categories and the links between overlapping categories. The categories were then checked for consistency and compared to obtain reliability between encoders [104]. In compliance with high-quality research practice, the analysis was performed by a research team that included an "internal" researcher who collected the data and an "external" researcher who remained independent of the project. This approach is used extensively in psychology and social science research to provide different perspectives of data. The data were analyzed by both researchers, and disputes were resolved through discussion, ensuring a high level of agreement between the evaluators and the collected data. In the last stage, competencies corresponding to the previously identified requirements and perspectives were defined. In this process, competencies corresponding to the challenges and perspectives identified in the first stage of coding were systematically identified and improved. Then, the competencies were divided into two categories: team members and the team leader. Then, the relationships between the identified competencies and the previously identified challenges and perspectives were analyzed; in the next step, the main competencies were summarized. In order to triangulate, additional notes from project managers were used, and all 50 respondents and a focus group were interviewed to reach agreement on the identified competencies.

For the case study, one of the leading technical universities in Poland—which carries out large-scale interdisciplinary projects corresponding to Sustainable Industry 4.0 needs—was selected. The analyzed projects were undertaken as part of the "Silesian University of Technology as a Center for Modern Education based on research and innovation" project, co-financed by the European Union. The implemented projects corresponded to topics reported by employers, in particular, regional enterprises and socio-economic institutions leading in the field of Sustainable Industry 4.0 and were of significant importance for the development of these enterprises and/or the development of the region itself. The projects

were of research and development nature and included interdisciplinary issues from various disciplines (materials engineering, environmental engineering, biomedical engineering, computer science, construction, architecture, medicine, automation, mechanics and machine construction). For the implementation of each project, interdisciplinary teams were established, the work of which was managed by one main tutor and two auxiliary tutors. In addition, each project was supported by industry experts with competencies relevant to the project or experts from the University with documented scientific achievements in a given field. The projects were supported by industry experts, and the projects were derived from real problems reported by Sustainable Industry 4.0 organizations, which validates the teams as participating in Sustainable Industry 4.0 projects and makes the results applicable to other Sustainable Industry 4.0 challenges. Fifty respondents (17 women and 33 men) took part in the study. Each of the respondents came from a different project with varied interdisciplinarity. The analyzed projects included both (1) teams in which members each had expertise in a given area, and the project dealt with problems at the crossroads of at least two areas, and (2) teams where only a single member had expertise in a given area, and the project dealt with issues from several areas.

Respondents were randomly selected to participate in the study in order to generate generalizable results with the least possible burden. Freedom of speech and anonymity were ensured during the research in order to obtain the most reliable answers. Thanks to the advanced implementation of Sustainable Industry 4.0 in the analyzed entity, the obtained results may provide good practices for building teams executing interdisciplinary Sustainable Industry 4.0 projects.

4. Results

When asked about the challenges and perspectives of working in interdisciplinary project teams implementing Sustainable Industry 4.0 solutions, the respondents pointed out numerous problems they faced, but they also highlighted opportunities this work entailed. Table 1 presents perspectives and challenges defined by the 50 respondents, along with the frequency of individual indications.

As seen in Table 1, the biggest challenges for the respondents were: coordination of the project and its individual parts (32 out of 50 respondents), integrative team leadership (27 out of 50 respondents), establishing a common language among specialists from different disciplines (27 out of 50 respondents) and building a team consisting of specialists with competencies required for the project (21 out of 50 respondents). Regarding perspectives of working in an interdisciplinary Sustainable Industry 4.0 team, the respondents particularly pointed out the possibility of obtaining better results (26 out of 50 respondents) thanks to synergy, a wide view of the project (28 out of 50 respondents), proper division of competencies, which allowed individual team members to focus on the areas of the project that were best known to them (25 out of 50 respondents) and mutual learning in the team (23 out of 50 respondents). For the next part of the study, the results of repeated interviews with the 50 respondents were used to define competence requirements for members of interdisciplinary Sustainable Industry 4.0 teams. Due to the fact that the interviews clearly emphasized the role of the leader(s) in project management, the research results (Figure 1) defined common competencies for the project team and additional competencies for the leader(s).

