Fostering knowledge sharing in the innovation process: Information and communication technology-based versus face-to-face relationships

Federica Ceci1 | Mariangela Lazoi2 | Marianna Lezzi2 | Heba Mohammad3

1Dipartimento di Economia Aziendale, University G.d'Annunzio, Pescara, Italy
2Dipartimento di Ingegneria dell’Innovazione, University of Salento, Lecce, Italy
3Computer Information Science Division, Abu Dhabi & Khalifa City Women’s Colleges, Abu Dhabi, United Arab Emirates

The paper investigates information and communication technology (ICT)-based and face-to-face interactions for knowledge sharing during the activities characterizing the innovation process rather than strategic or operative ones. It also discussed the benefits of working remotely in companies or in a network of companies, also due to the pandemic situation such as the one we are experiencing today. The research design is based on the exploitation of a case study in the aerospace sector. Qualitative data are collected with interviews, and a content analysis is applied for extracting data useful for exploring different kind of relationships. Three significant results are described about the role of face-to-face interactions in knowledge sharing; the interaction through ICT tools for communication; and the different types of support provided by ICT tools. The paper extends the state of the art with new evidence in the field of knowledge sharing and conversion for sustaining the innovation process. The findings are original since new insights for the analysis of relationships are provided. Furthermore, the research methodology is described in detail and can introduce managers and scientists in content analysis applications also for industrial exploitation.

1 INTRODUCTION

In 2000, Castells (2000) introduced the concept of “networked enterprise” as “the organizational form of the informational and global economy” based on connections and knowledge sharing among the participants using the digital technologies. The economy of this century is informational, global, and networked. Informational means that productivity and competitiveness are based on the capacity to generate and apply knowledge-based information. It is global because the business activities are arranged in an international and worldwide view. It is networked since the firms are linked together in networks, and productivity and competitiveness are measured not at the level of single firm but at the level of the whole network. Thus, the link between knowledge-based information, the global landscape, the network, and the rising of information-technologies draw the fundamental elements of the new economy. Information is considered as a product of the production process. This definition is still relevant, and further exploration is needed to analyze the organizational behavior of firms operating as “networked enterprise.” The concept of the “networked enterprise” is as relevant as ever in today’s pandemic situation in which remote collaboration and sharing knowledge have become a real necessity. In a networked enterprise, collaboration is relevant, and it comprises relationships between members of the same organization as well as with members of other organizations. Internal collaborations emerge for executing activities and sharing knowledge that involve different units and departments, while external collaborations involve actors located in other organizations. Such collaborations are aimed at reaching the same market goal or generating added value for their activities. Both internal and external collaborations are relevant because their execution can improve performance of products or services.
in the market. Interactions among different actors can boost innovation (Hagedoorn, 2002; Maurer & Valkenburg, 2013). Innovation requires energy and enthusiasm, and it is important to create an environment in which the employees’ ideas can flourish. A creative climate is required, and this involves developing appropriate organizational structures, communications policies and procedures, knowledge management processes, reward and recognition system, training policy, accounting and measurement systems, and deployment strategy. Innovative organizations carefully plan how to build an effective reward system that encourages the emergence of creative behavior (Tidd, Bessant, & Pavitt, 2001). Connections among actors facilitate innovation processes since their ideas, knowledge, and resources can be creatively combined (Nonaka & Takeuchi, 1995). Interactions are considered the vital way to gain access to rare resources, to participate and be involved in intensive processes of knowledge creation, sharing, and implementation. Information and knowledge are fundamental elements to manage innovation. Innovations, thanks also to the spiral of knowledge, are shared among different actors involved inside and outside an organization.

Therefore, relationships are more relevant than ever, and we observe a shift from a personal direct contact (i.e., face-to-face interaction) to communications based on information and communication technologies (ICTs). This is more relevant than ever due to the recent pandemic situation (Bratianu & Bejinariu, 2021; Lee, Tao, Li, & Sun, 2020; Van Looy, 2021). Face-to-face interactions have a crucial role in facilitating economic activities, as they enable the development of shared values, knowledge, and a common vision. These aspects facilitate the innovation process and have a positive impact on innovative performance. Hardwick, Cruickshank, and Anderson (2012) found that face-to-face interaction with customers is necessary for innovation, especially at its early stage. They emphasize the need of face-to-face interaction (with internal or external actors to the company) to build trust and share tacit knowledge (Anderson & Li, 2014; Latino, Corallo, Capone, Martino, & Trifoglio, 2016). Ceci and Iubatti (2012) stress that people with personal relationships are more willing to build a business-relationship, which facilitates innovative and economic activities within networks. However, recent technological progress, such as the wide use of ICTs, has boosted collaborations and interactions occurring among people located in different places. Therefore, people working within the same organization are also called to collaborate and communicate using ICTs. This is especially true and increasingly common in the current era of smart working and online relationships.

Since the wide spread of ICTs and virtual collaboration modalities, business people have started adopting different tools to communicate, collaborate, and to be connected with colleagues, suppliers, and customers. They use a variety of ICT tools to share knowledge and information (e.g., Ms Teams, Google Drive, Siemens Teamcenter). Recently, many technologies have emerged globally with industry 4.0 trends, focusing on emerging changes in the manufacturing industry (Corallo et al., 2018). These technological trends include: internet of things and services, ubiquitous information, visual computing, intelligent robotics, product life cycle management, cyber physical systems, and cloud computing among others (Posada et al., 2015). These technologies have led to the emergence of smart manufacturing, and they are strongly catalyzing the manufacturing industry (Camarinha-Matos, Fornasiero, & Afsarmanesh, 2017). Email, videoconferences, virtual communities, and other virtual tools can be used to connect with others. For example, the design process using virtual technologies is now easier and cheaper.

