Team Composition and Learning: How Knowledge Conversion Abilities Facilitate Team Learning Processes*

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ABSTRACT

Based on Nonaka's knowledge spiral theory, this study argued the four knowledge creating patterns, including socialization, externalization, combination, and internalization, can be conceived as four types of knowledge conversion abilities. We developed level, completeness, redundancy, and heterogeneity as four dimensions of team knowledge conversion abilities combination, and explored relationships between these dimensions and team learning processes, including framing/reframing, experimenting, crossing boundaries, diverging, and integrating perspectives. We found the level of team knowledge conversion abilities on socialization, combination, and internalization has positive relationships with team learning processes. The completeness and redundancy of team knowledge conversion abilities also have positive relationships with team learning processes, especially crossing boundaries and integrating perspectives. Besides, the heterogeneity of team knowledge conversion abilities has some negative relationships with team learning processes, especially experimenting. This study provides a new perspective about the application of knowledge spiral theory, and team composition research.

Keywords: team knowledge conversion abilities, knowledge spiral theory, team learning processes, team composition, knowledge management.

INTRODUCTION

Up until now, the focus of most research on knowledge creation and creativity has been focused on individual level only, such as how to stimulate the potential of individual's creativity, the relationship between individual's intelligence and creativity, etc. Researches on team level are still lacking. Another side, as for the researches on knowledge management, focuses are mostly on organization level, such as by designing and reengineering of organizational structure and culture, or to improvement on organization-wide information and communication technique to transform organizations into knowledge intensive or knowledge-creating companies. Thus, more team level researches on knowledge management and learning still needed to be done.

Nonaka is one of the earliest to develop the knowledge-creation theory crossing individual, team and organization level. The combination of his rigorous academic outlook and Japanese corporate background makes much of his work impenetrable to others. Nonaka's knowledge creating theory has increasingly been valued highly by researchers in the knowledge creating field.

In this study, we argued that four basic patterns of knowledge creation: socialization, externalization, combination, and internalization, can be conceptualized as different knowledge conversion abilities possessed by team members. But on team level, the individual knowledge conversion abilities are not the only point should be emphasized. The effect of combination of team members with different knowledge conversion abilities on team processes or outcomes is an important issue we want to explore in this study. Under this perspective, this study developed four constructs of team knowledge conversion abilities composition: "level", "completeness", "redundancy", and "heterogeneity".

Teams have becoming the basic learning units in organizations. The concept of team learning not only emphasizes cognitive learning, it also including learning through behavioral change, and affective experiences (Dechant, Marsick & Kasl, 1993). In the model developed by Dechant et al. (1993) team learning processes include framing/reframing, experimenting, crossing boundaries, and integrating perspectives. We thought the team knowledge conversion abilities composition might play an important role on team learning processes. Through these abilities, team members can understand the other persons' implicit perspectives or frames, externalize their own abstract concept, combine different kinds of frames or ideas, and internalize the created new frames. So we argue that these knowledge conversion abilities are important antecedents to facilitate effective team learning processes.

In conclusion, the object of this study was to explore the relationships between team knowledge conversion abilities composition and team learning processes. Except for providing a potentially important contextual situation of team learning. This study also introduced a new team composition variable: knowledge conversion abilities. So this empirical study also provides a new perspective on team composition study to understand how the composition of team members with different knowledge conversion abilities may affect team learning processes.

THEORETICAL BACKGROUND AND HYPOTHESES

Knowledge Spiral Theory

Nonaka's knowledge-creating theory has three dimensions and a quasi-dimension: (1) epistemology, (2) ontology, (3) time and practice, and (4) helpful organizational situations (Nonaka & Takeuchi, 1995). Epistemology is built upon tacit and explicit knowledge, which also brought in four modes of knowledge conversion: socialization, externalization, combination and internalization. Ontology is categorized into individual, team, organization and inter-organization. The dimension of time and activity is divided into 5 stages: sharing tacit knowledge, creating new concepts, confirming concepts, building archetype, crossing levels knowledge expansion. Lastly, in the quasi-dimension, there are five advantageous organizational situations: intention, decision-making power, creative chaos, redundancy, multiple abilities. The above four dimensions form jointly the "organizational knowledge-creation process ".

