Knowing What We Know Differently:
Knowledge Heterogeneity and Dynamically Ambidextrous Innovation

Introduction

Innovation is the constant creation, exchange and application of cross-boundary knowledge through systematic routines and/or informal interactions among knowledge workers (Cohen & Levinthal, 1990; Madhavan & Grover, 1998; Ikujiro Nonaka & Takeuchi, 1995). From this perspective, innovation constitutes a major source of the diverse-knowledge-based dynamic capability for organizational value creation, inter-firm competitive advantage and industrial heterogeneity (K. M. Eisenhardt & Martin, 2000; O'Reilly III & Tushman, 2008). Successful and competitive innovations rely on effective knowledge management implemented by a group of people who possess heterogeneous knowledge within identical governing structures (Grant, 1996a). Diversity may also be treated as a knowledge-based resource for innovation and firm performance (e.g., Richard, McMillan, Chadrick, & Dwyer, 2003). However, diverse human groups make the communication, organization, and integration of diverse knowledge challenging (Dougherty, 1992; Kearney, Gebert, & Voelpel, 2009; Smith, Collins, & Clark, 2005). From this viewpoint, knowledge heterogeneity (KH) (i.e., variety or diversity in knowledge composition) as a strategic resource is a more specific and direct construct affecting knowing and innovation processes (Cohen & Levinthal, 1990; Laursen, 2012; Laursen, Leone, & Torrisi, 2010), as resource configuration may be more important than the resource itself (Galunic & Rodan, 1998; Lin, McDonough, Lin, & Lin, 2013).

Prior research has examined knowledge heterogeneity by studying diversity in professional backgrounds, such as educational or functional records, which have formally been referred to as

informational diversity. Informational diversity is distinct from generic demographic (e.g., gender, age, race, etc.) diversity in that it focuses on the informational element and its distribution within a collective (see reviews in Horwitz & Horwitz, 2007; Lawrence, 1997; Milliken & Martins, 1996; van Knippenberg & Schippers, 2007; K. Y. Williams & O'Reilly, 1998). The reason for adopting such indices for knowledge heterogeneity is their concise representation of different knowledge categories (areas) for the possibility of further knowledge re-combination and use (Laursen, 2012). Despite this merit, however, static, proxy-based conceptualization and measurement is less practical in capturing the most updated overall structure and the time-sensitive nature of KH. Investigation should be conducted more dynamically and directly from the heart of knowledge essence and the processing mechanisms per se (Harrison, Price, Gavin, & Florey, 2002; Lawrence, 1997). This is a problem for both researchers and practitioners when they attempt to explain phenomena and solve problems with outdated understanding and measurement of knowledge. Because information and knowledge are constantly in flux within organizations (Tsoukas, 1996), knowledge diversity, seen as a variety of informational resources (cf. Harrison & Klein, 2007), can change over time spans, thus demanding a dynamic conceptualization at different levels of analysis[1].

The present study sets out to fill this gap by re-conceptualizing KH in order to examine its

[1] Note that the major purpose of this paper is not to make a distinction between demographic and informational diversities. Literature reviews and meta-analyses have revealed the difficulty in consistently and conclusively establishing differential effects of less job-related or demographic diversity compared to more job-related or informational (and thus knowledge-related) diversity on relevant outcomes (e.g., Horwitz & Horwitz, 2007; Van Knippenberg et al., 2004; Van Knippenberg & Schippers, 2007; Webber & Donahue, 2001). Rather, we concentrate on elaborating on the essence of the latter: within informational types of diversity, we wish to develop a more status quo and dynamic conceptualization for the concept of knowledge heterogeneity in order to benefit this and future research's application of this construct in explaining its relationships with other constructs (e.g., the ambidexterity in innovation).

influences on multidimensional innovation. For the first part of the research, we propose a re-conceptualization of KH with concerns about its structural and dynamic nature (Jackson, May, & Whitney, 1995) by jointly grounding on the locus and timing of knowledge processing. Clearly, the Organizational Learning literature using the Knowledge-based View notes that knowledge at different organizational levels changes over time (Crossan, Lane, & White, 1999), and such changes affect important organizational outcomes, such as innovation patterns and performance (March, 1991; Taylor & Greve, 2006). First, Locus of knowledge refers to the location where knowledge activities are implemented (Felin & Hesterly, 2007; Pisano, 1994), which leads to the differences between local and common knowledge (Dixon, 2000; Grant, 1996a; Postrel, 2002). From this locus-of-knowing perspective, although individuals carry knowledge, innovative outcomes are often generated by collective knowledge processing. Collective knowledge for innovation does not present the mere sum of the discrete and often diverse pieces of individual knowledge — it needs constant re-use, re-combination or re-configuration to renew organizational advantages (Galunic & Rodan, 1998). In this vein, diversity in knowledge can be investigated from both individual and collective levels of analysis. Second, with regard to the timing of knowing, which refers to the time point and period when individuals and collectives are involved in knowledge processing, more *dynamic* assessments of the collective knowledge state (I. Nonaka, 1994), including heterogeneity, is demanded. Because the constant changes in knowledge activities may cause variance in the collective knowledge state, organization researchers need to conceptualize KH with its evolutionary natures. In this vein, the development of diversity in knowledge can be investigated from different time orientations and periods (Harrison et al., 2002). Summing up and integrating the above two perspectives, adopting an *ex ante* proxy conceptualization of KH, such as composite educational or functional records, may

be problematic because this conceptualization implies only the *potential* while ignoring the *actual* state of KH. Indeed, studies have noted that the benefit of diversity in a collective (e.g., team) can be fully utilized when this collective makes active use of this distributed and broadened information (e.g., Ely & Thomas, 2001; Van Knippenberg et al., 2004). Hence, a re-conceptualization is justified and needed.

In the second part of the research, two important aspects of innovation (i.e., dynamics and ambidexterity) are considered to further demonstrate the functionality of our re-conceptualization of KH. Among all of the dimensions of innovation, traditional ones (e.g., speed, targets (product or service or managerial), and so forth) have been extensively addressed (Damanpour, 1991; Damanpour, Walker, & Avellaneda, 2009), while fewer authors have systematically investigated the dynamic and ambidextrous dimensions. As the tenet rationale of this paper, knowledge is one of the most critical bases for innovation; thus, although we recognize the importance of other dimensions of innovation, in this paper, we focus only on the ones that correspond to the dynamic and complex nature of knowledge (Damanpour, 1996; Damanpour & Gopalakrishnan, 2001). Although existing studies have successfully looked into how specific sorts of ambidexterity can reconcile internal diversity (Wang & Rafiq, 2014; Wei, Yi, & Yuan, 2011), few have demonstrated how diversity would influence the emergence of ambidexterity in innovation. Specifically, and respectively, these two aspects of innovation echo well the timing and locus of knowing elements of re-conceptualized KH. Recent studies have witnessed the importance of ambidextrous innovation, defined as the intent for, and the implementation of, both exploitative and exploratory approaches of organizational learning, improvement or creation (Birkinshaw & Gibson, 2004; Faems, Janssens, & Neyens, 2012; Gibson & Birkinshaw, 2004; He & Wong, 2004; Kostopoulos & Bozionelos, 2011; Lavie, Stettner, & Tushman, 2010; O'Reilly & Tushman,