This paper aims to understand if face-to-face communications, compared to ICT-mediated communications, have a value for supporting processes in organizations. We pay particular attention to innovative activities occurring both inside and outside the organization. Such activities are relevant for companies to produce added value and to shift their practices to remote working, establishing new ways to exploit the potential of knowledge sharing through the use of ICT tools in order to create innovation. We evaluate the frequency of the connections occurring among the different actors operating within the analyzed context. In doing so, we will consider the type of relationships, activities, and interactions. As “types of relationships,” we consider the relationships within the organization, aimed at reaching the same entrepreneurship goal, as well as the relationships among the different organizations that collaborate and cooperate in the development of the final result (e.g., a supply chain). As types of activities, following the classification of Ceci & Iubatti, (2012), we distinguish in (a) activities carried out to achieve an innovation (i.e., innovative activities); (b) activities related to the strategic choices of the organization (i.e., strategic activities), and (c) operative activities related to ongoing day-to-day tasks. Furthermore, relationships can occur via face-to-face interactions or can be based on ICT and web. The data were collected before the current pandemic emergency, but the results highlight practices that should also be adopted now.

In this research, we aim to explore the role of ICT tools in enabling relationships for innovation collaborations, contributing to the research stream on the role of knowledge sharing by means of relationships and interaction in distributed innovation process. Therefore, our scope is to clarify how ICT-based interactions and face-to-face support organizational activities. The research questions that motivate the study are: How do different types of communication modalities support the organizational processes in a networked enterprise? Do ICT-based relationships and face-to-face support innovation process in different ways? For addressing these questions, we conducted a case study and used content analysis as data analysis method. Content analysis is defined by Kolbe and Burnett (1991) as “an observational research method used to systematically evaluate the symbolic content of all forms of recorded communications.” Furthermore, one of the oldest and most complete definitions of content analysis cites (Paisley, 1969): “content analysis is a phase of information-processing in which communications content is transformed, through objective and systematic application of categorization rules, into data that can be summarized and compared.” This method is largely used by scholars in the management field (e.g., Ayoko, Ang, & Parry, 2017; Insch, Moore, & Murphy, 1997; Lajili & Zghal, 2009; Mir, Lu, Cantor, & Hofer, 2018).

The case study is focused on a company operating in the aerospace industry. In this industry, products are highly complex and require the
integration of knowledge and systems coming from different actors. This industry is characterized by a high degree of computerization due to the need to satisfy a high level of quality. Organizations are also required to collaborate with a wide set of other firms and to produce complex products. In addition, aerospace products require high levels of product and process innovation and mastery of various complex technologies. All these aspects make the aerospace industry a suitable case for the exploitation of the proposed research issues.

The paper is structured in the following way. Next section introduces the theoretical background leading the study. Section 3 introduces the research method and steps. Section 4 details the data collection and coding activities, while Section 5 provides an analysis of the data. Discussions are treated in Section 6, describing theoretical and practical implications; finally, a last section of conclusions ends the paper.

2 | THEORETICAL BACKGROUND

2.1 | Knowledge management and innovation

Knowledge management process and innovation are closely related (Castaneda & Cuelar, 2020; Mardani, Nikoosokhan, Moradi, & Doust, 2018), and the importance of a joint study of those two concepts has been highlighted by many scholars. For instance, Cavusgil, Calantone, and Zhao (2003) proved that the quantity of tacit knowledge shared and the innovative capabilities of the firms are strongly correlated: knowledge sharing acts as an enabler to convert tacit knowledge into explicit knowledge and, therefore, stimulates innovation.

The innovation process is based on knowledge sharing (Kremer, Villamor, & Aguinis, 2019). As evidence, Adams, Day, and Dougherty (1998) state that acquiring knowledge and skills through collaboration enables successful innovation.

In general, knowledge sharing refers to the exchange of expertise that enables the creation of new valuable products and services or the improvement of existing ones (Hoopes & Postrel, 1999). Moreover, knowledge sharing can also play a key role in predicting team performance (Mesmer-Magnus & DeChurch, 2009), as well as in generating new ideas and improving innovative capabilities within companies (Darroch & McNaughton, 2002). Furthermore, according to Belso-Martinez and Diez-Vial (2018), the involvement of firms in knowledge networks also leads to an increase in innovative capacity.

Brockman and Morgan (2003) argue that the knowledge management tools such as "use of innovative information," "efficient information gathering," and "shared interpretation" improve the performance and innovativeness of firms. Similarly, Darroch (2005), proved that knowledge dissemination has a positive impact on innovation success. However, the link between knowledge management and innovation is also influenced by the typology of innovation: different types of innovation require a differentiated knowledge management strategy (Darroch & McNaughton, 2002). They investigate the effects of knowledge management on three types of innovation, proving that knowledge management should be adapted to the desired outcome. Knowledge sharing is also influenced by the different communication means (Cerchione & Esposito, 2017; Nisar, Prabhakar, & Strakova, 2019; Pondel & Pondel, 2017). This paper aims to understand if face-to-face relationships, compared to ICT-mediated relationships, have a value for supporting activities in organizations. We pay particular attention to innovative activities.

2.2 | Distributed and collaborative innovation process

The largest stream of research representing distributed and collaborative practices of innovation refers to the paradigm called “Open Innovation” (Chesbrough, 2003). This research stream refers to the aptitude of firms (a) to use ideas and technologies external to their business, and (b) to grant others the use of ideas and technologies that they cannot or do not want to exploit directly. In particular, Chesbrough (2003) describes this phenomenon as a new paradigm for the organization of the innovative activity of the firm, to be contrasted with a model of “closed innovation” where firms use ideas and technologies born and generated within the organization. In later works, Chesbrough himself, together with other colleagues (Chesbrough & Bogers, 2003; Chesbrough, Vanhaverbeke, & West, 2006), further refined this concept, proposing a vision of Open Innovation as a “distributed innovation process (among multiple subjects) and based on an intentional management of knowledge flows that cross the boundaries of the organization through both monetary and non-financial mechanisms, depending on the compatibility with the business models of each firm” (Chesbrough & Bogers, 2003).

