# 과학기술지식 생산과 공유를 위한 협력 유형분류체계

## A typology of Collaboration Modes for Scientific and Technological Knowledge Production and Sharing

황 금 주 전남대학교 경영대학 경영학부 조교수 (kumju@chonnam.ac.kr)

ABSTRACT

This paper suggests a typology of the modes of collaboration for scientific and technological knowledge production and sharing (STKPS) based on knowledge communication types, including organizational factors, communication channel, intensity, and decision-making, that affect STKPS processes. It is mainly designed to rearrange ideas about collaboration drawn from the literature in order to develop a conceptual framework for categorizing modes of collaboration based on how communication patterns shape four modes of collaboration. In the conclusion and discussion part, practical implications, limitations of this study, and further studies are discussed. In particular, the practical implications propose communication patterns suitable for five stages of collaboration processes. As the collaboration initiation or set-up stage is critical, extensive face-to-face communication is recommended in the auditing stage. In the execution stage, media-based communication can be actively utilized, because collaborators will mostly exchange explicit codified knowledge supported by IT. The evaluation and reinforcement stages concentrate on tacit knowledge exchange and explicit knowledge evaluation, which requires intensive face-to-face communication including negotiations for evaluating collaboration outcomes and partnership.

***Keywords :*** *Collaboration for Scientific and Technological Knowledge Production and Sharing, Communication Patterns, Collaboration modes*

## Ⅰ. Introduction

### 1. Collaboration for Scientific and Technological Knowledge Production and Sharing

Since the 1990s, academic, industrial, governmental, and international collaboration has been proliferating (Adler et al., 2009), particularly collaboration involving scientific and technological knowledge production and sharing (STKPS). Collaboration did not originate from current scientific practice, but rather has a long history with big science (Heilbron, 1992). Collaboration has also been treated as a managerial tool for increasing scientific productivity or seeking financial rewards. For example, governments enthusiastically encourage collaboration under the banner of international competition. University–industry (U-I) collaborations have been actively utilized to obtain basic and applied technological knowledge that can yield high payoffs and act as a source of competitive advantage for both private firms and entire countries (Spencer, 2001, p. 432).

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† 교신저자
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Etzkowitz and Leydesdorff's (1997) triple-helix model (university-industry-government alliances for research collaboration)and Gibbon's et al.'s (1994) new mode of knowledge production (distinguished from the traditional disciplinary-based knowledge production based on linkages among academia, industry, and government) epitomize the process of how collaboration for STKPS has been established in a highly competitive, knowledge-based economy (Leydesdorff and Etzkowitz, 1997).

Many variables contribute to the classification of collaboration modes. The current study specifically focuses on modes of collaboration for STKPS. Some scholars (Rosenfield, 1992; Turner, 1992) have speculated that the modes of collaboration are determined by cross-disciplinarity. Luzski (1958) provided a complex matrix of variables, such as the standpoint of the research problem, theory, methodology, and group functioning, that can be used to elucidate the modes of collaboration. Given that communication can be used as the base system in collaboration for STKPS (Cohen and Levinthal, 1990; Eppler, 2007), this article considers communication to be primary. In addition, as the primary objective of collaboration is knowledge production and sharing, including traditional inter-disciplinary knowledge production and new modes of knowledge production (Gibbons et al., 1994), this study specifies communication in collaboration as knowledge communication. Eppler (2007) defines knowledge communication as the deliberate activity of interactively conveying and co-constructing insights, assessments, experiences, or skills through verbal and non-verbal means (p. 291).

## 2. Research Approach

Collaboration is the collective and organizational performance of the production and exchange of scientific and technological knowledge. Accordingly, this study develops a typology presenting modes of collaboration for STKPS by incorporating knowledge communication and organizational factors. The study will critically review extant theoretical and empirical representations of collaboration for STKPS as such understanding is expected to provide important implications for the management capacity of successful collaboration. To this end, the current notions of collaboration will be examined and challenged. As part of this reconceptualization, it is proposed that more theoretical and empirical attention will be given to knowledge communication interlinked with organizational factors.

Accordingly, this study provides a literature review on collaboration for STKPS and discusses knowledge communication as a framework to understand the process of collaboration. Thus, a typology of collaboration modes developed in relation to other work in the field, considering communication patterns linked to organizational factors, is outlined. Individual collaboration modes in the typology are explained in detail by presenting cases. The conclusion and discussion part includes practical implications with proposing communication patterns suitable for five stages of collaboration processes and limitations of this study, and finally suggests further studies.

## 3. Research Purpose

The current paper suggests a typology of the modes of collaboration for STKPS based on knowledge communication types, including organizational factors, communication channel, intensity, and decision-making, that affect STKPS processes. It is mainly designed to rearrange ideas about collaboration drawn from the literature in order to develop a conceptual framework for categorizing modes of collaboration based on how communication patterns shape various modes of colla-

boration. This study aims to understand how collaboration for STKPS can differ across knowledge communication types, including communication elements interlinked with organizational factors, which can be useful for designing appropriate knowledge management.