The description of these competencies is presented in Table 2.

As seen in Table 2 and Figure 1, the study identified a total of 15 competencies necessary to implement interdisciplinary Industry 4.0 projects. Among these 15 competencies, 9 (strategic perspective, communication skills, readiness to compromise, creativity, digital skills, ability to learn actively, ability to listen actively, conscientiousness and persuasion) are dedicated to the entire project team, while 6 (ability to coordinate work, conflict resolution, decision making, motivation, empowering and resource management) are assigned only to the leader(s). Table 3 shows the links between the defined competencies (Table 2) and the requirements and perspectives identified at an earlier stage (Table 1).

Table 1. Challenges and perspectives for interdisciplinary project teams implementing Sustainable Industry 4.0 solutions.

ID	Challenges	Number of Indications	ID	Perspectives	Number of Indications
W1	coordination of the project as a whole and the need to coordinate different parts of the project	32	P1	a comprehensive view of the project problem/product	28
W2	establishing a leader to integrate the project and share leadership within the team	27	P2	higher quality of the solution received	26
W3	different “language” presented by specialists from different disciplines	27	P3	effective use of the competencies held by individual team members—everyone is competent in what they do	25
W4	building a team with all the competencies required in the project, including digital competencies	21	P4	mutual learning in a team, drawing on the experience and knowledge of other specialists	23
W5	more time for the right communication flow	18	P5	the ability to solve more complex problems	22
W6	lack of possibility of mutual assistance in issues known only by individual team members	13	P6	the ability to solve innovative problems	20
W7	more time for the team to adjust to each other	12	P7	greater creativity	19
W8	rigid time frame	11	P8	the general knowledge of related disciplines acquired by the team members	16
W9	conflicts arising from a different perceptions of the problem	11			
W10	frequent changes in projects caused by unpredictable events related to the requirements of given disciplines and the emergence of new technological solutions	9	P9	shared responsibility for the outcome of the project, which contributes to greater involvement of the entire team	14

Source: own study based on the conducted research.

As can be seen in Table 3, all of the defined competencies are related to the challenges and perspectives of working in Sustainable Industry 4.0 interdisciplinary teams. Competencies dedicated to project team members slightly favor perspectives related to the implementation of analyzed projects than to cope with challenges, while the additional competencies identified for the project leader are slightly more focused on diagnosing challenges than understanding perspectives. Moreover, as shown in Table 3, most of the links between perspectives and requirements for project team competencies can be seen in relation to strategic perspective, communication skills and persuasion, while for leaders, competencies relate to work coordination, resource management, empowering and motivation.

The obtained results, as one of the first studies, present the competencies of team members and their leaders, combining the competencies necessary for Sustainable Industry 4.0 and their interdisciplinary context, thus identifying the interdisciplinary competencies of project teams and their leaders necessary for Sustainable Industry 4.0. Earlier studies in this area referred to the analyzed areas separately, not allowing for a holistic approach to this issue. What is more, unlike previous studies, this study highlights important

competencies in the analyzed areas, not only regarding the project manager himself, but also in relation to team members, which makes the results useful for HR managers who are searching for Sustainable Industry 4.0 employees as well as for project managers.