2013; O'Reilly III & Tushman, 2008; Raisch & Birkinshaw, 2008). Exploitative innovation implies that innovative activities build on existing knowledge to extend existing products and services to existing customers, while exploratory innovation engages people in pursuing new knowledge and its creative applications (Benner & Tushman, 2003). This topic has also been studied in contexts of inter-organization relationships (e.g., Faems et al., 2012) and emerging economies that both characterize resource scarcity and high innovation intensity (e.g., Lin et al., 2013). While ambidextrous innovation has been proposed as a useful approach for strategic knowledge developments (e.g., organizational learning) (Kostopoulos & Bozionelos, 2011; March, 1991; M. L. Tushman & Smith, 2002), many issues regarding knowledge and ambidexterity have not been fully studied (e.g., Raisch, Birkinshaw, Probst, & Tushman, 2009, p. 397). Specifically, against the consensus that knowledge is the essential foundation for modern innovation models, relatively few have studied the impact of the knowledge structure, defined as a representation of how individual-level cognitions, experiences, and information are associated, configured and organized onto collective knowledge (Galunic & Rodan, 1998; Kuhn & Corman, 2003; Lyles & Schwenk, 1992), on ambidextrous innovation.

To sum up simply, two research questions are proposed here: What is the essence of knowledge heterogeneity? How does this complex essence of knowledge heterogeneity influence ambidextrous and dynamic innovation? In response, the purpose of this study is to develop a more holistic conceptual model of KH to further analyze its relationship with dimensionalized innovation, presented as propositions that merit future study. Motivated by the argument that background diversity in education/functions and the subsequent diversely developed knowledge should be distinguished and articulated (Kang, Yang, & Rowley, 2006; Tsai, Baugh, Fang, & Lin, 2014), we take an even more extensive approach that incorporates both types of diversity as

different but inter-related forms of an identical construct of knowledge heterogeneity. Further, we examine the impacts of various forms of KH on different dimensions of innovation. An inductive qualitative approach was taken for the collection, analysis and interpretation of our data materials.

Theoretical background

From the knowledge-based view (Felin & Hesterly, 2007; Foss, 1996; Grant, 1996b), innovation incorporates complex knowledge-processing activities and thus demands good governance of heterogeneous knowledge (for discussion of other non-knowledge antecedents of innovation, see reviews by Damanpour (1991, 1996)). Extended from the seminal works on demographic diversity that addresses interpersonal (dis-)similarities in human attributes (Tsui, Egan, & O'reilly, 1992; Tsui & O'Reilly, 1989), knowledge heterogeneity represents a deeper-level consideration of critical human expertise, cognitive schema, and knowing processes and thus should be distinguished from demographic diversity (Fiol, 1994; Harrison et al., 2002; H. M. Williams, Parker, & Turner, 2007). As Bae and Koo (2009) indicated, knowledge heterogeneity (as opposed to knowledge relatedness) refers to a state in which sets of knowledge is either functionally or technically dissimilar with one another. Based on this view, we further argue specifically that KH can be defined as *the state of a collective knowledge structure of an organizing unit in which the members configure knowledge of various attributes (e.g., tacit vs. explicit) from different disciplinary, managerial or technical areas by utilizing different processing methods.*

Although the content of knowledge measurement represents a rich strand of research, the structural view of KH within organizations has not been sufficiently investigated. Two theories facilitate our inter-disciplinary understanding of KH but fail to fully investigate the concept. On one hand, although the Knowledge-based View emphasizes inter-organizational or higher-level

heterogeneity (e.g., Dooley, Fowler, & Miller, 1996), intraorganizational heterogeneity of collective knowledge has received less attention. Research that focused on inter-organizational idiosyncrasies and competitiveness may easily assume internal knowledge homogeneity while formulating theories and analyses (Rodan & Galunic, 2004). Nevertheless, the strategic differences between organizations should stem from *both* internal and external differences in knowledge. Although intraorganizational KH may construct barriers to external organizations that wish to imitate valuable intangible assets, this heterogeneity may also cause difficulties for internal knowledge processes.

On the other hand, Demographic Diversity studies emphasize the use of diverse demographical records (e.g., education) as proxies that represent knowledge inputs (Simons, Pelled, & Smith, 1999; Smith et al., 2005). Nonetheless, the mere measures using past background diversity records, though professional, are insufficient in depicting the current state of knowledge as a result of their negligence of the dynamically developing nature of knowledge and the fact that knowledge heterogeneity is implicitly a deeper-level diversity (Kang et al., 2006). Theoretical reasoning and empirical evidence of the relations between KH and organizational outcomes (e.g., decision making, group interaction, and especially innovation) have been inconclusive. This finding may be caused by the fact that demographic diversity implies only the *potential* to access diverse knowledge sources that would enable multiple perspectives and non-repetitive ideas; however, these benefits from diversity may be *realized* only after successful collective knowledge processing, which is often characterized by communicational and decisional inconsistencies and even conflicts (Pelled, Eisenhardt, & Xin, 1999).

Therefore, while important, the previous conceptualization captures only a partial

understanding of KH, which may lead to a confused relationship that contradicts common wisdom. For example, people with diverse educational records may easily be expected to conflict with each other because of the diverse ways they were educated before joining the unit (Pelled et al., 1999). In fact, however, these people may be highly consistent in their cognition because they have been working or socializing together for a while. As an instance, Fagenson-Eland, Baugh and Lankau (2005) found that education differences do not reduce the perception congruence of mentor-protégé dyads. Because heterogeneity arises from the interactions among the structural, contextual and procedural aspects rather than just the description of differences in human profile (Ancona & Caldwell, 1992; Tsui et al., 1992), it is important to further distinguish individual versus collective and pre- versus post-organizing development of KH.

Moreover, the true meaning of knowledge cannot be fully justified without linking it to important organizing consequences such as innovation. Innovation and organizational change are inherently interwoven with knowledge processing, ambidexterity, and dynamics (Reissner, 2005; Wei et al., 2011), which justified our selection of the dynamic and ambidextrous dimensions of innovation. Kim, Im and Slater (2013) argued that different types of knowledge impact new product advantages differently. There have also been studies that partially research knowledge-related diversity at different levels of analysis (e.g., Al-Laham, Tzabbar, & Amburgey, 2011; Carayannis, Kaloudis, & Mariussen, 2008; Frey, Luthje, & Haag, 2011). In this vein, we further argue that the dynamic and ambidextrous dimensions of innovation cannot be ignored when discussing the impacts of knowledge and diversity. Because it is meant as a wide array configuration of knowledge and knowing methods, KH may function in different dimensions of innovation. Dynamics in innovation refer to the evolution, (dis-)continuity, and transformation of innovative actions and outcomes (Damanpour & Gopalakrishnan, 2001; O'Reilly III & Tushman,

2008). Ambidexterity represents the flexibility, scope and configuration of innovation (Lubatkin, Simsek, Ling, & Veiga, 2006; Raisch et al., 2009; M. Tushman, Smith, Wood, Westerman, & O'Reilly, 2004).