## II. Literature Review

### 1. Literature Review on Collaboration

The literature on collaboration can be broadly classified into four categories. The first category includes literature on collaboration resulting in written works published collaboratively (e.g., Bordons et al., 1999; Glänzel et al., 1999; Gordon, 1980; Spencer, 2001; Wagner and Leydesdorff, 2005). The literature in this category commonly raises issues related to growing international research networks and snowballing interdisciplinary collaboration by using a bibliometric analysis method. However, research in this category cannot scrutinize the causes and effects of collaboration or its social implications in depth. More importantly, this literature does not probe what collaboration represents and implies in the course of the transformation of scientific inquiry per se, although it can function as an affirmation of the proliferation of collaboration.

The second category of collaboration research literature pertains to the history of big science that necessarily entails large-scale collaboration (e.g., Everitt, 1992 Heilbron and Seidel, 1989). This literature refers to the history and background of big science and is of use when investigating how social contexts influence and generate collaboration. For example, Galison and Helvy (1992) explored the origins and practice of big science. Their work provided useful insights into the social influences on big science as well as a comprehensive understanding of the implications of big science in a social, cultural, economic, and political context. The researchers further explored the manner in which scientists have used teamwork in the non-scientific spheres outside their disciplines in large-scale research, which helped explain how scientists adjust to new research conditions while conforming to an embedded culture. Yet literature in this category does not account for the spread of collaboration into all fields of science, from big science to little science. Indeed, little science has also become more collaborative. The literature in this category provides a partial source of information on collaboration.

The third category of research literature is related to organizational and operational collaboration (e.g., Adler et al., 2009; Fusfeld and Haklisch, 1984; Knorr-Cetina, 1999; Mackenzie and Jones, 1985; Schaffer, 2008; Traoré and Landry, 1997; Vaughan, 1999). This category focuses on socio-structural aspects of collaboration in that it refers to structural determinants of collaboration at national and international levels. This category is useful for understanding the organizational aspects of collaboration in terms of social changes and organizational distribution of material resources for knowledge production (e.g., funding and equipment). However, a common problem that emerges in this literature is the lack of explicit theoretical frameworks that fit into a sociological theory that explains the organizational aspects and determinants of collaboration. Knorr-Cetina's (1999) study and Vaughan's (1999) research in this category are particularly important these studies approach communication as a constituent of collaboration. Given the extremely limited research into communication as one aspect of collaboration, the significance of these two studies in the literature review is evident. Knorr-Cetina's (1999) study and Vaughan's (1999) research, which will be discussed in greater detail later, have become critical sources for developing

the typology of modes of collaboration in the current study.

The fourth and final category of research literature explains collaboration from the perspectives of business management and science and technology policy-making. This category examines the degree to which collaboration can bring benefits and drawbacks to businesses by producing and transferring scientific and technical knowledge as well as managing intellectual property (e.g., Ganesan and Kelsey, 2006; Inkpen, 1996; Marjit and Mukherjee, 1998; Vonortas, 1997). Perceiving collaboration as a practical method for producing and transferring knowledge is beneficial in that it allows for the understanding of why collaboration occurs and what functions collaboration serves. However, the problem with this literature is that it views collaboration as a mere managerial tool rather than as a distinct mode of knowledge production and dissemination. By following this managerial perspective, it is not possible to elucidate which social implications, organizational effects, and changes of knowledge production and dissemination systems are derived from collaboration.

Based on this literature review, a lack of research exists in micro-level management (e.g., communication, leadership, and decision-making processes) of collaboration for STKPS.

## 2. Knowledge Communication as a Fra-Mework of Collaboration Processes

Literature on knowledge management has recently expanded. According to Harada (2003), "knowledge management addresses the generation, representation, storage, transfer, transformation, application, embedding, and protecting of organizational knowledge" (p. 1738). The knowledge management literature tends to focus on management of tacit knowledge as a primary source of competitive advantage and design of interactive groupware technologies for sharing tacit knowledge (e.g., Hedlund, 1994; Nonaka, 1994; Nonaka and Takeuchi, 1995). However, most knowledge management literature limits itself predominantly to the intra-organizational setting rather than the inter-organizational context. Furthermore, knowledge management literature has focused on macro research into knowledge transfer at the organizational level (Szulanski, 1999) as well as the general motivational barriers to knowledge transfers (Husted and Michailova, 2002).

Although knowledge management-including knowledge production and sharing-becomes increasingly critical for most organizations, particularly high-technology and knowledge-based industries, knowledge production and sharing have not been sufficiently studied (Bircham-Connolly et al., 2005; Davenport and Prusak (1998); Dixon, 2002). Worasinchai and Bechina (2010) pointed out that several knowledge-sharing models exist, including direct interactions between people (as in Lederberg's model or Nonaka and Takeuchi's model) and indirect interaction through document creation (e.g., the drafting and delivering of reports) (p. 173). In addition, these knowledge-sharing models limit themselves to the intra-organizational level, which does not elucidate inter-organizational dynamic processes of sharing and transforming knowledge created by inter-organizational collaboration (e.g. university-industry R&D collaboration)into individual organizational knowledge.