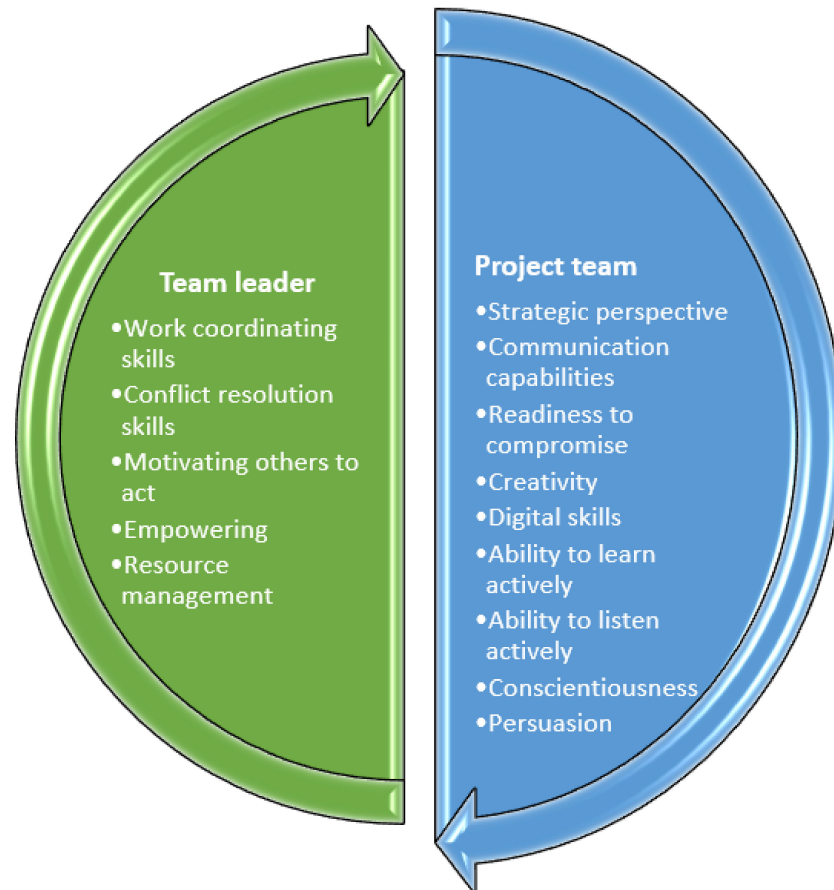


Figure 1. Competencies of interdisciplinary Sustainable Industry 4.0 teams.

Table 2. Description of competencies of interdisciplinary Sustainable Industry 4.0 teams.

ID	Competencies	Characteristics
SP	Strategic perspective	Provides a comprehensive view of the problems solved and considers the consequences of solving them in the short and long term.
CC	Communication capabilities	Active communication between all people involved, tailored to the requirements of each member. It also means being accessible to other team members and being able to communicate in a digital environment.
RC	Readiness to compromise	Enables working on the principles of cooperation and collaboration. It allows accepting different ideas, searching for a common solution to the problem and understanding interpersonal relations.
C	Creativity	Enables the use of different skills and knowledge, from different perspectives and worldviews of project team members to achieve a common solution. It allows going beyond one's own thinking patterns and to operate efficiently at the crossroads of different fields and disciplines.
DS	Digital skills	The ability to communicate and use information and data and to use digital technologies to solve problems and think critically. Building a learning environment in which new technologies are used in proposed solutions and for teamwork.

Table 2. *Cont.*

ID	Competencies	Characteristics
LA	Ability to learn actively	A willingness to experiment in order to learn and to innovate using knowledge from different disciplines and different technologies, guided by the digital way of thinking.
ALA	Ability to listen actively	Focus on cooperation in a culture of feedback, and openness to suggestions and ideas from team members outside their discipline
CN	Conscientiousness	A clear commitment to the direction one is working in, and to encourage other team members to support the direction chosen. It supports timely completion of tasks and cooperation at every stage of the project.
PR	Persuasion	Building a learning and innovation environment that enables presentation of an approach to other team members to encourage them to change their point of view, while understanding the position of other team members, recognizing the need to listen to that position and indicating the rationale for a change in approach
		Team leader
WC	Work coordinating skills	Enables coordination of the different parts of the project as a whole and directing the work of the project team members in such a way that together they achieve the desired result
CR	Conflict resolution skills	Eliminates, reduces and weakens conflict among team members, or gives it a certain direction in order to use its positive and creative features and thus achieve a better-quality solution
MD	Ability to make decisions	The ability to gather relevant information from a wide range of sources (including consideration of the challenges of using new, beneficial technologies) and, on this basis, make the right decisions
MO	Motivating others to act	The ability to influence (without using power) team members to stimulate them to achieve their goals, and to support them in their efforts
EM	Empowering	Involving team members in the decision-making process and engaging them in digital environments. Enables the creation of a participatory culture based on trust and cooperation, a sense of belonging and active participation.
RM	Resource management	Ability to organize work in a team and assign responsibilities in accordance with the competencies and personal characteristics of team members, and to monitor the effectiveness of teamwork

Source: own study based on the conducted research.