However, organizational knowledge-creation process is in fact rather complex, therefore, it is not possible to prove the validity of this model directly; just like Nonaka and Takeuchi (1995) mentioned that organizational knowledge creation processes should be seen as the ideal model for knowledge creation. Thus, to have a more meaningful theoretical proof, the focus should be placed on the core of this theory – "knowledge spiral". In knowledge spiral theory, four basic patterns for creating knowledge in any organization are suggested:

Socialization: from tacit to tacit

Sometimes, individual shares tacit knowledge directly with another. Here basic knowledge exchange is not through abstract language but by observation, imitation, and practice. Nonaka notes the meeting held by Japanese firms, often outside the premises, to undertake brainstorming. Herein there is a sharing of the realities of life to creating a situation relaxes everyone, and in so doing allows deeper communication.

Externalization: from tacit to explicit

This mode relies upon analogies, metaphors, hypotheses, and models being expressed through articulated language. Frequently there are gaps between the expressed knowledge and the world-view of the perceiver. This may be emphasized when a model is inadequate and a metaphor has to be employed (Kidd, 1998).

Combination: from explicit to explicit

Combination involves the conversion of explicit knowledge into more complex sets of explicit knowledge. In practice, the combination phase relies on three processes (Nonaka & Konno, 1998). Capturing and integrating new explicit knowledge is essential. Second, the dissemination of explicit knowledge is based on the process of transferring this form of knowledge directly by using presentations and meetings. Third, the editing or processing of explicit knowledge makes it more usable.

Internalization: from explicit to tacit

Nonaka suggests this mode is close to "learning by doing", and says it is only by absorbing and sharing the prior stages of socialization, externalization, and combination that an individual can develop his or her own internal assets, and thus bring them to bear upon the context and aims of the company. In practice, internalization relies on two dimensions. First, explicit knowledge has to be embodied in action and practice. Thus the process of internalizing explicit knowledge actualizes concepts or methods about strategy, tactics, innovation, or improvement. Second, there is a process of embodying the explicit knowledge by using simulations or experiments to trigger learning by doing process. New concepts or methods can thus be learned in virtual situation.

According to the concept of knowledge spiral, organizational knowledge is created through a continuous transform between tacit and explicit knowledge. The process is a never-ending spiral of tacit and explicit knowledge through four modes of knowledge conversion, i.e. socialization, externalization, combination, and internalization; and this spiraling process can spread out from individual, team, organizational to inter-organizational level (Nonaka, 1994; Nonaka & Takeuchi, 1995).

Knowledge Conversion Abilities

We argue these four processes of knowledge creation can be carried out at least through two approaches: (1) the implementation of organizational practices, (2) put together individuals

with different knowledge conversion abilities in a team.

Some of the organizational practices, which facilitate out the four processes of knowledge-creation, include five advantageous scenarios, five stages of activity, middle-top-down management, as well as hypertext organization (Nonaka & Takeuchi, 1995).

There is another possible approach to complete the four knowledge conversion processes. There are many studies show that each individual's innovative ability or cognitive style is different from one and another (Guilford, 1967; Dunnelte, 1976). These studies attempted to find out the relationship between creativity and personality or cognitive style (Raudsepp, 1983). Take Kirton's A-I theory for example, Kirton claims personal cognitive style difference can be described by an adaptation-innovation continuum, and measured by Kirton Adaptation-Innovation Inventory (KAI). An adaptator shows high degree of within-paradigms consistency, and an innovator shows high degree of consistency across paradigms. However, the differences in cognitive style do not mean the differences in creativity; they just show the differences of how creativity is presented (Kirton, 1976, 1978, 1989). Under this perspective, we argued the four patterns of knowledge conversion processes could be done through personal knowledge conversion abilities possessed by team members.

Nonaka & Takeuchi (1995) also imply the possibility of this perspective, for example: socialization enables an individual to obtain tacit knowledge from others through observation, imitation and practice (Nonaka & Takeuchi, 1995). Personal observation and imitation ability seem to be distinct from one person to another, for example, socialization is an important process when come across product development and interaction with consumers; Leonard-Barton (1995) calls this empathic design. When creating empathic design, which has a profound understanding of how user world runs, the most unusual but possibly the most hopeful method is an anthropological exploration: letting the explorer involves in the actual user environment, just like how anthropologist does in a foreign village. Apparently, when carrying out an empathetic socialization process, a trained (e.g. anthropologist), and an untrained person will have their differences in observation and imitation behavior, ability and performance. Raudsepp (1983) believes sensitivity, and the willingness to open up oneself to unknown situations is factors that are important to differentiate the level of an individual's creativity. Let's not go into the discussion of the differences in ability is due to innate characteristics or acquired training and styling, one thing we can be sure of is that individuals have their own distinct knowledge conversion ability in the socialization phase.