Methodology

The purpose of this research is to explore the essential meanings and influences of an important construct, namely, knowledge heterogeneity. Because of the exploratory nature of our research purpose, we adopted an inductive approach (e.g., Gioia, Corley, & Hamilton, 2013; Thomas, 2006) (see critical review in Guba & Lincoln, 1994). An exploratory case study with multiple material sources is appropriate for such innovative research questions on the construct (re-)conceptualization and the inter-construct relationship (Yin, 1994). For this investigation, we have designed a series of research actions to benefit construct meaning emergence and to achieve rigor in qualitative studies (Corley & Gioia, 2011; Gioia et al., 2013).

We chose to conduct interviews across a range of industries to maximize the scope of our analysis while extracting potential commonalities. Secondary data from newspapers, magazines, company publications (e.g., annual reports or meeting records), and websites were also analyzed (e.g., BusinessWeek, Fortune, The China Times, Commercial Times, CommonWealth Magazine, and the Wall Street Journal). Based on these information sources, we systematically constructed a set of case interviews by identifying the representative companies in the industries that contributed to the economy's innovation-based value creation. We sent out invitations to participate in the case study to companies listed by CommonWealth Magazine's Annual Top 1000 Companies, a leading and sound source referenced by studies of Taiwanese industries. Invitations were also based on the Ministry of Economic Affairs' Annual Representative Small

Business Enterprises in order to fulfill the goal of exploring identical phenomena across companies of different industries and sizes (and therefore combinations of attributes). Finally, through our own and expert opinions[2] (a simple survey for two practitioners, one government officer and seventeen professors), we were advised to contact twelve companies and a final of four companies responded by promising to join us with high level of participation (see appendix 1). The number of cases is comparable with studies on innovation (e.g., Marion, Friar, & Simpson, 2012), and each of the cases demonstrates our targeted research context where complex knowledge, human relations, and innovative activities are interwoven. We selected only case organizations that fit all of the following selection criteria well. First, the organization must be a benchmark in creating innovation policies and deploying assets and high-quality processes for implementing innovation. For example, as shown in the appendix, all four case organizations invest a high proportion of their finance capital in research and development. Second, the organization should constantly enrich their product, service and technological knowledge bases by knowledge management practices. All four organizations we selected have introduced fully functioning knowledge management systems (KMS). Third, the organization needs to perform a strategy with its core spirit to go beyond one single product, service, or market, and so on (e.g.,

[2] The invitation for experts was starting from an established professor who teaches and conduct research well on the topic of knowledge-based innovation. He referred the government officer and 6 professors to us (we invited other 11 professors based on our knowledge of who is qualified). The government officer then referred the two practitioners to us. Due to limited rationality we chose to rely on the knowledge-based trust on these experts' opinions when locating potential case organizations. We handed an extended abstract of the study (including the theory and methodology parts) to the experts and simply ask them to provide names of potential companies for us to invite (we did not limit the maximum number of invitation). Their answer was also simple – the organization names they think suitable for this study and may help for reaching the top management. They were also given an open question to address their thoughts on the core constructs of this study and the research on these constructs. From all of their provided names, we had 12 organizations that were commonly mentioned by all of the experts. Simply, the common reason expressed for the refusal of participation from these 12 organizations was the unfamiliarity to the core constructs. The responding four companies' participation were all based on the full top management supports and comprehensiveness of the core constructs– the top management got sympathy and can imagine about the phenomena related to knowledge heterogeneity and modern dimensions of innovation. For those four, we found that they just perfectly represented a good coverage of the twelve companies' types, so decided not to continue to expand the invitation. Such decision was also made due to the exploratory nature of the study.

sales to diverse downstream industries) in order to ensure a sufficient display of knowledge heterogeneity. All four organizations sell products and services produced with multiple technologies to a diverse set of markets or segments. Fourth, as our appendix indicates, the case organizations need to be the leading companies in their respective industries to ensure the representativeness of the cases and the materials collected by interviews and other methods.

A total of fifty-three interviews were analyzed (see appendix one). Because interviewees were from various roles and positions, the wording and examples in the "interview guidelines" offered to different interviewees for identical questions or constructs are slightly different; this ensures that the interviewees have the best understanding of our questions on the basis of their best knowledge. The interview guidelines were developed mainly based on the Miles and Huberman (1994) instructions, together with the abovementioned expert opinions. Some informants were interviewed repeatedly in order to address extensive questions about his/her previous interview comments, to clarify discrepancies between his/her previous comments and secondary data and to request referrals of further informants related to some of the previous comments. Further, we mixed the causal order of the questions in the interview protocol to a reasonable degree in order to prevent the interviewees from guessing the causality and connections between questions. We interviewed each interviewee one to three times. The primary interview languages were Chinese or English (some with a little Japanese); thus, all of the quotes were translated-back-translated before being presented here. The majority of interviews were completed between 2007 and 2011. To minimize subjective bias, all coding and categorizations were discussed and evaluated together by the research team of the author and two independent doctoral candidates in the innovation field (one of them is an experienced practitioner). For better argument quality, we triangulated the quotes with other sources of information or similar

quotes across the interviews (K. Eisenhardt, 1989). Overall, we adopted a procedure suggested by Hruschka and colleagues (2004, p. 311, p. 311) to improve inter-coder reliability. After the first interactive discussions of each of the coder's original and independent coding, averaged for every interview question, more than 85 % of codes had inter-coder reliability scores of Cohen's kappa that were larger than .9, and at least a kappa > .8 were gained for the other 15 % of codes, suggesting a high degree of inter-coder reliability. We also selectively summarized the significance of the findings (e.g., quotations and observations) and the strength of this evidence (indicated by the symbol '*') in the tables to facilitate our presentation. Below, we begin our discussion of the findings from dialectics between the informants' opinions, our observations and dialectics with the existing literature.

The major approach to obtaining the actual findings *and* developing further propositions was dialectics. We utilized a developed 2x2 framework that was strongly based on the locus- and timing-of-learning literature, which well incorporates and integrates both the Knowledge-based view and Diversity studies of Organization. Meanwhile, our qualitative approach enables us to analyze freely evidence in real organizational life. In sum, we parallel a guided theoretical frame and exploratory investigation of the findings based on qualitative data analyses. Through the dialectics between the two analyses, a re-conceptualization of KH and proposition development as a recursively confirmed exploration of our data was made. Below, we begin to develop the dialectics between the findings and theory. As stated above, the purpose of this paper is to develop a more holistic scheme of KH to further analyze its relationship with dynamic and ambidextrous innovation. Propositions 1 will fulfill the first part of the purpose, and proposition 2 will fulfill the latter part of the purpose.

Findings and Proposition Development

Re-conceptualization

We found evidence in support of the legitimacy of jointly adopting the timing- and locus-of-knowing dimensions. Our observations showed that organizations develop internal ecologies of diversified knowledge, composed of different human groups and knowledge objects and activities. Such diversified knowledge ecology is often developed in order to respond to complex and diverse external demands (Shaw, Hall, Edwards, & Baker, 2007). As one interviewee noted,

> "… in a world with short product life cycle, we do not just focus on one or a few very popular, hot-selling products. Instead, we develop many long-tailed products in many market segments, and as you know, in many different areas and industries." (CSJ-a-025)

Interviewee from another company also expressed:

> "We invest so much in R&D annually for better software. Our competitors are major driving force for our continuous learning and development. I often tell my friends … The one the boss believes most is his/her competitors. So, in addition to the technical knowledge, we also carefully deploy respective personnel for monitoring various industries and competitors, to gain sufficient and the most updated information of the situations from there…" (MST-a-178)

However, as mentioned earlier, prior research has commonly used a range of past records to *imply* current knowledge heterogeneity. Most respondents to our interviews referred to such narrowed conceptualization when they were asked about the importance of *knowledge* heterogeneity. With a natural reference to such a narrow definition, though, most respondents were aware of the fact that a team's knowledge stock and structure can change over time through a series of ongoing knowledge processes. The following comments typified all feedback across the case companies and supported the timing dimension of heterogeneity.