As innovation collaboration spreads outside the organization, its management faces new challenges. These challenges can include contrasting cultures, cognitive and geographic distance, varying capacities, and differing objectives for collaboration among various stakeholders (Barbaroux, 2002; Kiesler & Cummings, 2002; Smith, 2016; Weber & Heidenreich, 2016). Several authors explored the role of employees, their culture, and attitudes in affecting innovation performance. Relevant contributions analyzed how the characteristics and attitude of employees can influence the degree of openness of innovation activity and their outcomes (Mumford, Antes, Caughron, Connelly, & Beeler, 2010). To address such challenges, the role of relational capabilities is relevant. In the study of Dooley and O’Sullivan (2007), they introduce and discuss an integrated framework to support innovation from individual employees to the distributed network level. In line with this research stream, we aim to contribute to the understanding of the role of relationships and interaction in distributed innovation network.

2.3 | Relationships, face-to-face interactions, and innovation

The multidimensional nature of networks has been recognized by Ceci, Masicarielli, and Poledrini (2019), who found that personal relationships have a potential influence on innovation process. Networked firms intensify the embeddedness phenomena by developing different sets of personal relationships, which are likely to be
supported by informal contacts (Brown & Duguid, 2001). Personal relationships enhance embeddedness, which in turn allows firms to obtain significant outcomes, such as knowledge sharing and innovation diffusion. Activities based on close personal relationships are facilitated through the development of a sort of “business friendship,” which motivates firms to go beyond their formal contracts when doing business together. Information flows and communication within networks are intensified if the relationship is based on personal ties. Actors with personal ties trust each other’s behavior and are more willing to share knowledge and exchange information (Gulati, 1998; Mellewig & Weibel, 2007; Ceci & D’Andrea, 2014). In addition, they trust the quality of work done and are more willing to collaborate, innovate, and implement new processes.

Innovation has also been largely studied in association with the importance of face-to-face contacts (Acs & Varga, 2002; Barrot, Kuhlmann, & Popa, 2013; Brown & Duguid, 2001). For example, actors with personal relationships are more willing and ready to communicate and interact spontaneously through unscheduled face-to-face encounters and e-mail (Haythornthwaite & Wellman, 1998; Wellman, 2009). Moreover, Krugman (1991) argues that face-to-face contact will improve the chances of informal knowledge spillovers between firms and individuals; consequently, these face-to-face contacts will promote innovation (Pfeffer & Carley, 2013). The intensity of face-to-face contacts and its benefits related to innovation performance will vary according to the firm types and its industry (McCann, 2007). Hardwick et al. (2012) found that firms rely more on face-to-face interactions for innovation in spite of adopting one of the highly diffused ICTs. In their study, it was found that face-to-face interactions help in establishing trust and transferring tacit knowledge during the innovation process. In addition, their study highlights that the intensity of face-to-face interactions varies through the different phases of the innovation process.

2.4 Collaboration, ICTs, knowledge, and innovation

The use of ICTs in firms as a way to support innovation is widely recognized in the literature (Levy, Loebbecke, & Powell, 2003; Zhu, 2004). It has been argued that the use of ICTs in firms will shrink transaction and coordination costs, increasing the value of a transaction. ICT is seen as an important tool to communicate, to enhance external communication, to reduce inefficiencies, and to accelerate the communication process. Innovation and knowledge creation happen through an interactive, iterative, and network-based process (Konsti-Laakso, Pihkala, & Kraus, 2012), enabled by ICT.

In the innovation process, ICTs are considered essential to assure a high level of interaction, connection, and sharing between different actors. ICTs can be used to support and facilitate interaction and generate new ideas, communication and dissemination of information, as well as the creation and sharing of knowledge among the different nodes of a network. Collaborative technologies create a new space where information is distributed and made available for each actor. This new space is characterized by the wideness of access (i.e., possibility to access everywhere), the large scale (i.e., a large amount of information and processing on them), the distribution cognition and intelligence (i.e., information is distributed across actors, space, and time), and an invisible computing (i.e., the difference between the digital and real world is not visible) (Carley, 2000).

Firms are engaged in complex processes to produce complex products and complex innovations. For that, they are obliged to use collaborative technologies, tools, and methods to integrate and manage collaborative designs and collaborative knowledge. For example, a product can be designed with the support of standalone CAD applications or, with the aid of new technologies, with sophisticated and adequate CAX applications (i.e., CAD, CAM, CAE) based on Extranet or Internet that connect all partners in a synchronous or asynchronous way. Furthermore, the PLMS (Product Lifecycle Management System) is an example of collaborative tools, which could be used to manage and integrate information across the network (Marra, Di Biccari, Lazoi, & Corallo, 2018). Another collaborative networked framework that has been enabled by the emerging of cloud computing technologies is known as Cloud-based manufacturing design model (CBDM) (Wu, Rosen, Wang, & Schaefer, 2014). It enables a more efficient and effective approach to share and trace product information throughout its lifecycle. Moreover, networked actors can still use different, traditional technologies to communicate and collaborate. Actors can also use collaborative technologies to hold visual meetings to exchange ideas and discuss, and these discussions can be saved in a real-time database (Chen, 2007). The use of collaborative technologies and knowledge sharing has enabled distributed virtual teams to carry out their work effectively and generate innovation without meeting face-to-face (Gupta, Mattarelli, Seshasai, & Broschak, 2009). Multiple actors are involved in the innovation process and have to accomplish various specialized tasks and functions simultaneously: this cannot be easily achieved without technological support.