As for externalization process, tacit knowledge can be expressed through metaphor, analogy, concept, assumption or model, we can find out the correlation for an abstract or concrete idea,

and the creation and cognition process continues (Nonaka & Takeuchi, 1995). Intuitively, there is variation between people on their ability to use metaphor or analogy, and on a certain level, this ability can be trained. For instance, metaphor and analogy are two of the techniques that are trained by action research method (Altrichter, Posch & Somekh, 1993), and these are also trained in public speaking classes.

Internalization and combination also have their own techniques and training methods. School education places importance on how to organize different concepts or knowledge in a systematic way; and new explicit knowledge is created through classifying, increasing and combining existing knowledge (Nonaka & Takeuchi, 1995). Internalization is even more important to educational research and classroom instruction. Nonaka & Takeuchi (1995) relates internalization with learning by doing, and on the same token, cognitive psychology and action science have also stressed the importance and effect of learning by doing and experiential learning in the early 1980 (Anzai & Simon, 1979; Simon & Langley, 1989; Tomlinson, 1999; Schön, 1987). The research done by Berry & Broadbent (1984, 1987), Berry (1991) and Sanderson (1989) confirmed that human brain does exist an "implicit cognition mechanism" that's used for "implicit learning", and the decision making or learning behavior performance is possibly related to human's internal cognitive strategy.

Maybe that we can't be sure if an individual's abilities in internalization, combination, externalization or socialization are related to the differences in internal cognitive mechanism, but it seems that the acquired training will cause the variation in knowledge conversion ability at least.

Team Learning Processes

The concept of team learning not only emphasizes cognitive learning, it also including learning through behavioral change, and affective experiences (Dechant, Marsick & Kasl, 1993). Dechant et al. (1993) acknowledge learning involves the interplay of individual and group value, beliefs, norms, knowledge, and behavior with that of the collectivity in which the individual or group is embedded. Dechant et al. (1993) also developed a team learning model. At the core of the model were four learning processes: *framing/reframing*, *experimenting*, *crossing boundaries*, and *integrating perspectives.*

Framing refers to the team's initial perception of an issue, situation, person, or object based on past understanding and present input. *Reframing* refers to the process of transforming that perception into a new understanding or frame. *Experimenting* means group action is taken to

test hypothesis or moves, or to discover and assess impact. *Crossing boundaries* means the teams as a whole communicates and moves ideas, views, or information between and among other people. Boundaries can be physical, mental, or organizational. *Integrating perspectives* refers to group members synthesize their divergent views. Apparent conflicts are resolved through dialectical thinking and not compromise or majority rule.

Individuals and teams "think" as they initially perceive, thereby framing and reframing. They begin to "act" during the experimenting and crossing boundaries behaviors. Integrating perspectives occurs when this thinking and acting are synthesized from the diverse views of the team.

Team Knowledge Conversion Abilities Composition and Team Learning Process

On team level, the individual knowledge conversion abilities are not the only point should be emphasized. The effect of combination of team members with different knowledge conversion abilities on team process or outcomes is an important issue we want to explore in this study. In other words, from the perspective of team composition, combining individuals' knowledge conversion ability in a team to look upon the complete cycle of the four knowledge conversion processes in the knowledge spiral seems to be a topic worthy to do a research on. We will argue, when proper composition of team members with kinds of knowledge conversion abilities is achieved, the team learning processes will be facilitated.

Four different constructs of team knowledge conversion abilities composition were developed in this study: *level*, *completeness*, *redundancy*, and *heterogeneity*. We will discuss the possible relationship between each one of the constructs with team learning processes, and form hypotheses.