Table 3. Linking the defined competencies to the identified challenges and perspectives related to working in interdisciplinary Sustainable Industry 4.0 teams.

Competencies/ Challenges and Perspectives	Strategic Perspective	Communications Skills	Readiness to Compromise	Creativity	Digital Skills	Active Learning	Active Listening	Conscientiousness	Persuasion	Work Coordinating Skills	Conflict Resolution Skills	Decision Making	Motivation	Empowering	Resource Management
coordination of the project		+								+					
appointing a leader										+	+	+	+	+	+

Table 3. Cont.

Competencies/ Challenges and Perspectives	Strategic Perspective	Communications Skills	Readiness to Compromise	Creativity	Digital Skills	Active Learning	Active Listening	Conscientiousness	Persuasion	Work Coordinating Skills	Conflict Resolution Skills	Decision Making	Motivation	Empowering	Resource Management
different language	+	+	+				+		+		+				
required competencies of a team										+			+		+
more time for communication		+	+							+			+	+	
lack of possibility of mutual assistance								+	+						
more time to adjust to each other		+	+										+	+	
rigid time frame								+							
conflicts		+							+		+	+			
frequent changes	+				+							+			
a comprehensive view of the problem	+	+													
higher-quality results				+	+	+	+			+					+
effective use of individual competencies		+							+				+		+
mutual learning in a team		+				+								+	
ability to solve complex problems	+			+	+						+				+
ability to solve innovative problems	+	+		+	+	+	+								+
greater creativity	+			+		+	+			+					
general knowledge of the related disciplines	+					+	+								
shared responsibility for the results		+						+					+		

Source: own study based on the conducted research.

5. Discussion

The article poses two research questions. The first concerned requirements and opportunities connected with interdisciplinary Sustainable Industry 4.0 work, and the second concerned competencies of such team members and their leaders.

Answering the questions related to requirements and opportunities of such work, it was found that, in the studied projects, the biggest challenges were coordination of the project and combining its individual parts, integrative team leadership, establishing a common language among specialists from different disciplines and building a team, while perspectives connected with such work included the possibility of obtaining better results thanks to synergy, a wide view of the project, proper division of competencies and mutual learning in the team.

Answering the second research questions, related to competencies of interdisciplinary Sustainable Industry 4.0 teams, it was found that 15 competencies are necessary, and, among these 15 competencies, 9 are dedicated to the entire project team (strategic perspective,

communication skills, readiness to compromise, creativity, digital skills, ability to learn actively, ability to listen actively, conscientiousness and persuasion), while 6 are assigned only to the leader(s) (ability to coordinate work, conflict resolution, decision making, motivation, empowering and resource management).

The considerations presented in the article allow a deeper understanding of the specificity of work in Sustainable Industry 4.0 teams. When analyzing the characteristics of Sustainable Industry 4.0 work and the requirements set here for various groups of professions, it can be concluded that the 4th Industrial Revolution has unequivocally transformed the business sector around the world. This is shown in various studies [105,106], which emphasize that, in order to ensure a successful transition to Sustainable Industry 4.0, it will be necessary to change the management paradigm and apply a new approach to teaching and improving the individual competencies of employees. Although research in the field of Sustainable Industry 4.0 uses different levels of analysis to explain the changes brought about by the new fourth era of digitization and their impact on the development of the labor market and the technologies themselves, as many authors point out [38], the literature lacks an analysis of the impact of the sustainable 4.0 paradigm on employees. Some of the few publications that pay attention to this aspect are the studies by [53,107,108], in which the authors emphasize that Sustainable Industry 4.0 poses challenges in the social sphere, requiring companies to develop the highest level of competence of their specialists and attract new talent able to deal with the increased complexity of new technologies.