3 RESEARCH DESIGN

The research design is based on an embedded single case study (Yin, 2003), analyzed with content analysis. We conducted a detailed analysis of activities and modes of interactions (communication) in a large aerospace firm. We decided to perform a single case study since it is critical to collect useful information to evaluate the diffusion of ICT in the network and understand how the existing relations, internal and external, impact on the innovative firm activities. Furthermore, it is an embedded case study because it analyzes not only the firm, in its general aspects, but also the activities and relationships inside its organizational units.

The conceptual model proposed in Figure 1 is analyzed in order to graphically describe the connection between the types of relationships based on face-to-face interactions or ICTs (i.e., type of interactions) and organizational activities.

Data are collected with interviews and analyzed using the content analysis (Bryman & Bell, 2015). Content analysis is an approach for quantifying the contents of predetermined categories in a systematic and
replicable way. With the content analysis application, a quantitative analysis of qualitative data is performed. Different authors describe and organize the steps to reach a sound content analysis (e.g., Kassarjian, 1977; Neuendorf, 2002). From these studies, five phases are identified and applied for reaching the result described in this paper: (a) study, (b) collection, (c) pre-coding, (d) coding, and (e) analysis.

In the study phase, researchers conducted the literature review and defined the research questions and elements of analysis. This phase is useful to train researchers on the topics object of the study and the organizational context. In this phase, researchers defined an ad-hoc questionnaire composed of open questions to collect information from employees. In the collection phase, researchers identified the firm, selected the interviewees, and administered the interviews following the questionnaire. In the precoding phase, researchers compiled a casebook that includes attributes and information about the interviewees. Further, a word frequency query is realized to count the most frequent words. These words are assigned to nodes and researchers compiled a dictionary emergent from the data. The dictionary included nodes and sub-nodes. Researchers established the unit of measurement for analyzing the available contents (e.g., words, sentences, paragraphs, and so on). Starting with the dictionary, researchers wrote the codebook and the coding form. At this phase, the different elements of the analysis are called nodes and can be split into sub-nodes based on the interviews contents. During the coding phase, researchers analyzed each interview and assigned a portion of the text to the nodes and sub-nodes. Coding is realized using NVivo software, a Computer Assisted Qualitative Data Analysis (CAQDAS). The coding form reports portions of the text assigned to the different variables/nodes and its results. Researchers conducted two rounds of coding. The last phase is the analysis: in this phase, a descriptive statistical analysis based on data from the researcher’s coding is done. In the following sub-sections, we describe the tools and procedures created and used for the content analysis application.

4 | DATA COLLECTION AND CODING

4.1 | Industrial context

The selected industrial context, the aerospace sector, is characterized by tight relationships between the players at all levels of the supply chain. The higher levels are the richest in interactions and risk sharing.

In the lower level, relationships focus on execution of orders without participation in the decisional process and risk sharing. The firm analyzed (that we will call Aerospace for anonymity issues) is specialized in the design, development and manufacturing of aerospace propulsion components and systems for aircraft. Aerospace is a first-level supplier and has developed strict relationships with its customers satisfying their technological and product requirements; aerospace collaborates with second-tier suppliers and other actors such as Universities and research centers. Furthermore, Aerospace is called to manage a large network of suppliers. Its role as a first-level supplier requires the application and respect of many rules and constraints defined by the prime contractor. Aerospace is also called to impose a set of constraints on its suppliers, controlling their activities. To better describe the aerospace industry context, one respondent’s words: “The aircraft design is done by the network. The design is distributed among global firms. (…)”

4.2 | Questionnaire and interviews

Data are collected with interviews based on open-ended questions organized in a questionnaire composed of four sections (Annex 1). The open-ended questions are chosen for stimulating perspectives, views, and opinions shared among the participants (Creswell, 2003) and are particularly useful to catch the interviewees’ point of view without influencing them, by allowing the use of own words (Buratta, Sabbadini, & Fortunato, 1989).

Interviewees are selected with the nonprobabilistic “snowball” sample technique that allows to choose a convenience sample and is used in the qualitative study (Bell & Bryman, 2006). It is the most suitable approach to analyze a context where the insights on a topic are hidden at different levels of the organization. Initial interviews were conducted with the roles of the firm more relevant for the study; these interviewees suggested others roles to be involved. This process was repeated several times until we obtained a complete picture of the analyzed topic. Figure 2 gives an overview of the interviews conducted. Each interview is digitally recorded and completed transcribed.

4.3 | Variables (nodes) of the analysis

On the basis of the analyzed literature and the knowledge on the industrial context, we identified seven core variables. The variables are also called
nodes for the content analysis. Variables are divided in sub-nodes for better focalizing their meaning. They are: (1) innovative activities; (2) operative activities; (3) strategic activities; (4) internal relations; (5) external relations; (6) face-to-face interactions; and (7) ICT-based interactions. A definition for each node is reported in the following table (Table 1):

### Table 1: Definitions

| Variables (Nodes) | Definitions |
|-------------------|-------------|
| 1 Innovative activities | All the activities performed to improve and change the way of working or the realized product are included. |
| 2 Operative activities | It is composed of the day-to-day technical activities done to perform the tasks and satisfy the business objectives. |
| 3 Strategic activities | It is related to the strategic planning of the firm and involves the objectives definitions, the resources used to reach them, and the definition of the firm policy. |
| 4 Internal relations | It is about the relationships between employees inside the same plant. |
| 5 External relations | It refers to the relationships that the firm employees have with actors working outside the plant. |
| 6 Face-to-face contacts | It is about all aspects of physical meetings. |
| 7 ICT tools | It groups all the tools based on the use of the information and communication technologies for performing the activities. |

## 4.4 Casebook definition

Each interview is characterized by four attributes: (a) the division where the interviewee works (e.g., Aeroengine, ICT, Automation system, and Process Improvement); (b) the month in which the interview is done (May, June, or October); (c) the interviewee's role in the firm; and (d) the length of the interview in minutes. The duration of each interview varies by and depends on the role of the interviewee, knowledge of the investigated topics, and personal attitude. The average duration of the realized interviews is 35 minutes. The total duration of the interviews is 426 minutes, more than 7 hours that corresponds to 48,981 words, the main raw material on which the content analysis is performed. The set of interviews details is the so-called casebook.