> "Our current innovation capacity is more than just what you can see from our personnel bio records …"(CSJ-a-057); "… Originally when this company was built up, we did not have such diverse

> workforce. All came from a chemical [background]. I have been here for a long time so I know that. However, now we are starting to have people with various backgrounds, not just because we hire new staff, but because of the learning and changes of the original guys…." (CSJ-a-048)

Additionally, the issue of the locus-of-knowing dimension was made explicit when confusions emerged, as we asked interviewees to freely describe knowledge heterogeneity. Most respondents referred to a specific individual's knowledge, whereas few others commented on the overall state of heterogeneity. A respondent questioned:

> "It is not clear, when you asked about the diversity in knowledge, who and what you were referring to. I mean, if you ask about me, yes, I think I have a diverse set of knowledge because I have two Master's degrees, I worked for different companies in different industries, and I've experienced many different challenging on-the-job projects for my current role… However, if you are talking about my team, are you talking about the diversity of each of us or the overall diversity of the team? However, again, having a group of people who all have diverse knowledge does not always mean having a team with diverse knowledge and that is useful in practice. I mean, should it be called diversity if not all of the diverse knowledge from people can be applied and integrated into practice?" (WST-a-121)

The comment also demonstrates that it is thus useful to adopt an ego- vs. socio-centric view when assessing the issue of locus for heterogeneous knowledge because knowledge collectives should be defined beyond the traditional hierarchical boundaries (Brown & Duguid, 2001). The egocentric view is useful in identifying personally owned KH, while to the socio view is effective for grasping the KH of collectives (Rodan & Galunic, 2004).

In sum, we suggest that KH can be better understood by re-conceptualizing it with a typology that takes timing and locus of knowing into joint consideration. We continue to discuss the typology developed based on these confirmed dimensions. From our observations, there are four types within the overall knowledge heterogeneity concept, which fit the tentative theoretical framework well. Individual Professional Backgrounds (IPB) (cell 1, Figure 1) describes the

diverse, past knowledge that was captured in a retrospective identification of a specific person's past (i.e., the period before being organized into the current unit for innovation) academic and job-related professional records. For example, David earned a bachelor's degree in Information Science and an MBA and served in an R&D department before he served as a project manager in a current new product development project initiated by the marketing department. The knowledge he learned later in the NPD project could not be captured by merely his bachelor's or MBA degree. One typical description of such individual knowledge background diversity is often categorized in two aspects – educational and functional:

> "… I actually studied Chemistry but not the Electric machinery as you just guessed. I studied in the field of Environment engineering in my graduate school period. I found a job later, which was related to that area. But I soon jumped to HP as a salesman, in charge of workstation-related products. Then, I joined Intel to help deal with the telecommunication business with DDM as my major responsibility, urging governmental units or other companies like the CHT to let them adopt Intel's IT framework. In this period, I had contact with MST, and as you know, I joined MST later. Now I am still in charge of the same task as at Intel. Just changed direction a bit… That was what I brought from those [previous] jobs. But sometimes I feel things don't work like they did before, and I don't know why … Many of the partners I work with now are in a similar situation." (MST-e-027)

Collective Profession Backgrounds (CPB) (cell 2) represents the *composite description* of all of the members' professional demography (i.e., IPB). These two concepts were widely seen in the existing literature. Our matching and comparison work between the secondary data (mainly from HR departments), and the updated expertise categories on knowledge management systems or company web sites showed that the IPB and CPB are often different from, but may be incorporated in, the most updated expertise categories (or project descriptions). Moreover, even the "most updated" expertise categories commonly still cannot describe the current knowledge heterogeneity well because these secondary data sources often reveal the explicit part of

knowledge only and are not updated every day.

Cell (3) (i.e., Individual Evolving Knowledge Portfolio (IEKP)) describes one's knowledge portfolio created after continuous learning journeys, from which one gains and accumulates new knowledge after being assigned responsibilities for innovation. Over time, different members' knowledge portfolios may go in convergent or diversified directions because of the autonomous application of knowledge that may somehow conflict with the directions of overall organizational commitment (G. S. Baugh & Roberts, 1994). One of the respondents in the MST Company stated,

> "I am now in the Global Technical Support Center. Before I came here, I was part of the [software product name] team and moved to the development team of server-side software, database, data warehouse, etc… These are very different learning experiences for me. However, they all are memories now. Although these jobs share some common software knowledge, such as objective-oriented programming, GUI, and so on, I need further learning of the most newly updated know-how and technology from now on [emphasis added]. In addition to updated technical know-how, I need to know more about market information and customer psychology and thoughts in order to give better customer support and services." (MST-b-002)

IEKP represents a knowledge portfolio that resulted from a dynamic process of knowledge acquisition for a specific person. The IEKP facilitates our understanding of why and how a member thinks differently at different time points during innovation. In our cases, the important factors affecting this portfolio include autonomous learning (e.g., technological exploration granted by the company), information renewal (e.g., updating technical or industrial news), rotating project assignments, personal improvisations and so forth. Moreover, the IEKP often contributes to organizational innovation by enabling people to perform independent tasks in a more experienced or creative fashion in collective knowledge processes. Thus, the IEKP often accompanies professional reputation and identity construction.

Cell (4), Collective Evolving Knowledge Portfolio (CEKP), refers to inter-dependent developments in the knowledge portfolio among individuals. Whereas IEKP contributes more to individual innovation capability, the configuration of all members' various knowledge portfolios may more greatly influence organizational innovation capacity. Moreover, CEKP considers knowledge as more than a domain-area "object" (e.g., the concept of an atom in Chemistry, the concept of quantum mechanics in Physics, or "performance" in Management Science) -- it covers the procedural and contextual aspects of knowledge (Hsiao, Tsai, & Lee, 2006) when dealing with knowledge structure. Our analyses show that the conceptualization of CEKP should incorporate the domain-based, procedural and contextual dimensions of collective knowledge. The last section of Table 1 integrates the information regarding the evidence and comments from our interviews. Note that we do not imply that the CEKP is more important than others in influencing innovation. The four types of KH can function for collective innovation separately or simultaneously.