Level of knowledge conversion abilities

Level of knowledge conversion abilities means the level of four abilities about socialization, externalization, combination, and internalization that team members may possess. According to the knowledge spiral, these four abilities will facilitate the process of knowledge creation. Through these abilities, team members can understand the other persons' implicit perspectives or frames, externalize their own abstract concept, combine different kinds of frames or ideas, and internalize the created new frames. We argue that these knowledge conversion abilities are important antecedents to induce effective team learning processes.

Thus, if members in a research and development (R&D) team have high level of these abilities, it will have a positive effect on team learning processes. The following hypothesis is

suggested.

> *Hypothesis 1: Level of team members' knowledge conversion abilities is positively related to team learning processes.*

Completeness of knowledge conversion abilities

Completeness means whether the team as a whole is lacking one or more knowledge conversion abilities. In Nonaka's knowledge spiral theory, the complete processes is comprised of all four modes of knowledge conversion (Nonaka, 1994; Nonaka & Takeuchi, 1995), and this seems to imply the completeness of knowledge conversion processes, i.e. if team members only have some of the knowledge conversion abilities, and the team as a whole is lacking one or more knowledge conversion abilities, then team members can not contribute effectively to the enhancement of team's knowledge creation. We also think teams may not go through framing/reframing, experimenting, crossing boundaries, and integrating perspectives processes of learning if they lack complete knowledge conversion abilities. Thus,

> *Hypothesis 2: Completeness of team members' knowledge conversion abilities is positively related to team learning processes.*

Redundancy of knowledge conversion abilities

Redundancy refers to that whether all team members possess all four of knowledge conversion abilities. The differences between redundancy and the completeness of the knowledge conversion capabilities is that the concept of completeness is focus on whether a team possess all four of the knowledge conversion abilities; and redundancy assumes that knowledge conversion abilities of individual team members can accumulate.

Redundancy is another important concept that was emphasized by Nonaka. In the eyes of most managers, information redundancy may be seen unnecessary or should be avoided because it will increase the loading of information flow. Thus, information redundancy is considered inefficient. But, Nonaka (1990) states that information redundancy should be looking from the perspective of information quality not the quantity. Redundant information may add more meaning to the information that already existed in an organization. In addition, when team members share this redundant information, they are able to clarify the meanings of some particular information; and this redundant information can also cause this particular information to expand further. It can also bring about the same effect if it applies to knowledge conversion abilities.

If all team members possess all four knowledge conversion abilities, then we can say that there is redundancy in their knowledge conversion abilities. This redundancy in knowledge conversion abilities will increase the depth of communication between members; hence, the overall amount of knowledge conversion abilities possessed by team members may influence the team learning processes. These arguments suggest

> *Hypothesis 3: Redundancy of team members' knowledge conversion abilities is positively related to team learning processes.*

Heterogeneity of knowledge conversion abilities

Heterogeneity means whether team members are good at different kinds of knowledge conversion abilities. The concept of heterogeneity has been widely discussed in studies relating to group composition, and these studies mostly have been focused on the heterogeneity of demographic variables, e.g. age, gender, ethnicity, education etc., or job related variables, e.g. tenure, functional background, industry background etc. (Tsui, Egan & O'Reilly, 1992; Forbes & Milliken, 1999).

Cognitive processing theory divides an individual's cognitive process into 2 types: automatic processing, and active processing (Bargh, 1982; Louis & Sutton, 1991). Louis and Sutton (1991) and Austin (1997) believe that when doing routine jobs, using automatic processing to deal with problems will be more efficient; however, if a job requires more creative thinking, then using active processing will have better effect than using automatic processing. Austin (1997) pointed out that heterogeneous teams would have more "surprise events" due to the differences in members' opinions, perspectives and schemas. These surprise events may push team members changing their cognitive process to active process, and induce team members to notice new information. This change may facilitate the framing/reframing, diverging, crossing boundaries, and experimenting processes.

Everyone possesses different knowledge conversion abilities, some may be good at externalization, and some maybe better at combination. In perspective of cognitive processing theory, this kind of heterogeneity in knowledge conversion abilities will cause team members switching to active processing mode and hence induce creative abrasion (Leonard-Barton, 1995; Leonard-Barton & Swap), and that will further facilitate team learning processes. The following hypothesis is suggested.