## 4.5 Dictionary creation and coding

The coding process is preceded by the definition of a dictionary emergent from the data, constructed using the most frequent words inside the set of interviews. The dictionary is useful to lead the assignment of portions of the text to content analysis nodes.

To obtain the dictionary, with the support of the NVivo software, a word frequency query is elaborated by extracting the 1,000 most frequent words in the text. This list is also composed of words repeated less than 10 times, plurals and articles, pronouns, adverbs, auxiliary verb and the modal, causative, and phrasal verbs. This kind of words is deleted, and the final list is composed of 196 words. For each concept (activity or relations), we assigned the relevant words among the 196 identified. To construct an exhaustive list of words, we used an Italian dictionary of synonyms and antonyms for each word and included the related and relevant synonyms and antonyms in our dictionary. The can be found in Annex 2.

Two coders (that are two of the authors), working independently, proceeded the relevant sentences using the text search function in the NVivo software. The 12 interviews are carefully read, and each portion of the text is evaluated in order to be assigned or not to the nodes. They manually checked the entire text to capture coding errors.
due to the multiple possible meanings of the words or negative sentences, and, at the end of the coding, they compared and discussed their coding decisions, obtaining a shared version, commonly agreed, that is the one used for the analysis.

### 4.6 Coding form design

Once the interviews are coded, a set of quantitative data emerges based on the number of interviews, sentences, and words coded at each node. They are reported in the coding form for analysis, further investigations and conclusions. The coding form is used to register the numeric information related to the coding data (Lombard, Snyder-Duch, & Bracken, 2003). The used coding form is a schema composed of a four-column table. The first column contains the node/sub-node name; the following columns contain the number of interviews, the number of sentences, and the number of words coded for each node/sub-node. The coding form is completed in each round of the coding process and supports data analysis. The final coding form used for data analysis is available in Annex 3.

### 5 DATA ANALYSIS RESULTS

After the coding activities, we performed a co-occurrences analysis with the use of cross tables. Cross tables (named Matrix Coding Queries in Nvivo) count the number of words that are used in the text while referring to a specific concept and are generally used to compare items and identify patterns. In the following tables, we report the results of the cross tables: on the lines and column there are the items coded; while the cells' content is the percentage and the number of words in which the items are coded together. This suggests an overlapping of two concepts.

In Table 2, the results report the importance of each interaction type (i.e., face to face, ICT) with respect to the different activities (i.e., innovative, strategic, and operative). In addition to face-to-face and ICT tools, there is a column that reports the value of other tools mentioned in the interviews (e.g., phone). We included this column since it is important for providing a complete picture. Moreover, the importance of the different modalities of interactions in activities with internal or external actors is shown in Table 3. A detail of the role of the various ICT tools in the different firms’ activities is instead available in Table 4.

The cross-tables analysis allows to investigate how different concepts overlap in the interviewees’ discourses and points of view. The analysis led to three significant results: (a) the role of face-to-face interaction is higher in innovative activities than in strategic and operative activities (Table 2); (b) ICT tools-based interaction is equally important for external and internal communication (Table 3); and (c) ICT tools differently support innovative, strategic, and operative activities (Table 4).

Cross tables suggest that the incidence of the tools for communication is different according to the typology of activity. Table 2 reports the percentage of use of each communication tool for the different activities, and it is easy to note that in innovative activities, the use of face-to-face interactions (24%) is higher than in operative (13%) and strategic (20%) activities.

Our results suggest also the important role of the use of ICT-based tools in internal and external activities. Table 3 reports the percentage of use of the interaction types compared with internal and external relationships. The use of ICT tools is equally distributed: 54% for external relationships and 52% for internal relationships. When focusing on the use of face-to-face interactions, some differences emerge. In internal relationship, there is a larger use of face-to-face interaction (23% external and 34% internal), but this is not surprising: it is easier to have face-to-face interaction with people located in the same building than with people remotely located. It is interesting to note, instead, that the amount of ICT-based interactions does not change between the two typologies of relationships. This suggests that ICT tools do not replace face to face.

Finally, results (see Table 4) suggest important evidences relevant for understanding the role of the different ICT tools in supporting firms’ activities. Analyzing the use of ICT tools across the different firms’ activities, we notice a balanced distribution of tools in innovative activities (ICT for communication: 33%; ICT for design: 32%; ICT for management: 35%). The situation is different for operative activities (ICT for communication: 16%; ICT for design: 50%; ICT for management: 33%) and strategic activities (ICT for communication: 25%; ICT for design: 18%; ICT for management: 46%). More specifically, ICT tools for design are much more frequently used in operative activities, while ICT for management tools is more frequently used in strategic activities.

### 6 DISCUSSION

#### 6.1 Theoretical implications

The obtained results address the proposed research questions and provide a specialization of the conceptual model. Considering the first...
The role of communication

The role of ICT tools in firms’ activities

essential to assure high level of interaction, connection, and sharing communication process. In innovation process, ICT is considered in the literature (Levy et al., 2003; Levy et al., 2003). It is argued that the use of ICT in firms will shrink transactions, it confirms the use of ICT in firms as a way to support innovation, as widely recognized in the literature (Acs & Varga, 2012; Brown & Duguid, 2001; McCann, 2007). Moreover, Krugman (1991) argues that face-to-face contacts will improve the chances of informal knowledge spillovers between firms and individuals; consequently, these face-to-face contacts will promote innovation. Empirical observations stress that the variation in the frequency of face-to-face interactions is a characteristic varying in each sector.