Insert Figure 1 here

Insert Table 1 here

Overall, a major difference between cell (3) / (4) and cell (1) / (2) is the timing of collective knowledge construction. Understanding this, studies can better respond to the call for delicate research on the temporal impacts of team diversity (Harrison et al., 2002; Horwitz & Horwitz, 2007). Whereas cells (1) and (2) each consider the status of the personal or collective knowledge

profile from a historical perspective, cells (3) and (4) put more emphasis on the continuous development and change in the knowledge structure. According to a top management member, it is critical to understand this difference to exploit the value of all forms of KH:

> "It is important to know the past capability of our human resources. After all, this is what we rely on to recruit these creative people. However, it is more important to know, or to help them know, the potential trajectory of their capability development in the future. It would also be dangerous if you assess current differences [in knowledge] solely by looking into how they differed before." (MST-a-193)

Though we have argued that it is critical to know the distinct forms of KH, these forms may be interrelated because knowing is dynamic and (co)evolutionary in nature. Innovation is dynamic in nature (Basile & Faraci, 2015). It is an innovative ecology concept that emphasizes the (co)evolutionary influences among the diverse people, knowledge and knowing practices. An interviewee gave an abstract but suitable metaphor:

> "You know Darwin? Ok, then you can see the people who are in innovative projects are like major species in an eco-system. The work environment and technologies they apply to finish innovative requirements are also species. Then you can see that those species can evolve together, and one's evolution may influence evolution of one another. Before they were brought here, they grow, change or die separately. But when they were grouped here for some reason, like a seed of dandelion flying to somewhere they did not belong, they would interactively change with, or stimulate changes on, the whole new environment of innovation." (MST-d-057)

Along the development trajectory, some form(s) at the ego level or during the pre-organizing period may be transformed into forms that emerge at the socio-centric level or in later periods of innovation. Possibly, the CPB, which is commonly calculated by the IPB, and the IEKP, which may be related to and transformed from IPB, can affect the formation and transformation of CEKP. This finding is valid because individuals often need to integrate both old and new knowledge:

> "I came here [R&D department] just at the beginning of this month. Based on my previous proposal, we are now collaborating with the Industrial Technology Research Institute (ITRI) in developing various applications of… We need to know many new things, of course, because of the newly committed business area; though technologies of displaying and hardware production are similar with the previous cases, the market demands various application and imagination. So we, not just me, need to learn more about the technological knowledge of the IC card of the metro transportation system and think how to integrate the LCDs into these "funny" cards. We also need to combine what all of our members have or had before into group knowledge …" (WST-a-001)

See figure 1 for the four transformational paths among the four distinctive forms of KH. Based on all of the dialectics between theoretical discussions and our case evidence, we propose the following:

Proposition 1: *There are four distinct but interrelated forms of knowledge heterogeneity -- IPB may serve as a historical foundation for the IEKP and CPB; in turn, IEKP and CPB may influence the formation of CEKP.*

Relationships with Innovation

It is widely accepted that contingencies exist and affect the relationship between diversity and organizational consequences through some elaboration processes (van Knippenberg, De Dreu, & Homan, 2004; van Knippenberg & Ginkel, 2010). Contingent effects of knowledge structure on innovation have been made clear in existing research (Tsai et al., 2014). Still another reason for these contingencies is the investigation on the surface-level, easy-to-capture presentation of KH. Though most studies consider diverse human characteristics, it is the underlying diversity in current *knowledge* itself that directly influences innovation.

Dynamics

We consider the dynamics of innovation in two aspects: timing and realized/potential (yet

unrealized) innovation. Our KH typology complements empirical or review studies that focus on influential moderating variables (e.g., Horwitz & Horwitz, 2007), bringing back the essence of KH in explaining the contingent relationships among diversity, knowledge and innovation. First, IPB is associated with ongoing innovation in an uncertain way. To demonstrate the shape of this relationship, we drew a question mark in the first cell of Figure 2. Separate consideration of an individual person's diversity in professional backgrounds generates few clues for predicting how and how much s/he may contribute knowledge to innovation. All of the interviewees from our four case companies expressed doubt in predicting the effects of personal professional backgrounds on collective (and even individual) innovation. A chief R&D officer noted the following from a practical perspective:

> "…it depends… Sometimes, we had pending projects or urgent customer needs and no idea about the next step until someone suddenly proposed a refreshing idea. On the other hand, every knowledge worker has his own preference and long-rooted belief system, which is difficult to communicate with when you simply have a conflict of ideas… Sometimes, a lot of time is spent on that stuff…" (CSJ-a-076)

Following this argument, CPB represents the professional demography of all members and may offer slightly better predictions of the contribution of diverse knowledge. CPB is actually understood with a more "complete formula" compared to IPB (as commented by most manager-level interviewees) – we can roughly predict the good and the bad of bringing together people from diverse backgrounds, but we cannot ensure how to bring them together. Thus, in accordance with the literature, our observation shows that CPB is associated with innovation in an inverted-U shape. However, the CPB demonstrates only a "reasonable projection" with regard to the *potential* merits or drawbacks of KH that eventually may not necessarily be realized in innovation. We calculated the CPB scores for randomly selected innovation projects with the Blau (1977) approach and then consulted with HR and innovation project managers in the case

companies. We found better predictability of CPB for earlier than for latter stages of innovation in a roughly inverted-U shape (i.e., comparing projects within a company, innovation performance in earlier stages was low when CPB was either high or low (one standard deviation above or below the mean score), but not clear for CPB's influence on latter stages).

****Insert Figure 2 here****

The IEKP clearly sketches a specific person's knowledge-developing trajectory and directions, which in turn predict the most updated ways people think and respond to others' knowledge and innovative behaviors (e.g., proposals, comments, and ideas). Thus, compared with IPB as a different kind of individual account for KH, the IEKP provides better predictability for ongoing innovation implementation. Interestingly, however, such predictability went in extremely positive or negative directions in the projects within the case companies. In some innovative projects, encouraging the autonomous development of heterogeneous knowledge structures ends up generating even more serious problems of fault lines of thoughts and/or emotions. The reason for this situation seemed to be very personal and uncontrollable – it depends on specific persons' influences. As expressed by many of the interviewees at different positions, a short but representative opinion was offered:

> "Oh, I bet it's not about how diverse the expertise is in our department. It's about whose diversity matters. Like our boss [the department leader], he'd ask us following what he reads and thinks, and that changes all the time!" (SPP-e-020)

Although this representative comment referred to the influence of the formal leader's IEKP, other respondents also mentioned the roles of senior workers (e.g., engineers) and non-senior workers with aggressive goals and personalities.

We found a more stably positive relationship between CEKP and innovation. The members we studied were more likely to relate their own differentiated knowledge to each other if they were involved in loosely-coupled mutual learning and adaptation. Compared with independent knowing, such as autonomous learning, co-participative and co-evolving knowing makes people more aware of and compatible with one another. Compared with the IEKP, CEKP is a result of the co-participative knowing that casts actual and continuous influences on collective innovation. We received the following comment:

> "Different colleagues have different styles of presenting their reports in those conferences or regular technology meetings … Sometimes, they also change between styles. I guess this is not just because of different personalities or prior training but also because of their continuous learning and interpersonal influences on the learning of one another. Overall, it is as if we have various types of singers who have been representing their minds and thoughts through different forms of interpretation and presentations of the lyrics and music. However, when they sing together, they need to understand and fit into one another's styles and overall atmosphere – not just singing the same song, but singing the same song and keeping a variety of performance features" (CSJ-a-045).