As the analysis shows, the changes caused by the new 4.0 paradigm are also reflected in the higher requirements for project team members, which are indicated as an important element of Sustainable Industry 4.0. This is also associated with a change in the approach to 4.0 project management itself, which, in this case, is more complex, innovative, burdened with a higher level of risk and requires the cooperation of highly specialized employees from various disciplines, often supported by employees from their economic–social environment. This is consistent with previous analyses in this area [22,109] that emphasize that Sustainable Industry 4.0 will bring radical changes in relation to project management. For example, refs. [22] points out that traditional project management styles must be changed in order to adapt to the 4th Industrialization Revolution with many variations, and that there are many challenges connected with project managers in Sustainable Industry 4.0, as it is certain that a project manager must have improved soft and hard skills to implement complex, autonomous and sustainable Industry 4.0 projects.

One of the key aspects of cooperation in 4.0 teams is their interdisciplinary nature due to the fact that interdisciplinarity is strongly related to innovation [110]—which is an inseparable element of Sustainable Industry 4.0—and due to the increasing complexity of projects and tasks faced by modern employees [111]. The requirement of interdisciplinarity of projects implemented for Sustainable Industry 4.0 is also emphasized in publications by other researchers. Refs. [112,113] indicate that complex problems cannot be solved within one discipline, and employees, including team members, require appropriate personal and social skills, defined as interdisciplinary competencies, in the era of the modern 4.0 economy. Among these competencies, the authors mention: solving complex problems in various disciplines, communication between disciplines, handling interdisciplinary cooperation and teamwork, and using integration potential to create innovation. Similar conclusions were obtained in this study, which shows that the most important challenges and perspectives related to the work of such teams includes coordination of individual parts of the project, communication between members from different disciplines, and a broad view of the problems raised in the project. This is also in line with other research, where attention was paid to difficulties in integrating the different parts of the project e.g., ref. [50] or problems in going beyond their knowledge disciplines, e.g., ref. [77].

Moreover, leadership is extremely important in the context of the analyzed subject matter, as it enables effective teamwork. Contemporary research in this area highlights the role of inclusive leadership, which is linked to the concept of shared leadership, as also noted in this research. As [114,115] point out, the project team also has an inclusive role,

which is to fill knowledge gaps by providing people with the right competencies to the team at different stages of the project. That is why it is so important that team members are entitled to use their competencies effectively in developing a project solution and to take on leadership roles if necessary [116]. This is consistent with research, e.g., ref. [88] conducted in the area of Sustainable Industry 4.0, which stresses that if leadership is more collaborative, participatory and decentralized, people feel more encouraged to make decisions and experiment to create an agile and responsive network culture.

According to the results of the research, the members of teams should mainly have competencies such as: strategic perspective, communication skills, willingness to compromise, creativity, digital skills, ability to learn actively, ability to listen actively, conscientiousness and persuasion. This is confirmed by previous reports that indicate that there should be an important soft component to manage (and face) the introduction of new technologies [39], and so-called soft skills are increasingly important in the current digital age, and can constitute its key element as competences resistant to changes [38,41].

In light of the conducted research, it was also revealed that the project manager plays a key role in the digitization process. Due to changes in work methods and the challenges facing Sustainable Industry 4.0, changes and challenges are also faced by project managers. Key competencies identified for the 4.0 project leadership role were highlighted: ability to coordinate work, conflict resolution, decision making, motivation, empowering and resource management. This is consistent with other research on 4.0 project leader competencies. This is also confirmed by [7], which indicates that the most significant changes related to the requirements of Sustainable Industry 4.0 project managers are communication style, interaction, speed and ability to work, and basic knowledge. They also add that the project manager must have improved soft and hard skills to implement complex and autonomous Industry 4.0 projects, and that the competencies related to Sustainable Industry 4.0 go beyond those defined by PMI or IPMA for the role of project manager.