About the importance of face-to-face interaction, even if these findings are not linked to the stages of innovation, we can assume that they are coherent with what it is suggested by Hardwick et al. (2012), where it is highlighted that face-to-face interaction is more used in early stages of innovation. Furthermore, innovation has also been largely studied in association with the importance of face-to-face contacts (Acs & Varga, 2012; Brown & Duguid, 2001; McCann, 2007). Moreover, Krugman (1991) argues that face-to-face contacts will improve the chances of informal knowledge spillovers between firms and individuals; consequently, these face-to-face contacts will promote innovation. Empirical observations stress that the variation in the frequency of face-to-face interactions is a characteristic varying in each sector.

Considering the role of ICT tools in internal and external relations, it confirms the use of ICT in firms as a way to support innovation as widely recognized in the literature (Levy et al., 2003; Zhu, 2004). It is argued that the use of ICT in firms will shrink transaction and coordination costs, increasing the value of transactions. ICT is seen as an important tool to communicate, to enhance external communication, to reduce inefficiencies, and to accelerate the communication process. In innovation process, ICT is considered essential to assure high level of interaction, connection, and sharing between different actors. ICT can be used to support and facilitate collaboration and generation of new ideas, communication and dissemination of information, and creation and sharing of knowledge among different actors of a network.

Discussing about how ICT tools support firms’ activities, the results showed that different innovative activities are equally supported by ICT tools. However, operative activities rely more on operational ICT tools that support design activities such as PLMs (Marra et al., 2018) or parts of CBDM (Wu et al., 2014), while strategic activities rely more on ICT for management tools. These results are in line with the nature of the activities that require different specifications in terms of ICT tools during different stages of the innovation process. Innovation activities do not have any preference; this is a consequence of the transversal approach to innovation that characterizes the innovation process in the aerospace industry.

6.2 Managerial implications

Management can benefit from the results of the paper, which provides guidance for their activities and allows them to define the types of relationships and interactions that best support the implementation of innovation. In particular, in the paper, we provide a set of recommendations for improving knowledge sharing during the innovation process on the basis of internal or external collaboration by modifying the use of communication modes. These results are based on the analyzed sector but can be applied also to others similar in terms of product type (e.g., space) or supply chain (e.g., automotive and naval).

The paper confirms the relevance of face-to-face interactions of knowledge sharing in the innovation process. This result, if contextualized in the current period, translates into a warning for companies to invest in activating interaction mechanisms based on the same preconditions as face to face (e.g., trust, business friendship) also in remote work. Nowadays, as the pandemic has slowed down the growth of several sectors, reducing the chance to have face-to-face interactions, companies need to invest in fostering the innovation process with ICT.
tools but leveraging on the value and characteristics of face to face. This type of relationship is at the core of the socialization and is the fundamental means for the transformation of tacit knowledge into explicit knowledge. Therefore, companies have to work in this direction to enable the sharing and transformation of knowledge useful to realize new products, services, or organizational processes.

Furthermore, the study also underlines the importance of ICT-based interactions, both for internal or external communication, and does not detect any differences between the two types of communication. This contribution is relevant and enables the definition of a common strategy for the two types of communication, based on the same ICT tools. In each case, ICT has the same relevance and can support the process of socialization and externalization of knowledge with positive results, in terms of volume and quality of knowledge shared within a network of relationship. For example, the use of communication tools, such as Google Meet, can support, in the same way, the communication between internal employees and between them and external partners. In fact, both types of communication may have the same benefits (e.g., ease of communication and lower transfer costs) but also the same problems (e.g., poor network connection, leading to low audio or image quality) and biases (e.g., lack of facial expression when not sharing one’s image).

Considering the last result of our study, this can allow companies to share their technological choices based on the types of the organizational activities they conduct. The support of ICT tools for innovative activities does not differ from the purposes of communication, design, or management; they have the same weight. If the management has to choose an ICT tool for innovative activities, it can focus on the concrete needs of the company (e.g., data sharing in the supply chain, faster communication channel, or virtual design review) relying on no difference in relevance. On the other side, strategic and operative activities need to carefully evaluate the introduction and use of ICT tools, promoting design tools in strategic activities (e.g., a product data management system) and management tools in operative activities (e.g., a program management system).
Finally, practitioners can benefit from the application of content analysis for examining organizational behavior. The detailed description available in the paper for addressing the analysis can be used to apply the method also in other contexts.

7 | CONCLUSIONS

With this research, we aimed to explore the role of ICT tools and face-to-face in enabling relationships for the innovation process, contributing to the research stream on knowledge sharing and interaction in the distributed innovation network. Results are based on the application of content analysis for the analysis of industrial collaboration dynamics. Findings are threefold: firstly, the role of face-to-face interaction is more important in innovative activities than in strategic and operative activities. Secondly, ICT tools-based interactions are equally important for external and internal communication; this suggests that ICT tools do not replace face-to-face interaction while developing innovative projects. Thirdly and lastly, ICT tools differently support innovative, strategic, and operative activities.

The application of content analysis can be considered by scientists and managers as a tool for performing an internal audit and for evaluating and understanding important organizational elements and relationships. Its application and findings may suggest improvement initiatives and new organizational policies. Nevertheless, this study has certain limitations arising from the case study methodology followed: the research involves a single case study, which limits the findings generalization. To enhance the generalizability of the results, future research should replicate the case study in other contexts using the same methodology. Such replication allows researchers to determine whether the results of the present study are due to specific contingencies of firm operating contexts or whether they can be generalized in different contexts. To increase the generalizability of the results, we plan to build a quantitative data collection to capture the features of the phenomenon on a larger basis, in different sectors and geographical contexts.

As regards the content analysis approach, in general, it has some weaknesses in looseness of the reliability indexes and in the coding done by researchers that may have an impact on the objectivity of the results. Moreover, since the duration of each interview is variable, information extracted and used in the study is reduced to the cataloguing of the words referring to each of the nodes studied. These weaknesses are faced, in the paper, with a round of coding by each author and with an accurate description of the rules and tools of coding in order to deeply document the decisions that lead the study and to permit an easy repetition by other researchers.