From this viewpoint, CEKP presents a state in which each member may have different initial (i.e., IPB or CPB) and changing knowledge structures (i.e., IEKP), but because of adaptive and loosely coupled mutual learning, the members may eventually maintain collective knowledge development directions while keeping a variety of paths. One respondent sharply commented,

> "After all, the criteria to evaluate all crews and how they make use of backgrounds are simple: technological needs minus potential managerial risks. Diversity in backgrounds is just the potential they can release to fulfill your expectation, but that's just potential! What is more important is caring about how things will go after you get diverse people on the way together. Or why we do need the so-called 'management'?" (MST-d-60)

In sum, with different relationship shapes, both IEKP and CEKP may generate more direct

impacts on ongoing and collective innovation because they capture the continuously updated, complex configuration of knowledge for actual innovation. Although focusing on the pre-organizing forms of KH is also important, these forms may have more potential for the planning, set-up, and initiation of innovations. In sum, we propose thoughts regarding the dynamics (i.e., time periods and the actual-versus-potential influences) of the four forms of KH on innovation.

Proposition 2a: *The IPB is associated with innovation in a relatively uncertain relationship shape. The CPB contributes to innovation in an inverted-U shape, but the IEKP contributes to innovation positively in earlier stages and with less certainty in the latter stages, depending on the integration of this autonomous KH development process. CEKP is positively associated with innovation.*

Proposition 2b: *Relatively, the IEKP and CEKP contribute more to the actual, ongoing innovation, whereas the IPB and CPB contribute more to the potential for innovation performance; the IPB and IEKP facilitate more individual innovation, whereas the CPB and CEKP facilitate more organizational innovation*

Ambidexterity

Despite the influences on the depth of innovation (i.e., dynamics), KH is also influential on the breadth of innovation (i.e., exploitation vs. exploration). In intensely competitive and fast-changing organizational environments, it is critical to maintain a steady exploitation of current resources while being exploratory for confronting uncertainty and sustaining entrepreneurship. Risk-sharing, organizing for various combinations of resources, constant survival and value creation all demand organizations to own "the capacity to simultaneously

achieve alignment and adaptability (Gibson & Birkinshaw, 2004, p. 209)." He and Wong (2004) found that exploitative and exploratory approaches can jointly influence innovation. However, through what factors can this capacity be supported? Existing literature suggests improving the structural, contextual, and process elements to achieve ambidexterity (Birkinshaw & Gibson, 2004; M. Tushman et al., 2004). Beyond that, Kim and Rhee (2009) argued that internal variety results from a combination of practices and is highly associated with organizational knowledge over time. Birkinshaw and Gibson stepped closer to this thesis by linking organizational structure and human capital capabilities, then by contending that for structural ambidexterity, organizations deploy more specialist employees, while for contextual ambidexterity, more generalist members are utilized. Wang & Rafiq (2014) located organizational cultures that facilitate contextual ambidexterity and found an association between these cultures and innovation. Less, however, has been examined specifically from the knowledge structure perspective.

Our interviews found that most of the innovative companies tend not to prejudicially treat KH as a cost for governance, but rather as an opportunity to simultaneously perform broader innovative behaviors. The feedback from the software company on stepping toward the mobile devices application market demonstrated this intent.

> "Our crews have generally had many experiences in operating systems and software. Due to the technical characteristics of each of these systems and software and the different experiences they gained in different phases, they have also learned different techniques, knowledge and work practices. However, I do not consider this fact as a very serious problem if we wish to bring all of those diverse crews together in creating something new in the smartphone area. Sometimes, all or part of the diversity we got to know via their past background can be brought into current innovation—through some kind of transformation or treatment. ... You can explore new opportunity from their knowledge, but surely, you can also do something to exploit everyone's existing characteristics as well. Both happen, and it is not a technical but

a managerial issue." (MST-d-051)

Aligned with our observation and understandings, this feedback showed that innovative companies were not so bothered by a diverse pile of knowledge – they seek exploratory ways to utilize knowledge, while exploiting members' professions learned from the past. Unlike the Similarity-Attraction theory (Byrne, 1971), dissimilarity in knowledge may serve as a motivating foundation for interpersonal attraction because of the complementarity of the different knowledge possessed by different individuals. The Information/Decision-making perspective of organizational diversity argued that although intra-group diversity may constitute interpersonal barriers to communication and the like, this group has better connectivity to extra-group information sources, which can benefit the overall performance of the group (K. Y. Williams & O'Reilly, 1998, pp. 86-87). Knowledge from a single person can hardly fulfill collective innovation. By contrast, with appropriate integration, KH in different forms may serve as nutrients for different innovations. Not *all* diversities within an identical organizing unit have to be accounted for in every innovation project at all stages, though. A diverse knowledge structure should generate variant impacts through their own transformation at different stages of innovative organizing. In this sense, the true functionality of knowledge for concurrent implementation of various innovations lies in the flexibility and adaptability in a knowledge portfolio (structure).

> "Currently, we focus on the in-mold labeling technology, but we can also do business in all areas of the wider defined in-mold [IMD] decoration technologies, which include IMR, IMF, IML, etc. The combination of these different specialties in a clearly defined area provides us with not only the capability to be flexible in responding to market needs but also an exploratory capability to respond to unexpected changes in policies or markets. Continuous collective learning facilitates integrating people's different learning over time to be applied to product innovation in various industries" (SPP-a-002).

Prior knowledge is often exploited for value addition, while exploratory action based on a

constant renewal of knowledge benefits new value creation (March, 1991). Lin et al. (2013) indicated that the combination of multiple practices is more beneficial for ambidexterity than operating those knowledge activities individually. Aligning these thoughts, as more forms of KH exist, the likelihood that organizations can utilize different forms of innovation simultaneously increases. We propose that

Proposition 2c: *The greater extent of the co-existence and transition of distinct forms of KH, the better the chance for firms to perform ambidextrous innovation: while IPB and CPB benefit exploitative innovation, IEKP and CEKP facilitate exploratory innovation.*

Conclusion and Implications

Both knowledge and innovation are critical cornerstones of organizational capability building and competitive advantages (Bierly III, Kessler, & Christensen, 2000; Lang, 2001). Nonetheless, just as an organization's distinctive knowledge base might be difficult for other organizations to imitate, the heterogeneity of local and distinctive knowledge could be difficult to be processed internally (Letiche & Hattem, 2000; Tenkasi & Boland Jr, 1996). Distinctively identifying the nature and structure of knowledge is critical before putting the concept of knowledge into research or practice. However, little systematic attention has been paid to this intraorganizational knowledge heterogeneity or to the influences of knowledge heterogeneity on emergent innovation models. The present paper proposed a theoretical *and* practical typology of the essence of KH based on the dialectics between literature and empirical observations. Further propositions were discussed regarding the differentiated influences of the four forms of KH on dynamic and ambidextrous dimensions of innovation.