> *Hypothesis 4: Heterogeneity of team members' knowledge conversion abilities is positively related to team learning processes.*

METHODS

Samples

R&D teams were the objectives of this study for knowledge sharing and creation activities included in the primary task of these teams. A total of 341 questionnaires were distributed to team members of 62 R&D teams. Completed questionnaires were returned from 295 individuals of 56 R&D teams. But four teams had to be dropped from the study because of an inadequate number of team member responses (the threshold is 2/3 of total team members), leaving 260 individuals of 52 R&D teams from 25 companies included in the following analysis (a 84 percent response rate of the teams). 76.5% of the respondents were male, 41.9% had had master degree. The average age of the respondents were 31.14 years (s.d. = 5.69), and average corporate tenure was 3.29 years (s.d. = 4.49). The teams in our sample had an average size of approximately 6 members (s.d. = 3.13), and an average tenure of 27 months (s.d. = 32.48).

Measures

Knowledge conversion abilities

Since there is not any instrument already exist to measure personal knowledge conversion abilities, therefore we decided to develop the scale ourselves. We formed a 5 people discussion group to find out what are the personal knowledge conversion abilities about socialization, externalization, combination, and internalization. We weren't satisfied by the results of our discussion since our experiences weren't enough to provide information for us to develop the assessment test. Therefore, we decided to employee the focus group technique hoping to gain more insight on what are commonly used in any groups that have done creative thinking.

Focus group. 24 EMBA students and 20 undergraduate business administration major students were invited to participate in focus group. The EMBA students are placed into three groups according to the industry they are working in so the focus groups can show better effects. These can be grouped as: manufacturing, financial, consulting and service; and each groups have 8 participants. The forth focus group including the 20 undergraduate students. All of these students had taken creative thinking class, and had had experienced working in groups on creative thinking projects.

At the beginning, facilitators in each group stated that the focus group's purpose and the main topic of the focus group. The length of the focus group was around 1.5 hours. After

the brief introduction, each focus group started with the facilitator asked each participant's experience in product development and what they thought was knowledge creation, as well as what they thought was socialization, externalization, combination and internalization. This part was used to achieve a common knowledge ground of the topic for the focus groups. The second part of the focus group was aiming to find out what were the skills or behaviors that are most commonly used for socialization, externalization, combination, and internalization.

The discussion in each focus group was recorded and translated to transcripts. Transcripts of each group were coded by at least two people, and then the coded results were discussed among all five coding members to ensure the given label by the coders were appropriate. These coding results were then transformed into individual statements and arranged in 4 categories of knowledge conversion abilities: socialization, externalization, combination, and internalization. We got 44 statements as measuring items of draft version on a 7-point Likert scales anchored by 1 = "strongly disagree" and 7 = "strongly agree".

Pilot study and item analysis. The draft version of the knowledge conversion abilities scale was tested with a sample of 183 undergraduate students, and 171 valid samples were received.

Two types of analysis were used to conduct item analysis. In the first analysis, each scale item was correlated with the total of the remaining items on the construct for which it was created. Besides, reliability is done by taking out one item at one time and checking if Cronbach's a coefficient for the specific construct is greater than if the item is included in the measurement. If alpha coefficient was greater when the item is not in the measurement and the correlation was low, then the item was eliminated. After this analysis, there were total of 6 items been eliminated.

Second, a principle components factor analysis was conducted with varimax rotation. Four factors were extracted, representing the constructs of socialization, externalization, combination, and internalization. Items with greater loading on the construct for which it was created were retained. Finally, we got 25 items to be used in the survey, 5 items for internalization, 7 items for externalization, 7 items for socialization, and 6 items for combination.

Refinement of the knowledge conversion abilities scale. Using survey data from 260 individual samples, we conducted a principle components factor analysis with varimax rotation again to confirm the scales' dimensionality. This analysis produced four factors representing the constructs of socialization, externalization, combination, and internalization, each having eigenvalue above 1.0 and together accounting for 56 percent of variance in the

data, which duplicate the results of pilot study and reconfirmed the scales' dimensionality. These results established the discriminant validity of the four constructs of knowledge conversion abilities. Table 1 gives items and loadings. In the cases of internalization and externalization, one item each did not consistently discriminate between the four factors. In socialization, two items did not consistently discriminate between the four factors. These four items were dropped from further analysis. Cronbach's a coefficients were between .70 and .87, shown in table 1.