The main limitation of this study is, by definition, a limited research method. Therefore, it is necessary to repeat this study in different contexts, in organizations of different sizes and types of projects, and in different countries. While our qualitative method allowed for an in-depth examination of the context, it also, to some extent, limits the reliability of the findings. By incorporating quantitative methods and replicating this study with either a quantitative or blended method, future research can further enhance the reliability of these findings. For example, quantitative research can be conducted to analyze the relationship between the identified competencies of interdisciplinary Industrial 4.0 project teams and the success of these projects. Moreover, some of the identified challenges and opportunities related to interdisciplinary Sustainable Industry 4.0 work may also apply to other areas. Therefore, future research could shed more light on the clear challenges and perspectives related to interdisciplinary Sustainable Industry 4.0 work, as some of them may relate to overall organizational transformation. Moreover, it is also worth considering how the competencies of such teams in other countries and cultures are developed, as the project environment is expected to have a significant impact on the competence requirements of the analyzed teams. A comparative analysis of competencies of teams implementing single-area Sustainable Industry 4.0 projects with the results obtained would also be cognitively interesting. This would indicate whether team cooperation influences the competencies required to a large extent. One limitation is also that 50 individuals spoke from the perspective of 50 teams, so individual's findings were confounded by their teams. Therefore, it is not possible to conclusively state whether the obtained results represent individual idiosyncrasies or team differences. Therefore, in future research, the target group can be expanded to include multiple members of a given team to get a more complete picture of the differences between teams.

6. Conclusions

The obtained results, as one of the first studies on this topic, present the competencies of team members and their leaders, combining the competencies necessary for Sustainable

Industry 4.0 and their interdisciplinary projects, thus identifying the interdisciplinary competencies of project teams and their leaders necessary for Sustainable Industry 4.0. Earlier studies of this topic referred to the analyzed areas separately, not allowing a holistic approach to this issue. What is more, unlike previous studies, this study highlights important competencies in the analyzed areas, not only in relation to the project manager himself, but also in relation to team members, which makes the obtained results useful for HR managers who are searching for Sustainable Industry 4.0 employees as well as for project managers.

This article is a contribution to the literature on management in the area of team competency management and from the perspective of organizations implementing sustainable 4.0 projects, thus extending the theory of human resource management to Sustainable Industry 4.0 and developing the argument for a greater focus on improving the soft skills of employees, in particular on developing their interdisciplinary skills. In practice, the article responds to the needs of companies and educational institutions (e.g., universities and colleges) to reflect on the desired competencies of employees—including, in particular, members of project teams implementing Sustainable Industry 4.0. projects—to cope with upcoming industry and sectoral changes. Hence, the obtained results are the basis for identifying the following recommendations for future teams implementing similar projects:

1. Awareness by the organization that Sustainable Industry 4.0 projects require interdisciplinary project teams and often also additional external support. Project team members can come from areas directly and indirectly related to the project topic. In this context, it is important to create organizational opportunities for cooperation within such teams.
2. Making the organization's management aware of important competencies necessary to implement interdisciplinary Sustainable Industry 4.0 projects.
3. Taking into account that project management 4.0 very often requires a transition from a classic to an agile approach to project management, which is the basis for innovation and customer satisfaction.
4. The need for an integrative approach to team leadership by the project manager, aimed at supporting an agile environment,
5. Taking into account whether the proposed project management frameworks allow for the additional time and communication costs required for the successful implementation of interdisciplinary 4.0 projects.

The study also contributes to the knowledge base concerning project management in the area of individual competence development of project team members and the management of interdisciplinary and sustainable 4.0 projects, indicating that the modern 4th Industrial Revolution requires a new, more flexible and agile approach to project management and new competencies of team members, including, in particular, the project manager. Thus, the obtained results will allow for more thoughtful team selection and, consequently, for greater effectiveness of the implemented projects.

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