Unlike knowledge management literature, the field of knowledge communication focuses on the micro aspects of knowledge transfer, emphasizing the role of communication behavior patterns for knowledge transfer (Eppler, 2007). Eppler (2007) maintained that "knowledge communication designates the successful

transfer of know-how (e.g., how to accomplish a task), know-why (e.g., the cause-effect relationships of a complex phenomenon), know-what (e.g., the results of a test), and know-who (e.g., the experiences with others) through face-to-face (co-located) or media-based (virtual) interactions" (p. 292).

It is important to emphasize a holistic understanding of knowledge communication, as Eppler (2007) contended that "communication cannot be limited as a tool to transmit pieces of information but should be viewed as creating contexts of re-constructing insights, new perspectives, or new skills as well as sharing or disseminating information and emotions" (p. 292). Moreover, the holistic understanding of knowledge communication has a thread of connections with a ritualistic view of communication. According to Carey (1989), the ritual view of communication perceives the original or highest manifestation of communication not in the transmission of intelligent information, but in the construction and maintenance of an ordered and meaningful cultural world that can serve as a control and container of human action (pp. 18-19). Consequently, communication is regarded as a social and cultural interaction in which the social interaction of communication occurs not only through messages, but also through the performance of the production and exchange of messages.

Many studies have tackled the interaction between the innovation and development of information and communication technologies (ICT) and the evolution of organizations' capacity for new knowledge generations (e.g., Antonelli et al., 2000 Ataman, 2004; Hendriks, 1999), and decision-making (e.g. Russo and Shoemaker, 1989; Zaltman, 1983).

However, despite the fact that communication is a key activity in organizational knowledge production and sharing (e.g., Browne and Ramesh, 2002; Eppler, 2007; Gratton and Goshal, 2002; Straub and Karahanna, 1998), few studies have delved deeply into organizational factors and contexts of knowledge communication, let alone knowledge communication in the context of collaboration for STKPS.

## III. Typology of the Modes of Collaboration

### 1. Criteria for the Typology of Collaboration Modes

Collaboration is the interface between organizations. In most cases, individual actors in collaboration represent individual organizations that collaborate as a member of their mother organizations. Consequently, collaborators behave within their organizational norms and rules as well as cultures or climates rather than constructing another behavioral pattern and culture within the collaborative boundary. As a great deal of collaboration is transient and project-based, collaborators do not tend to build up new norms, behavioral patterns, or cultures for collaboration.

Collaborators generally use their organizational communication systems rather than build up new communication systems for collaboration. In addition, communication between collaborators follows organizational communication paths rather than individual communication paths. Individual actors may be able to take and develop interpersonal communication networks from their relationships with partners at later stages. Official communication tends to occur within organizational communication during collaboration. Hence, inter-organizational communication is a key scope of communication in collaboration, though collaboration also includes intra-organization, for example multi-disciplinary collaboration between departments at a university or a firm.

Neher (1997) highlighted an important point-namely, that organizational communication studies have expanded their boundary of business orientation to include the complexity of modern organizations such as universities, governmental agencies, non-profit agencies, and professional societies. Neher (1997) also identified the research scopes of organizational communication, concluding that organizational communication scholars rely on the application of research in and principles resulting from the study of different levels of human interaction in organizational contexts. Organizational communication scholars are concerned with communication specifically at the organization-wide level, such as studying the flow of messages through networks linking groups within an organization and organizational climate or culture involving the entire pattern of relationships within an organization (Neher, 1997, p. 24).

Communication research related to collaboration would be very difficult and easily lost if one did not view the communication process of collaboration as organizational communication as collaboration embraces principles and research issues related to various levels of communication study, ranging from interpersonal to large group communication. In addition, how one views collaboration determines the focus of studies examining communication in collaboration. By emphasizing the interpersonal networks of collaboration or external boundaries spanning individuals'activities, interpersonal communication research might offer a more pertinent framework. It is particularly relevant in the examination of international collaboration seeking to tackle organizational culture or climate as organizational cultures are intertwined into organizational structures and hierarchy. In addition, the superior and subordinate relationships at the inter-organization-wide communication level can be relevant for core and periphery relationships.

Although very few studies investigate communication in collaboration for STKPS, many researchers in the field of operation management have looked into the relationship between inter-organizational communication and buyer-supplier performance (e.g., Carr and Pearson, 1999; Claycomb and Frankwick, 2004; Prahinksi and Benton, 2004; Cousins and Menguc, 2006). The positive role of collaborative communication in inter-organizational relationships has also been found in the relationship marketing literature (e.g., Anderson et al., 1994; Kogut and Zander, 1992; Mohr et al., 1996; Schultz and Evans, 2002). According to Modi and Mabert (2007, p. 45), the conceptual development of collaborative communication is guided by the literature related to the mechanistic perspective of organizational communication (Krone et al., 1987) and extensions in the context of inter-organizational communication by Mohr and Nevin (1990).