Insert Table 1 about here

Team knowledge conversion abilities composition

This study developed four dimensions of team knowledge conversion abilities composition: level, completeness, redundancy, and heterogeneity. We develop indexes as following.

Level of knowledge conversion abilities. We calculated the mean value of team members on socialization, externalization, combination, and internalization abilities as measurement indexes of knowledge conversion abilities level.

Completeness of knowledge conversion abilities. First, we calculated the mean value of teams on socialization, externalization, combination, and internalization abilities. For each of the knowledge conversion abilities, the teams above the mean value coded 1, else coded 0. Once the dummy variables were coded for each knowledge conversion abilities, four dummy variables were summed up as indexes measuring completeness of knowledge conversion abilities.

Redundancy of knowledge conversion abilities. For each knowledge conversion abilities, we compared individual team member's level with means of all samples. The member who above the means coded 1, else coded 0. Once the dummy variables were coded for each knowledge conversion abilities of each team members, four dummy variables of all team members of each team were summed up as indexes measuring redundancy of knowledge conversion abilities. If the team is composed of five individuals, and all knowledge conversion abilities of all team members are above mean value, the completeness index of the team is 20; if all knowledge conversion abilities of all team members are under mean value, the completeness index of the team is 0.

Heterogeneity of knowledge conversion abilities. A coefficient of variation across team

members in each team was calculated, for each of the four knowledge conversion abilities, to assess variation in knowledge conversion abilities. A score of 0 indicates perfect homogeneity along the given dimension. Once the heterogeneity coefficients were calculated for each knowledge conversion abilities, the four were averaged into a single heterogeneity index.

Team learning processes

Team learning processes were constructed from 28 items that taken from Team Learning Survey (TLS) (Dechant and Marsick, 1993) and other team learning theory. Team members assessed team learning processes according to their individual perception. Factor analysis of data revealed a five factors solution, assessed framing/reframing, experimenting, crossing boundaries, diverging, and integrating perspectives processes of team learning respectively. 11 items that not consistently discriminate between factors, or ambiguously loaded on one more factors were dropped from further analysis. Finally, we got 17 items to be used in further analysis, 3 items for framing/reframing, 2 items for experimenting, 2 items for crossing boundaries, 4 items for diverging, and 6 items for integrating perspectives. Cronbach's a coefficients were .72, .81, .65, .57, and .87 respectively.

Control variables

Team size and team longevity were used as control variables. Group size was a control variable in our study because the literature on groups or teams has noted that size is a key variable influencing group dynamics and performance (Brewer & Kramer, 1986) and because larger teams have more potential for heterogeneity (Bantel & Jackson, 1989; Jackson et al., 1991). We controlled for team longevity because previous research has found that the average tenure of group members often influence group interactions and performance also (Pelled, Eisenhardt & Xin, 1999).

Data Aggregation

Because team is the analysis unit of this study, we need to aggregate the individual data on team learning process. Before creating team-level variables, we assessed the level of within-team individual agreement for the five dimensions of team learning process measures (Rousseau, 1985). A one-way ANOVA, using team affiliation as the independent variable to determine if there was greater variability in the ratings between teams than within teams. The F-ratios were significant for framing/reframing, diverging, and integrating perspectives ($F = 1.49$, $p < .05$; $F = 1.87$, $p < .01$; $F = 1.45$, $p < .05$), but not significant for experimenting and crossing boundaries ($F = 1.06$ and 1.10 respectively). We also used an interrater reliability

coefficient r_{wg} (James, Demaree & Wolf, 1984, 1993) to examine the intragroup reliability of responses. The r_{wg} for framing/reframing, experimenting, crossing boundaries, diverging, and integrating perspectives are .89, .79, .77, 90 and .88 respectively, all above .70 (George, 1990). These scores suggest a acceptable level of agreement within the teams. These findings legitimized our aggregating dimensions of team learning process by averaging the individual team member scores.