For theoretical implications that provide a stimulus for future studies, the present study combines and contributes to organizational and strategic management theories (i.e.,

Knowledge-based View, Demographic Diversity, and Innovation Literature). First, for the Knowledge-based View, this study brings an extensive conceptualization of KH to shed light on the future research on knowledge-based phenomena. Our efforts remind researchers to correctly utilize the concept and measures of *intra*-organizational knowledge heterogeneity and its evolution. Furthermore, the differences and interplay between individual and collective (i.e., the loci of) knowledge bases are central to knowledge management studies (Argote, McEvily, & Reagans, 2003; Grant, 1996a; Kimmerle, Cress, & Held, 2010; Ikujiro Nonaka & Takeuchi, 1995). We have illustrated this issue in the conceptualization of knowledge structure. A strong argument results that in the sense of knowledge (structural) heterogeneity, collective knowledge might not be equal to the "shared knowledge" or "common knowledge," as has been adopted largely in research (Dixon, 2000). Shared knowledge can maintain a heterogeneous structure, and this can be perceived correctly or biased by the collectives that possess this collective knowledge. The rigor of the theoretical substance and dimensionality can facilitate empirical validity (Priem, Lyon, & Dess, 1999). Empirical studies may often ignore the basic assumptions on knowledge structure to avoid methodological complexity. Nevertheless, assuming knowledge heterogeneity or homogeneity can fundamentally alter the proposed/hypothesized effects of knowledge and related empirical results. This paper provides a good reminder and reference with respect to the theorization and measurement for future works, with knowledge and/or its structure as a major construct.

For demographic diversity studies of organizations, we articulate an important but less-recognized form of diversity (i.e., knowledge heterogeneity), which can be categorized as a kind of deep-level diversity (Harrison, Price, & Bell, 1998; Post, 2012), thus formally extending the scope of diversity research into a dynamic knowing context. This is especially useful because

the current workplace emphasizes human capital that is melded simultaneously by human attributes and knowledge capability. Diversity in demographic attributes has been studied largely in terms of gender, race, and so forth in settings that actually demand a good understanding of the knowledge context, such as cross-functional projects (e.g., S. G. Baugh & Graen, 1997). KH is thus complementary to demographic diversity and is highly expected to be jointly considered as a potential research topic in Organization and Management research. Further, our findings on the four forms of KH and those on the developmental paths among the different forms of knowledge heterogeneity provide a future research direction for re-thinking the dimensionality of the many taken-for-granted types of diversity and their evolution. For example, because the concept of culture has been constructed based on a rich essence involving multiple levels (e.g., societal, social, organizational, and sub-culture levels) and philosophical rationales (e.g., subjective or objective), efforts toward an integrative re-conceptualization of the construct of cultural diversity may advance related study findings.

For the third theoretical implication and related future studies, researchers may also benefit from investigating the influences of KH by focusing on different aspects of innovation. With the care for the dynamic and structural (i.e., ambidextrous) aspects of innovation, research should pay equal attention to response factors of a dynamic and structurally complex nature (here, knowledge heterogeneity) and their influences on innovation. Although this paper has reported rich findings for KH innovation relationships, more can be done to understand the influences of KH on different types of innovation (e.g., product, process, or service innovation) (Chesbrough & Spohrer, 2006), on innovation in cultural cooperative relations (Nielsen & Nielsen, 2009), or on different organizing or governance structures of innovation (e.g., close versus open innovation models) (Chesbrough 2006), to name a few.

For practical implications, we suggest assessment, construction, and education and training for employees' abilities for knowledge heterogeneity management. When well organized, KH can be treated as a valuable slack resource strengthening the organization's capability to step between exploitative and exploratory innovations. Indeed, ambidexterity should be a strategically dynamic capability to make good use of collective knowledge (O'Reilly III & Tushman, 2008). Excessive knowledge bases, even though they are heterogeneous, may serve as a foundation for capability flexibility if managers understand and apply it well (e.g., Brusoni, Prencipe, & Pavitt, 2001). Thus, investments in different forms of capability-domain-expanding knowledge are equally important as those in homogeneous, specialized knowledge. Knowledge portfolio management, assessment and application for (at least) the four *different forms* of KH will offer useful guidance when setting up and leading teams for innovation projects. Clearer, decision makers or organizational change managers should evaluate for which type of innovation (individual or organizational; or, exploratory, exploitative, or ambidextrous as the propositions noted) can be realized based on their understanding of the organization's knowledge structure in terms of heterogeneity. Knowledge or MIS managers, on the other hand, should plan for suitable knowledge creation and processing strategies, according to the organization's future vision of innovation ambidexterity. Moreover, for HR managers, education and training of employees to familiarize them with the development and utilization of heterogeneous knowledge are also critical for innovation.

Limits of the present study warrant a call for more valuable future studies. First, because of the inherent nature of case studies, our arguments and findings may be context specific. While we have not necessarily derived propositions, we have discovered some important commonalities among the case organizations, demonstrating the potential for further generalization. For

example, while we have found evidence and tried to explain the fact that the outcomes of IEKP can depend on one or a few specific persons' influences, we have not made a formal proposition. Future studies are encouraged to examine, generalize, and expand our propositions and key observations to a larger sample (including examination of samples from other countries). In another example, we discussed the impacts of different forms of KH on the "potential" for versus realization of innovation. By empirically operationalizing innovation potential as the likelihood for the innovation to be realized, future studies can actually collect data on experts' practical assessment of the likelihood of success of innovation projects (e.g., implementation and goal achievement) and examine our argument here. In other words, there are still mediating, moderating, or contextual factors to be explored to explain the effect of re-conceptualized KH on innovation, though dividing the concept of KH into four forms has already resulted in an effort to address the contingent empirical effects. Second, we have not considered differences in the heterogeneity of different knowledge types, such as know-how, know-why, know-whom and even know-who-knows-what, as the Transactive Memory System literature emphasized. We encourage future research to focus on and search for the meanings and influences of heterogeneity in these knowledge types.

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Locus-of-knowing / Timing-of-knowing	Individual (Ego-centric)	Collective (Socio-centric)
Pre-organizing	(1) Individual Profession Backgrounds (IPB)	(2) Collective Profession Backgrounds (CPB)
Post-organizing	(3) Individual Evolving Knowledge Portfolio (IEKP)	(4) Collective Evolving Knowledge Portfolio (CEKP)

* The arrows: four transformational paths (a ~ d) between distinct states of knowledge heterogeneity

Figure 1. A Typology for Knowledge Heterogeneity (KH)

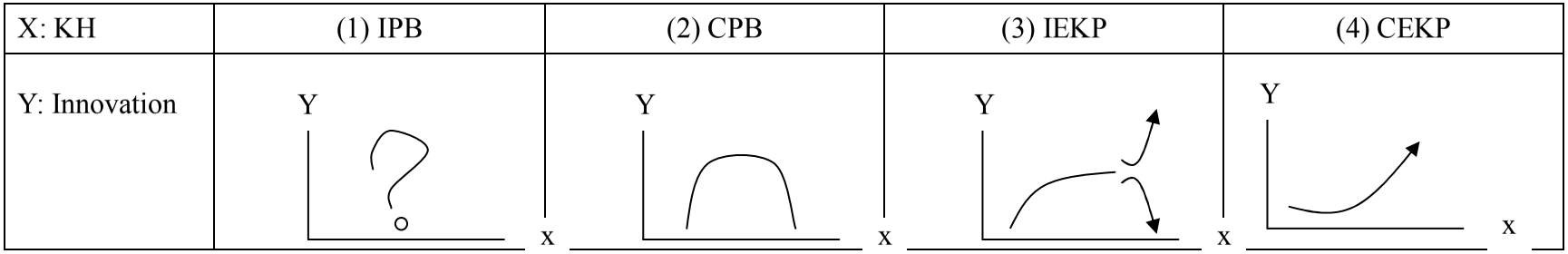

Figure 2. Influences (conceptual) of knowledge heterogeneity on innovation dynamics