Mohr and Nevin (1990) suggested four essential aspects of inter-organizational communication, including frequency (the amount of communication), direction (the pattern of contact between organizations), content (message or information, including informal communication), and modality (medium of communication, such as face-to-face communication and e-mail). The typology of the modes of collaboration proposed here is intended to correlate collaboration modes with inter-organizational communication types to investigate how collaboration operates, using communication channels and intensity as primary criteria. Communication channels' (i.e., Mohr and Nevin's modality) criterion refers to the degree of openness and interchangeability of various channels. For example, it considers whether collaborators freely and interchangeably use verbal and written channels or channels used by technology. Communication intensity is Mohr and Nevin's frequency.

Meanwhile, the content aspect of Mohr and Nevin's inter-organizational communication model is a broader concept, although the current study discusses informal communication, focusing on the function of informal communication in collaboration. For instance, in some cases, collaborators use informal collaboration to build up collaborative relationships rather than to obtain information.

The purpose of collaboration may also govern communication types. For example, technology transfer based on service and consultancy communication can be limited within the technology transfer boundaries whereas collaborative knowledge production can encourage intensive and extensive reciprocity of communication. Communication type shares similar meanings and contexts of 'direction' in Mohr and Nevin's (1990) aspects. The communication type criterion is associated with the degree of exchange of ideas and information occurring freely in collaboration, which takes on two forms : reciprocal communication, which refers to the free exchange of ideas and information, and non-reciprocal communication, which is limited to consultancy and service. Communication intensity indicates the degree of the collaborators' interactions during collaboration. The criterion of decision-making processes relates to organizational dissimilarities between collaborative parties' organizational structures and cultures.

Organizational factors are important criteria that interrelate with communication channels and intensity in this typology. Rollinson et al. (1998) asserted that "organizational factors can interfere in a communication process and include organizational culture, structure, strategy, management style, and technology" (p. 158). They also argued that organizational structures and management styles-together with the organization's culture and size-have a combined influence on the communication process. Accordingly, organizational structure and decision-making processes are included as criteria of the suggested typology in this paper as various organizations with different organizational characteristics participate in the collaboration for STKPS. For example, universities (expert-centered decision-making and horizontal communication) and corporations (authority-centered decision-making and vertical communication) have different decision-making systems derived from their distinctive institutional characteristics.

Accordingly, the current paper developed a typology of collaboration modes based on five criteria drawn from Mohr and Nevin's essential aspects of inter-organizational communication and organizational structure and decision-making processes-namely, communication channels, communication types, communication intensity, organizational structure, and decision- making processes.

The proposed typology of collaboration modes will be initially classified as either a communitarian mode of collaboration, a democratic mode of collaboration, a hierarchical mode of collaboration, or a bureaucratic mode of collaboration.

## 2. Four Modes of Collaboration in the typology

A communitarian mode of collaboration implies that all communication channels are open and used freely and interchangeably the communication is reciprocal and communication intensity is high while a decentralized organizational structure is established in this mode. A democratic mode of collaboration is relatively open and interchangeable in communication channels it is a non-reciprocal type of communication of medium intensity that also involves a decentralized organizational structure.

<Table 1> Modes of collaboration and characteristics

| Modes of Collaboration | Criteria by the communication process | Features |
|---|---|---|
| Communitarian mode | Communication channels<br>Communication types<br>Communication intensity<br>Organizational structure<br>Decision-making | Open, free and exchangeable<br>Reciprocal<br>High<br>Decentralized<br>Scientists-centered |
| Democratic mode | Communication channels<br>Communication types<br>Communication intensity<br>Organizational structure<br>Decision-making | Relatively open<br>Non-reciprocal<br>Medium<br>Decentralized<br>Scientists-centered |
| Hierarchical mode | Communication channels<br>Communication types<br>Communication intensity<br>Organizational structure<br>Decision-making | Open<br>Non-reciprocal<br>Low or high<br>Centralized<br>Scientists-centered |
| Bureaucratic mode | Communication channels<br>Communication types<br>Communication intensity<br>Organizational structure<br>Decision-making | Restricted<br>Non-reciprocal<br>Low<br>Centralized<br>Administrative authority-centered |

The most important difference between these two modes is that a communitarian mode firmly establishes a sense of community between collaborators and shows stable and long-term communication whereas collaboration in university-industry (U-I) R&D collaboration is a typical example of the democratic mode of collaboration. Due to organizational tensions between university and industry described in the following section, free information exchange is not included in the democratic mode, which does not have a sense of community primarily.

Meanwhile, a hierarchical mode implies that communication channels are either limited or open. Formal communication is used more than the informal variety in this mode, but informal communication is open in certain cases. The hierarchical mode is also characterized by a non-reciprocal communication type, providing either low or high communication intensity. This mode contains a centralized organizational structure. Finally, a bureaucratic mode has restricted communication channels, non-reciprocal communication, a low level of informal communication, and low communication intensity. This mode also has a centralized organizational structure.

Decision-making processes remain scientist-centered in three modes-namely, communitarian, democratic, and hierarchical. In addition, the decision-making process includes open channels of communication among collaborators in these modes. In the bureaucratic mode, decision-making is hierarchical and administratively authority-centered. As this mode includes a management level as another layer of collaboration, decision-making processes exclude open channels of communication among collaborators who conduct scientific activities.