ORCID

Mariangela Lazoi  https://orcid.org/0000-0003-4280-1597

REFERENCES

Acs, Z. J., & Varga, A. (2002). Geography, endogenous growth, and innovation. International Regional Science Review, 25(1), 132–148.

Adams, M. E., Day, G. S., & Dougherty, D. (1998). Enhancing new product development performance: An organizational learning perspective. Journal of Product Innovation Management, 15(5), 403–422.

Anderson, A., & Li, J. (2014). Entrepreneurship and networked collaboration: synergetic innovation, knowledge and uncertainty. Journal of General Management, 40(1), 7–21.

Ayoko, O., Ang, A., & Parry, K. (2017). Organizational crisis: Emotions and contradictions in managing internal stakeholders. International Journal of Conflict Management, 28(5), 617–643.

Barbaroux, P. (2002). Identifying collaborative innovation capabilities within knowledge-intensive environments: Insights from the ARPANET project. European Journal of Innovation Management, 15, 232–258.

Barrot, C., Kuhlmann, J., & Popa, A. (2013). Influence of personal communication networks on innovation adoption—Using multi-agent simulations to project the launch of an innovative medical device. International Journal of Innovation and Technology Management, 10(05), 1340021.

Bell, E., & Bryman, A. (2006). The ethics of management research: An exploratory content analysis. British Journal of Management, 18(1), 63–77.

Bell, E., & Duguid, P. (2001). Firm’s strategic choices and network knowledge dynamics: How do they affect innovation? Journal of Knowledge Management, 22(1), 1–20.

Bratianu, C., & Bejinariu, R. (2021). COVID-19 induced emergent knowledge strategies. Knowledge and Process Management, 28(1), 11–17.

Brockman, B. K., & Morgan, R. M. (2003). The role of existing knowledge in new product innovativeness and performance. Decision Sciences, 34(2), 385–419.

Brown, J. S., & Duguid, P. (2001). Knowledge and organization: A social-practice perspective. Organization Science, 12(2), 198–213.

Bryman, A., & Bell, E. (2015). Business research methods (4th ed., pp. 3–764). Oxford, England: Oxford Press.

Buratta, V.; Sabbadini, L.L.; Fortunato, E.. Manuale di tecniche di indagine—il questionario: Progettazione, redazione e verifica 1989. Note e relazioni Vol.2, n.1

Camarinha-Matos, L. M., Fornasiero, R., & Afsarmanesh, H. (2017). Collaborative networks as a Core enabler of industry 4.0. (eds) collaboration in a data-rich world. PRO-VE 2017. IFIP advances in information and communication technology, vol. 506. Cham, Switzerland: Springer.

Carley, K. M. (2000). Computational analysis of social and organizational systems. Organizational Science, 34(2), 4–10.

Castaneda, D., & Cuellar, S. (2020). Knowledge sharing and innovation: A systematic review. Knowledge and Process Management, 27(3), 159–173.

Castells, M. (2000). The rise of the network society (2nd ed.). West Sussex, England: Wiley-Blackwell.

Cavusgil, S. T., Calantone, R. J., & Zhao, Y. (2003). Tacit knowledge transfer and firm innovation capability. Journal of Business & Industrial Marketing, 18(1), 6–21.

Ceci, F., & D’Andrea, D. (2014). Knowledge dynamics in fragmented industries. International Journal of Innovation and Technology Management, 11(2).

Ceci, F., & Lubatti, D. (2012). Personal relationships and innovation diffusion in SME networks: A content analysis approach. Research Policy, 41(3), 565–579.

Ceci, F., Masciarelli, F., & Poledrini, S. (2019). How social capital affects innovation in a cultural network: Exploring the role of bonding and bridging social capital. European Journal of Innovation Management, 23(5), 895–918. https://doi.org/10.1108/EJIM-06-2018-0114

Cerchione, R., & Esposito, E. (2017). Using knowledge management systems: A taxonomy of SME strategies. International Journal of Information Management, 37(1), 1551–1562.
Tidd, J., Bessant, J., & Pavitt, K. (2001). Managing innovation: Integrating technological, market and organizational change (3rd ed.). NJ: John Wiley and Sons Inc.

Van Looy, A. (2021). How the COVID-19 pandemic can stimulate more radical business process improvements: Using the metaphor of a tree. Knowledge and Process Management, (n/a). 1–10. https://doi.org/10.1002/kpm.1659

Weber, B., & Heidenreich, S. (2016). Improving innovation capabilities by cooperation: Examining effects of core network management functions and relational mechanisms in the industrial goods sector. International Journal of Innovation Management, 20, 1650074.

Wellman, J. (2009). Organizational learning: How companies and institutions manage and apply knowledge. New York: Palgrave Macmillan.

Wu, D., Rosen, D. W., Wang, L., & Schaefer, D. (2014). Cloud-based design and manufacturing: A new paradigm in digital manufacturing and design innovation. Computer-Aided Design, 59, 1–14.

Yin, R. K. (2003). Case study research: Design and methods (3rd ed., pp. 1–181). CA: Sage Publications.

Zhu, K. (2004). The complementarity of information technology infrastructure and e-commerce capability: A resource-based assessment of their business value. Journal of Management Information Systems, 21(1), 167–202.

How to cite this article: Ceci F, Lazoi M, Lezzi M, Mohammad H. Fostering knowledge sharing in the innovation process: Information and communication technology-based versus face-to-face relationships. Knowl Process Manag. 2021; 1–15. https://doi.org/10.1002/kpm.1668
ANNEX AND TABLES A.

Annex 1 - Questionnaire

Activities
1. Could you illustrate the business activities of your company?
2. How is the workflow (process) inside your organizational unit (division), from the first contact with the customer until the manufacturing, the postselling support and the maintenance activities?