RESULTS

Table 2 presents means, standard deviation, and correlations. Significant correlation coefficients between dimensions of team knowledge conversion abilities composition indicate that these dimensions are not completely independent. The level of two team knowledge conversion abilities is positively related to framing/reframing, diverging, and integrating perspectives: socialization(r = .28, p < .05; r = .29, p < .05; r = .30, p < .05), and combination(r = .26, p < .10; r = .37, p < .01; r = .39, p < .01). The level of internalization is positively related to experimenting and integrating perspectives (r = .27, p < .10; r = .25, p < .10). Completeness also positively related to framing/reframing, crossing boundaries, and integrating perspectives (r = .24, p < .10; r = .24, p < .10; r = .37, p < .01). Heterogeneity negatively related to experimenting (r = - .25, p < .10).

Insert Table 2 about here

We conducted two types of analysis to test hypothesis. First, the dimensions of team learning process, including framing/reframing, experimenting, crossing boundaries, diverging and integrating perspectives were used as dependent variables in a set of hierarchical regressions. The dimensions of team knowledge conversion abilities composition were entered into the equation after the set of control variables (team size and team longevity in months) had been entered. Results presented in table 3.

Insert Table 3 about here

The results indicate that level of three knowledge conversion abilities had significant effects on some team learning process dimensions. The level of Socialization ability was positively related to diverging (b = .29, p < .05) and integrating perspectives (b = .29, p < .05), and marginally positively related to framing/reframing (b = .27, p < .10) and crossing boundaries (b = .26, p < .10). Combination ability level was positively related to diverging (b = .33, p

< .05) and integrating perspectives (b = .36, p < .05), and marginally positively related to framing/reframing (b = .24, p < .10). Internalization ability level was marginally positively related to experimenting (b = .28, p < .10) and integrating perspectives (b = .23, p < .10). These results support Hypothesis 1.

In support Hypothesis 2, the completeness of knowledge conversion abilities had positive effects on all dimensions of team learning process, and significant effects on integrating perspectives (b = .33, p < .05) and marginally significant effect on crossing boundaries (b = .24, p < .10). Redundancy of knowledge conversion abilities also had positive effects on all dimensions of team learning process, and and significant effects on integrating perspectives (b = .35, p < .05) and marginally significant effect on crossing boundaries (b = .29, p < .10). The results also confirm Hypothesis 3. But contrary to our prediction of Hypothesis 4, heterogeneity of knowledge conversion abilities was marginally negatively related to experimenting (b = - .25, p < .10).

Besides, we entered all team knowledge conversion abilities composition variables simultaneously into five hierarchical regression equations, predicting framing/reframing, experimenting, crossing boundaries, diverging, and integrating perspectives respectively. When entered simultaneously, team knowledge conversion abilities composition variables were able to explain an additional 12 percent of variances (p < .10) in framing/reframing, an additional 14 percent of variances (p < .10) in experimenting, an additional 21 percent of variances (p < .05) in crossing boundaries, an additional 20 percent of variances (p < .05) in diverging, and an additional 23 percent of variances (p < .05) in integrating perspectives over what the control variables explained.

Further analysis was conducted in order to investigate the relationship between team knowledge conversion abilities composition and team learning process, and also to discover which dimensions of team knowledge conversion abilities composition have most impact upon team learning process. Since there are multiple dependent and multiple independent variables, canonical correlation analysis was used. This technique was appropriate because its aim is to develop parsimonious linear combinations of dependent and independent variables that maximize correlations between each set of linear combinations. Here, the structure coefficients are the beta weights used to form the respective dependent and independent linear combinations. In other words, applying these standardized weights to the respective variables produces the canonical variables. The standardized coefficients are the respective zero-order correlations of the variables with the linear combinations (i.e., canonical variables). Because previous research (Cooley & Lohnes, 1971; Jones, 1986) has shown that the structure coefficients have the greatest stability, they were used for interpretive purposes.

The results of the canonical analysis give one significant canonical function (p < .05). On the canonical function of the independent variables, the level of socialization, and combination abilities load high (.60, and .69). Completeness of team knowledge conversion abilities also load high (.50). The level of externalization and internalization abilities and redundancy of knowledge conversion abilities, and redundancy and heterogeneity of team knowledge conversion abilities loads low (.15, .17, - .15, .21). For the dependent variables, framing/reframing, crossing boundaries, diverging, and integrating perspectives load high (.64, .58, .85, and .71), and the experimenting lower (- .14). These results show that the level of socialization and combination abilities, and Completeness of team knowledge conversion abilities have more significant positive effect on team learning processes, especially framing/reframing, crossing boundaries, diverging, and integrating perspectives. Results of canonical analysis support hypothesis 1 and 2.