Accordingly, the Communitarian mode is ideal for in-depth and reciprocal collaboration with intensive communication compared to the other three modes.

The Democratic mode has limited communication, yet it uses open communication channels, however non-reciprocity restricts more interactive collaboration. The Hierarchical and the Bureaucratic modes show non-reciprocal communication in the centralized structure which restricts interactive collaboration compared to the Democratic mode.

## IV. Cases of Collaboration Modes Applied According to the Typology of Collaboration Modes

It should be noted that collaboration cases of the Communitarian mode and those of the Bureaucratic mode are very rare, and most collaboration cases may be classified into either the Democratic or the Hierarchical mode depending on characteristics and purposes of collaboration. In this section, cases which represent individual modes will be presented.

### 1. Communitarian Mode of Collaboration

Collaboration can sometimes be firmly established by the content of science. For example, in big science, a communitarian mode of collaboration is common. Knorr-Cetina (1999) described the collaboration mode of experimental high-energy physics (HEP) as a post-traditional communitarian structure (p. 180). She further defined a post-traditional communitarian structure as structural forms that attempt to implement collective ways of working and downgrading the individual to an epistemic subject, emphasizing that such communitarian mechanisms involve collective ownership and 'free' circulation of work (p. 165). According to Knorr-Cetina, the collaboration of HEP is characterized by management through the content, is based on distributed cognition, and is linked to communitarian mechanisms. This intersection of management through the content and communitarian mechanisms is reflected in all levels of collaboration, including the organizational format, form of leadership, and group structure. Knorr-Cetina made an interesting point : Collective consciousness produced by discourse as a moral force enables voluntaristic collaboration (pp. 179-180).

Although Knorr-Cetina (1999) delivered an opaque concept of 'collective consciousness,' she suggested that a moral force is a collective consciousness that generates a communitarian mode of collaboration. In the current paper, collective consciousness is perceived as a sense of belonging and a collective identity. Furthermore, a 'moral force' refers to organizational integrity that reinforces and sustains a particular organizational culture that reflects organizational behavioral rules and individuals' normative obligations.

Communitarianism is an ideology that affects the organizational culture and integrity as well as members' collective identity. Members' communitarian attitudes can initially be channeled by organizational contexts, which in turn are formed by the scientific content. Collaboration generated by the content eliminates competition between collaborators as an individual knowledge producer and maximizes organizational stability. Collaborators are collectively aware that they are elements of the organizational structure and that this structure is derived from the scientific content necessitating collaboration. This organizational structure enables intensive and discursive communication. In this sense, discourse reflects and maintains an actor's communitarian attitude. Communitarianism as an organizational ideology is a pivotal impetus in producing a communitarian mode of collaboration. The firm sense of community among collaborators also seems to distinguish the Communitarian mode of collaboration from the Democratic mode of collaboration.

In addition, the organizational contexts in experimental HEP contain open communication channels and show high communication intensity. As Knorr-Cetina explained, discourse generates collective consciousness, and communitarianism operates through communication. Furthermore, organizational contexts encourage discursive communication, which occurs in all situations in this collaboration.

As collaborators freely exchange their ideas and information through discursive forms of communication, their collaboration relies on reciprocal communication. A decentralized organizational structure is thus established, and the decision-making processes are attributed to scientists (Knorr-Cetina, 1999). Overall, the organizational structure is decentralized.

Knorr-Cetina (1999) further stated that "information need not be gathered and processed by a centralized control hierarchy that decides what is to be done and issues commands to individuals who then perform the task. Proliferated discourse spaces exist, and they include formal and informal space" (pp. 173-174). Based on this understanding, a decentralized organizational structure exists alongside freely open and exchangeable communication channels and collaborators' use of informal and formal situations in he Communitarian mode.

## 2. Democratic Mode of Collaboration

For technology-intensive firms, the use of inter-organizational networks necessary for obtaining key knowledge is inevitable (Liebeskind et al., 1996; Owen-Smith and Powell, 2004; Powell et al., 1996; Song, 2006). Technology-intensive firms tend to engage in external R&D collaborations with universities, research institutions, and venture companies (Owen-Smith and Powell, 2004). Obtaining key knowledge requires a high level of absorptive capacity (Cohen and Levinthal, 1990) as well as extensive interactions between knowledge seekers and knowledge bearers (Almeida and Kogut, 1999). This R&D collaboration between university and industry is an example of the democratic mode of collaboration. From the university collaborators' point of view, the R&D collaboration is characterized by a trade-off between funding for knowledge production and organization maintenance and focused research interests in commercially applicable scientific knowledge.