Table 1. The effects of different forms of knowledge heterogeneity on Innovation: Conceptualization and evidence (strength)

	Meanings	Selected quotes ("")
IPB	**Individual diverse professional (e.g., educational or functional) backgrounds** ***	"I am now in the Global Technical Support Center. Before I came here I was part of the [software name] unit, and moved to the development team of server-side software, database, data warehouse, etc… These are very different learning experiences for me. But they all become memories now. Although these jobs share some common software knowledge such as objective-oriented programming, GUI, and so on, I need further learning of the most newly updated know-how and technology *from now on* [emphasis added]. Besides updated technical know-how, I need to know more about market information and customer psychology and thoughts in order to give better customer support and services." (MST-b-002) "I came here [R&D department] just in the beginning of this month. Based on my previous proposal, we are now collaborating with the Industrial Technology Research Institute (ITRI) in developing various applications of… We need to know many new things, of course, because of the newly committed business area; though technologies of displaying and hardware production are similar with the previous cases, the market is demanding various application and imagination. So we, not just me, need to learn more about technological knowledge of the IC card of the metro transportation system and think how to integrate the LCDs into these "funny" cards. We also need to combine what all of our members have or had before onto group knowledge …" (WST-a-001)
CPB	**Composite diverse professional backgrounds** ***	"Our current innovation capacity is more than just you can see from our personnel bio records …" (CSJ-a-057); "… Originally when this company was built up, we did not have such diverse workforce. All came from a chemical [background]. I have been here for a long time so I know that. But now we are starting to have people with various backgrounds, not just because we hire new staffs, but because of the learning and changes of the original guys (CSJ-a-048)" "… But the most interesting part is that I am not the only who has such diverse experiences. Most of us share a similarity in diversity. I am the example of an individual who is originally trained in Chemical [engineering] but jumped to other areas … There are still many others who have jumped like me; from telecommunication to marketing, mechanical engineering to software development, mathematics to … Anyhow, we are now gathered together and work toward similar goals. The similarity in diversity may change again, and again. You know, this is partially because the invisible hand [emphasis added] of our boss organizes us, but if there is any other factor? We don't get it well." (MST-e-028)
IEKP	**Individual diverse learning portfolio and trajectory** **	"It is important to know the past capability of our human resource. After all this is what we rely on to recruit these creative people. But it is more important to know, or to help them know, the potential trajectory of their capability development in the future. It would also be dangerous if you assess current differences [in knowledge] solely by looking into the fact how they differed before." (MST-a-193) "Oh, I bet it's not about how diverse the expertise is in our department. It's about whose diversity matters. Like our boss [the department leader], he'd ask us following what he reads and thinks, and that changes all the time!" (SPP-e-020) "… We [most of the founding team] were in the electronic industry which emphasizes much of the importance of Logistics… In a competition against a larger competitor for a fat order in the early years [when starting up], we applied those Logistic techniques to push ourselves to shorten the delivery time of our product and statistics regarding the trial production and proposal. We also developed techniques based on such Logistic thinking to speed up the project … So our competitor in Tainan [then the leading company in the labeling industry] did not know anything of how we could be so faster than them." (SPP-a-023) "… But sometimes we also benefit from them [the customers]. Sometimes they have to teach us first before we can do things well for them. They wish we can do exactly according to what they imagine. This is good because they own some special know-how in the industry. Well … at least we've leant something new from them … for our engineers … I think they also like it. For them, they also learn new things in every new project they participate in. Then we can bring these experiences in different areas to every new project and exchange with new co-workers …" (WST-b-014)
CEKP	**Individual diverse learning portfolio and trajectory in configuration (but**	"We worked with a consultant company in U.S. and developed systematic learning material. It wasn't only developed for personal skills or cognition for different individuals independently. But it is for developing a knowledge whole organic unit. There is an old Chinese saying that 'Just sweep before your own door.' We have to avoid such mind-set when talking about imperatives of expertise development. We spent almost ten million dollars to develop something that could help individual members develop their own special techniques but also help develop a knowledge system with diverse but well-connected individual know-how for specific department or the company as a whole. This is because the change is happening at the collective level." (MST-a-125)

	not just aggregation) ***	"Currently, we focus on the in-mold labeling technology, but we can also do business on all areas of the wider defined in-mold [IMD] decoration technologies, which includes IMR, IMF, IML, etc. The combination of these different specialties in a clearly defined area not only provides us the capability to be flexible in responding the market needs, but also an exploratory capability to respond to unexpected changes in policies or markets. Continuous collective learning facilitates integrating people's different learning over time to be applied to product innovation in various industries." (SPP-a-002) "… We don't expect to compete or even survive by doing precise [emphasis added] forecasting. The more important thing is to respond quickly, rather than to chase a truth in the future by forecasting based on previous facts … Anyway, that is why I agree that it is necessary for a company to constantly have many different capabilities and think how to mix these capabilities well for a better response. It's just like an investment portfolio and thus the more you are mixing difference with differences in a variety of ways, the less the competitors can see your true face. But sometimes even we ourselves don't get what, how and why such mix can help our R&D and protect this company's core." (WST-a-033)

*** indicates highest strength of evidence interviewed and/or observed ** moderate strength * implicitly sensed
[…] in the quotes denote notes added by the authors with agreement to the author team and independent expert judges
IPB = individual demographic diversity in profession; CPB = composite demographic diversity in profession; IEKP = expanded career knowledge portfolio; CEKP = collective knowing heterogeneity

Appendix 1. The case companies and the informants

Cases / Information	CSJ	MST	SPP	WST
Core products/services	Chemical intermediate products customized and sold to a broad set of downstream markets	Software, operating systems, mobile device, (cloud) information services, tablet PC	Technical packaging applied in a broad set of downstream markets	Consumer electronics, car electronics, mobile devices
Company age	35+	35+	10+	15+
Ownership structure	Taiwan-Japan international joint venture	Subsidiary of a US-based MNC	Fully-owned local company	A local company listed in stock market
Technological scope	Moderate to broad	Broad	Moderate	Moderate to broad
R&D intensity	High	High	High	High
Recorded IPB and CPB[α]	Low	High	Moderate	Low to Moderate
Reported and observed CEKP	High	High	Moderate	High
Interviewees[*]	1 Vice president; 1R&D Head executive; 2 Marketing manager; 7 Engineers; 2 marketing staffs	1 Vice president; 1 marketing department head; 2 R&D Alliance executive; 5 senior marketing executive; 2 Human Resource executive; 12 R&D staffs and engineers	1 Chief executive officer; 1 Finance vice president; 3 R&D staff	2 R&D executive; 2 Marketing executive; 7 R&D engineers; 1 HR executive

[*] The available number of interviewees was affected by the company sizes. Some interviewees were interviewed more than once. Company names were requested to keep anonymous.

[α] IPB = individual demographic diversity in profession; CPB = composite demographic diversity in profession; IEKP = expanded career knowledge portfolio; CEKP = collective knowing heterogeneity