Relationship
For each phase of your workflow, could you specify:
1. Which units (divisions)/persons your unit interface with?
2. Which is the meeting frequency?
3. Which are the relationship types (formalized, agreements, etc.)?
4. In which way? (phone, e-mail, mail, face-to-face)?
5. Which is the meeting duration?
Could you describe the relationships with:
6. Other units (divisions)?
7. Other plants?
8. Occasional/unoccasional suppliers?
9. Customers?
10. Competitors?
11. Other important relationship (universities, research centers, consulting firm, government agency, trade-union, etc...)?

Information technology
12. Do you use ICT technologies? Which? (ERP, internet, E-mail...)
13. Are some processes performed with the support of information technologies?
Do you use ICT in the relationship with:
14. Customers?
15. Suppliers?
16. Other units?
17. Other divisions?
18. Other?
19. Could you explain how they work?
### Annex 2 - Dictionary Emergent from the Data

1. **Innovative activities:**

| Activity                         | Description                                                                 |
|----------------------------------|-----------------------------------------------------------------------------|
| Change management                | Change, improvement, programs                                               |
| Process improvements             | Process, activity, new, change, engineering, solution, improvement, need, internal |
| Product innovation               | Component, gearbox, turbine, engine, system, product, new, change, engineering, research |
| ICT innovation                   | Partner, unity, improvement, development, technologies, information technologies, new, change, 3D, CAD, PLM, internet, need SAP |

2. **Operative activities:**

| Activity                         | Description                                                                 |
|----------------------------------|-----------------------------------------------------------------------------|
| Product manufacturing            | Factory, production, job, development, integration, internal, product, process, engine, gearbox, turbine, aeronautic |
| Product data management          | Type, model, dimension, sequence, data, details, parts, item, definition, requirement, phase, standard, specification, features, code, resource, level, structure, request, information, PLM |
| Product design                   | Differentiation, calculus, project, development, model, design, aeronautic, system, product, component, gearbox, turbine, engine |
| Quality control                  | Quality, analysis, check, process                                           |
| After-sales                      | Service, check, support, management, process, revision                      |

3. **Strategic activities:**

| Activity                         | Description                                                                 |
|----------------------------------|-----------------------------------------------------------------------------|
| Production planning              | Time, duration, cost, competency, resource, order, demand, capacity, management, problem, project, activity, procurement |
| Customer management              | Request, terms, order, need, programs, partner, agreement, management       |
| ICT management                   | Technologies, internet, computer science, SAP, workflow, PLM, applications, portals, tools |
| Supplier management              | Supplier, management, order, time, capacity                                  |

4. **Internal relations:**

| Activity                         | Description                                                                 |
|----------------------------------|-----------------------------------------------------------------------------|
| Inside the unit                  | Group, colleague, unit, together, team                                      |
| Between units                    | Headquarter, plant, division, units, department                             |
| Collaboration based              | Collaboration, internal, interaction, sharing, information, respect, informal |

5. **External relations:**

| Activity                         | Description                                                                 |
|----------------------------------|-----------------------------------------------------------------------------|
| Suppliers                        | Supplier, sharing, formal, consulting                                       |
| Customers/partners               | Customer, partner, formal                                                   |
| Other actors                     | Competitor, university, association, formal                                 |
| Other plants                     | Plants                                                                      |
| Collaboration based              | Respect, collaboration, sharing, exchange, unit, together, communication, team, network |

6. **Face to face contacts:**

| Activity                         | Description                                                                 |
|----------------------------------|-----------------------------------------------------------------------------|
| Face to face                     | Meeting, course, communication, contact, conversation                       |

7. **ICT tools:**

| Activity                         | Description                                                                 |
|----------------------------------|-----------------------------------------------------------------------------|
| ICT for design                   | Unigraphics, CAD, 3D, PLM, software                                          |
| ICT for communication            | Email, internet, workflow, netmeeting, portal, computer                     |
| ICT for management               | Portal, SAP, workflow, computer                                             |
### Annex 3 - Coding Form

#### Final coding form

| Node                          | Interviews | Sentences | Words  |
|-------------------------------|------------|-----------|--------|
| **1) Innovative activities** |            |           |        |
| Change management             | 4          | 12        | 1,293  |
| Process improvements          | 9          | 34        | 2,126  |
| Product innovation            | 8          | 20        | 1,550  |
| ICT innovation                | 12         | 81        | 6,038  |
| **2) Operative activities**   |            |           |        |
| Product manufacturing         | 10         | 58        | 4,308  |
| Product data management       | 11         | 46        | 2,766  |
| Product design                | 10         | 86        | 6,518  |
| Quality control               | 6          | 14        | 723    |
| After-sales                   | 4          | 13        | 498    |
| **3) Strategic activities**   |            |           |        |
| Production planning           | 7          | 19        | 1,755  |
| Customer management           | 6          | 24        | 1,786  |
| ICT management                | 9          | 78        | 5,382  |
| Supplier management           | 8          | 31        | 2,039  |
| **4) Internal relations**     |            |           |        |
| Inside the unit               | 12         | 74        | 4,816  |
| Between units                 | 12         | 147       | 10,298 |
| Collaboration based           | 6          | 14        | 909    |
| **5) External relations**     |            |           |        |
| Suppliers                     | 12         | 85        | 4,364  |
| Customers/partners            | 12         | 114       | 7,475  |
| Other actors                  | 12         | 52        | 2,296  |
| Other plants                  | 12         | 57        | 3,069  |
| Collaboration based           | 6          | 18        | 1,087  |
| **6) Face-to-face contacts**  |            |           |        |
| Face to face                  | 12         | 66        | 3,967  |
| **7) ICT tools**              |            |           |        |
| ICT for design                | 10         | 45        | 3,405  |
| ICT for communication         | 12         | 76        | 2,759  |
| ICT for management            | 12         | 61        | 3,554  |