Despite the shared necessity of the R&D collaboration between collaborators, communitarianism does not exist in this type of collaboration. Organizational tensions can be the most critical barrier impeding extensive interactions in the R&D collaboration between the university (public knowledge production and dissemination oriented) and the company (commercialization of scientific knowledge oriented) (Bjerregaard, 2010; Kang and Park, 2005). Bjerregaard (2010) explained that, "conflicting institutional logics gave rise to competing conceptions of the time horizon for the concrete project work. The public researcher attempted to extend the project period for the R&D work in order to ensure the research quality in accord with scientific criteria required for publication, whilst the SME (Small-Medium enterprise) partner initially tried to pull the project in the opposite direction towards fast commercialization and application" (p. 104). Indeed, due to different time orientations, face-to-face communication can be relatively limited.

Tensions derived from different organizational goals and culture between the university and the company can lead to communication problems affecting the ongoing collaboration management. According to Bjerregaard (2010), to overcome this problem, collaborators should engage in a trial-and-error process of negotiations and adaptations to new information with the col-

laboration partners. Accordingly, organizational tensions in the R&D collaboration produce relatively limited communication (i.e., a relatively insufficient knowledge exchange flow). In this case, information exchange can be minimal, and marginal tacit knowledge interchange occurs during collaboration.

Collaboration through the exchange of information is necessary, but Bjerregaard's (2010) study demonstrated that conflicting organizational goals and culture can seriously impede the knowledge exchange. Industry collaborators sometimes have to protect industrial data from being exchanged and protect the confidentiality of data from commercial information leaking. Consequently, collaboration takes the form of non-reciprocal communication. Information protection also restricts informal communication, which can cause other collaborators to suspect that information on their work may be leaked through informal communication. Communication intensity is essential for sharing tacit knowledge, yet information protection reduces communication intensity. The organizational structure is decentralized as the nature of R&D collaboration is project-based and laboratories in which university collaborators work remain fragmented (Knorr-Cetina, 1999). Each researcher provides technical expertise in collective projects. As a result, project-based collaboration leads decision-making processes to remain the responsibility of individual collaborators.

## 3. Hierarchical Mode of Collaboration

The hierarchical mode of collaboration is related to collaboration settings associated with the hierarchical relationship among collaborators. For example, specific technology transfer, in which a corporation provides funding to a university, is a hierarchical mode of collaboration. This case shows more service or contract based technology-transfer, which can be usually subsumed under collaboration, rather than U-I collaboration in the Democratic mode. As "a practical and strategic means of increased collaboration" (Andreosso-O'Callaghan and Qian, 1999, p. 123), technology transfer serves as an example of a hierarchical mode of collaboration. Cameron and Le Bas (1999) argued that "knowledge-especially tacit knowledge, such as uncodified knowledge, skills, know-how, and algorithms-is found primarily within the people who carry out the work" (p. 251). Thus, skilled manpower is the most important asset in the market related to the production and obtainment of knowledge.

However, short-term knowledge transfer indicates that technology transferors may not be willing to transfer tacit knowledge not explicitly required by transferees. However, tacit knowledge is a prerequisite for obtaining technology from the point of view of transferees.

Furthermore, Rothboeck (2000) asserted that "both technology and technological knowledge have an exclusionary component. Whereas the former turns out to be exclusive because transferred technology does not provide access to tacit knowledge, the latter denies access to networks for knowledge generation" (p. 53).

Thus, communication intensity might be low. In addition, communication channels might be open, but formal communication may be used exclusively. Informal communication and discursive conversations, which can be a good vessel for delivering tacit knowledge, may be limited. Extensive interactions-rather than codified written documents including codified knowledge-can enable collaborators to share tacit knowledge. As technology transfer is based on consultancy and service, this kind of collaboration uses non-reciprocal communication. Such collaboration is extremely transient in most cases, making it difficult to determine what organizational factors such collaboration exhibits. However, hierarchical relationships between trans-

ferors and transferees result in a centralized inter-organizational relationship. Unfortunately, literature examining communication processes and organizational aspects of collaboration for technology transfer is scarce.

## 4. Bureaucratic Mode of Collaboration

The bureaucratic mode of collaboration is related to the collaboration setting associated with an administrative structure. This administrative structure is often found in techno-scientific knowledge production in industrial or government-related organizations.

Vaughan's (1999) study of engineering decisions at the National Aeronautics and Space Administration (NASA) provides an excellent example of how scientists and engineers are excluded in terms of communication during higher-level decision-making processes in the bureaucratic mode of collaboration. The study further demonstrates how the bureaucratic mode shapes knowledge production processes in a techno-scientific collaboration. The major theme in Vaughan's work is the demonstration of the conjunction of organization and technology affecting the production of knowledge and knowledge claims on a routine basis (p. 915).

As in Knorr-Cetina's (1999) study of experimental high-energy physics presented in the Communitarian mode, Vaughan's (1999) case was subsumed under big science. The difference between the two studies is that Knorr-Cetina's case focused on a micro-level of organizational units in big science, whereas Vaughan's study focused on organizations that are meso-level structures. In other words, Knorr-Cetina's work targeted scientists' and engineers' work units, which form a micro level within the hierarchical administrative structure of big science. This unit is made up of separate work places for scientists and engineers. Other levels stand on top of this level in the entire organizational structure of big science. An administrative structure, decision-making structure, and managerial structure co-exist as different levels alongside the scientists' and engineers' work units at the fundamental level.

By envisaging layers of structures throughout the organizational structure of big science, one finds that managerial features are embedded in big science. Such bureaucratic features cannot be considered as collaboration. However, collaboration may imply that a body of knowledge is constructed in the form of a collective performance in the organizational context. Furthermore, knowledge production is constructed at various levels of decision-making processes in some examples of big science, as in the NASA case. Accordingly, bureaucratic features can also reflect collaboration modes.

Vaughan (1999) described the Flight Readiness Review (FRR), a multi-tiered, hierarchical, bottom-up pre-launch decision-making process (p. 924), arguing that the rule-governed organization organized the disorderly technology, systematically transforming messy, ambiguous evidence into science-based technical fact through the FRR process (p. 924). FRR involves four stages, with each stage moving up the hierarchy (from stage IV to I). According to Vaughan (1999), the FRR structure mirrors the physical joining of the component parts into a fully assembled vehicle (p. 925). Vaughan explored the communication issues in stage IV, stating that, "The full creole was legitimate cause for discussion, so the charts' restrictive quantitative data were supplemented by intuition, hunch, qualitative assessments and differences in epistemic cultures that became part of conversation. The core set disagreed and argued the technical issues" (p. 927).

As the stages move up the hierarchy, communication intensity decreases, communication channels be-

come restricted, and the communication type becomes non-reciprocal. For example, Vaughan states, "these upper-level reviews dramatically curtailed the amount of information that entered into the discussions. More significantly, also gone were the working engineers assigned to the booster project. They were free to attend, but no longer had an official voice, so the intricacies of booster technology known only to people closest to it were excluded from the discussion. Oral exchange was more formal and harshly adversarial" (p. 927). The restriction of discursive communication by controlling the use of the creole and the expression of scientific actors' individual and informal opinions made the communication less personalized. Quantitative data replaced human communication and were exclusively used as communicative agents. This is an excellent example of how scientific actors are excluded from higher-level communication in complex development projects.

Consequently, a bureaucratic mode of collaboration can be said to exist at the meso-level of organizational structure in big science. In this mode, communication channels are restricted, communication intensity is low, and the communication type is non-reciprocal. In addition, the organizational structure adopts a centralized form. The most important feature is that decision-making is hierarchical and administrative authority-centered in this mode.

## Ⅴ. Conclusion and Discussions

### 1. Conclusion

Various types of collaboration convey different patterns of communication. The dynamics of collaboration associated with the organizational context result in particular characteristics of collaboration being formed. Organizational tensions in R&D collaboration limit information exchange and reduce communication intensity. Meanwhile, the stable and expertise-centered organizational structure molds communitarianism in big science. In this case, intensive communication and free information exchange operate in the communitarian form of collaboration. Research into collaboration should not limit itself to either an intra-or an inter-organizational context. Collaboration includes not only U-I R&D collaboration and big science like high-energy physics, in which collaborators from various organizations gather to share equipment and the nature of the research requires many collaborators, but also highly structured organizations like NASA

On the other hand, communication patterns determine the modes of collaboration. Analyzing the communication process provides the most pertinent approach to understanding how collaboration is organized and operates. Such an analysis for each instance of collaboration can provide insights into the collaboration process, collaboration modes, and collaboration features associated with the dynamics of collaboration. For example, it cannot be understood how unruly technology (which systematically transforms messy and ambiguous evidence) becomes science-based technical fact through hierarchical and managerial communication processes without analyzing the communication processes in big science.

Moreover, the relationship between the superficial and apparent results of collaboration and what scientists and engineers are actually doing in the collaboration process is a significant issue to be discussed. The communication process reflects where scientific actors stand in terms of their organizational position and governs scientific knowledge as outcomes of collaboration. This point accounts for how close scientists are to the autonomy of organizational contexts that control knowledge production means and epistemic subjects. Scientists' autonomy of organizational con-

texts increases in remoteness, moving from a communitarian mode to a bureaucratic mode. Remoteness from scientists' autonomy of organizational contexts can be measured by examining communication patterns. This article has examined how working scientists and engineers assigned to the booster project were excluded from shaping scientific knowledge and decision-making in a bureaucratic mode.

## 2. Practical implications

Managing collaboration can be a challenge, as collaboration may encounter communication problems as well as potential conflicts and identity issues derived from various organizational settings, cultures, and goals. Collaboration is designed to achieve STKPS. In this sense, as many researchers have emphasized that tacit knowledge is key for the completion of collaboration for STKPS. In the tacit knowledge exchange, the communitarian mode could be optimal. It should be acceptable to say that tacit knowledge exchange for STKPS can be improved if the collaboration mode moves from the Bureaucratic mode up to Communitarian mode in the typology. For explicit knowledge exchange, as the Hierarchical and Bureaucratic modes are designed to exchange, store and present procedures and explicit knowledge, the two modes might set up better IT and information management systems than the Communitarian and the Democratic modes. However, implicit knowledge becomes an issue in collaboration for STKPS in terms of knowledge management, practical implications here focus on tacit knowledge exchange. Chang and Li (2007) suggested that "previous studies indicated that IT solutions can efficiently facilitate explicit knowledge access and utilization, while implicit knowledge sharing and transformation is decided by people-to-people interactions" (p. 479). A high-level of interpersonal interactions for implicit knowledge sharing and transformation requires trust and commitment likewise, the communitarian mode needs a collective sense of belonging and commitment based on shared goals, trust, perspectives, values, norms, and cultures. However, it is very difficult to reach the level of communitarian mode, which may require extensive interactions and long-term relationships. Accordingly, the democratic mode of collaboration can be more realistic and visible. In this sense, the practical implications should focus on how to facilitate the democratic mode of collaboration.

One clear disadvantage of the democratic mode is non-reciprocal communication types. To reduce the negative effect of the non-reciprocal communication that restricts extensive information exchange, collaborators should accept each other's goals, benefits, and advantages obtained from the collaboration. For this, they should openly discuss their limitations for information exchange and potential problems with organizational goals and individual authority granted from organizations.

For practical implications, I would like to suggest communication patterns suitable for individual collaboration stages of the collaboration process. As collaboration modes vary by purposes and natures of collaboration, it is difficult to make general collaboration processes applicable to every case of collaboration. Consequently, the current paper focuses on the U-I R&D collaboration representing the democratic mode. As U-I R&D collaboration has proliferated (Adler et al., 2009; Cyert and Goodman; 1997, Etzkowitz and Leydesdorff, 1997), but not yet well-established in terms of a micro-level of management, such as communication and decision-making (Adler et al., 2009; Cyert and Goodman, 1997; Erno-Kjolhede, 2001). Furthermore, intra-organizational collaboration has been studied in terms of interdisciplinary collaboration

(e.g. Bordons et al., 1999 Hinze, 1999), and technical communication related to the different use of technical terms across disciplines has become a main issue.

This paper takes Chang and Li (2007)'s five stages of knowledge management for the U-I R&D collaboration, including auditing, planning, execution, evaluation and reinforcement, and briefly suggests appropriate communication patterns for individual stages. It should be noted that though Chang and Li's stages are designed for knowledge management IT and portal systems, the stages also represent generic collaboration processes. In the auditing stage, individual partners should thoroughly check their knowledge resources, and this stage requires internal communication. U-I partners should agree with intensive communication with sufficient face-to-face communication which can facilitate reciprocal communication. In this stage, informal communication can boost morale amongst collaborators. Collaborators should intensively discuss about the scope information exchange, organizational goals, benefits, expectations, roles and responsibilities, etc. As such, the collaboration initiation or set-up stage is critical, and extensive face-to-face communication is recommended.

In the execution stage, collaborators will individually conduct allocated work, and mostly exchange explicit codified knowledge supported by IT. Media- based communication can also be actively utilized in this phase of collaboration. The evaluation and reinforcement (developing knowledge management processes for future collaboration) stages concentrate on tacit knowledge exchange and explicit knowledge evaluation, which requires intensive face-to-face communication. Communication in this stage concentrates on negotiations for evaluating collaboration outcomes and partnership. Moreover, intensive communication can build positive relationships, which in turn can lead to long-term collaboration.

## 3. Limitations and Further Studies

Criteria used to analyze the communication patterns in this typology formed useful analytical categories. They can be used to examine how individual collaboration operates and what underlying systems it employs. Communication intensity, channels, and types along with organizational factors represent the communication patterns of collaboration, which in turn reflect how collaboration operates.

Nevertheless, it should be emphasized that the aim of the fourfold typology of modes of collaboration is to show how communication patterns shape different characteristics of collaboration. The fourfold typology arises from rearranging ideas about collaboration drawn from the literature. As such, this typology is not designed to classify individual collaboration, but to exemplify how communication patterns shape various modes of collaboration. In addition, this typology is a conceptual framework that can be used for making broad distinctions between modes of collaboration. Thus, the actual function of the typology is rather to exhibit how communication patterns form conceptual modes relating to scientists'autonomy in organizational contexts, increasing in remoteness from a communitarian mode to a bureaucratic mode.

The limitation of this study lies in the fact that this typology is rather conceptual than practical. Future research should concentrate on finding what communication patterns and organizational factors can facilitate collaboration processes and important successful factors for collaboration by providing in-depth case studies or both quantitative and qualitative empirical research. Additionally, further studies should focus on specific contexts of collaboration, such as U-I R&D collaboration, rather than aim at generic collaboration. Individual criteria for the typology of collaboration modes, communication channels, types and intensity, and organizational structure and decision-making processes,

can be further studied in-depth according to stages of the collaboration process.

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## 저 자 소 개

황 금 주 (Kumju Hwang)

현재 전남대학교 경영대학 경영학부 조교수로 재직 중이다. 이화여자대학교를 졸업하고 University of Reading에서 커뮤니케이션 석사, 영국 Imperial College, University of London에서 경영학박사를 취득하였다. 주요 관심분야는 R&D 지식경영과 지식커뮤니케이션, 녹색소비자 구매의사결정과 녹색마케팅, Integrated Marketing Communication, 국제협상 등이다.