CONCLUSIONS

This study argued that four types of knowledge creating patterns in Nonaka's knowledge spiral theory: socialization, externalization, combination, and internalization, can be conceptualized as different knowledge conversion abilities possessed by team members. We developed four constructs of team knowledge conversion abilities composition: level, completeness, redundancy, and heterogeneity, and explored the relationships between these constructs of team knowledge conversion abilities composition and team learning processes. Our results showed that the level of socialization, combination, and internalization abilities positively related to team learning processes. Completeness and redundancy of team knowledge conversion abilities also have positive impact on team learning processes.

In our previous study, we had found that team knowledge conversion abilities composition affect knowledge sharing and knowledge creation in teams (Huang & Wang, 2002). The findings support that knowledge spiral theory established by Nonaka and colleaques (Nonaka, 1991, 1994; Nonaka & Takeuchi, 1995). Through processes of socialization, externalization, combination, and internalization, knowledge can transform between tacit and explicit dimensions. In the knowledge creating processes, all four of these patterns exist in dynamic interaction, a kind of spiral of knowledge. The overall pattern of findings in this study may also be conceived as extensions of knowledge spiral theory, because they showed that it's possible to affect team learning process through the composition of team members with socialization, externalization, combination, and internalization abilities.

This study also provides a new perspective about the application of knowledge spiral theory. If conceptualizing socialization, externalization, combination, and internalization as different

knowledge conversion abilities, we can improve team learning processes by proper team member composition. Through selection or training, team members with these different knowledge conversion abilities interact in teams to facilitate team learning process, and may further improve knowledge sharing and creation.

This research also showed the concept of knowledge conversion abilities is a research area with potential in team learning and knowledge management. The knowledge conversion abilities scale developed in this study also provided a useful instrument for future research. Besides, the growing team composition research focused on the impact of demographic diversity mostly (Milliken & Martin, 1996; Williams & O'Reilly, 1998). Recently, cognition or personality composition in teams has got more and more attention in team composition research (e.g., Barsade, Ward, Turner & Sonnenfeld, 2000; Kilduff, Angelmar & Mehra, 2000; Miller, Burke & Glick, 1998; Taggar & Manor, 2002). The knowledge conversion abilities composition seems to be a potential topic for future research.

REFERENCES

Altrichter, H., Posch, P., and Somekh, B. (1993). *Teachers investigate their work: An introduction to the methods of action research*, Routledge.

Anzai, Y. and Simon, H. A. (1979). The theory of learning by doing. *Psychological Review*, 86, 124-140.

Austin, J. R. (1997). A cognitive framework for understanding demographic influences in groups. *The International Journal of Organizational Analysis*, 5(4), 342-359.

Bantel, K. A., and Jackson, S. E. (1989). Top management and innovations in banking: Does the composition of the top team make a difference? *Strategic Management Journal*, 10, 107-124.

Bargh, J. A. (1982). Attention and automaticity in processing of self-relevant information. *Journal of Personality and Social Psychology*, 43, 425-436.

Barsade, S. G., Ward, A. J., Turner, J. D. F., and Sonnenfeld, J. A. (2000). To your heart's content: A model of affective diversity in top management teams. *Administrative Science Quarterly*, 45, 802-836.

Berry, D.C. (1991). The role of action in implicit learning. *Quarterly Journal of Experimental Psychology*, 43, 881-906.

Berry, D. C., and Broadbent, D. E. (1984). On the relationship between task performance and associated verbalizable knowledge. *Quarterly Journal of Experimental Psychology*, 36A, 209-231.

Berry, D. C., and Broadbent, D. E. (1987). The combination of implicit and explicit learning

processes. *Psychological Research*, 49, 7-15.

Brewer, M. B., and Kramer, R. M. (1986). Choice behavior in social dillemma: Effects of social identity, group size, and decision framing. *Journal of Personality and Social Psychology*, 50, 543-549.

Cooley, W., and Lohnes, P. R. (1971). *Multivariate data analysis*, New York: John Wiley & Sons.

Dechant K., and Marsick, V. J. (1993). *Team learning survey: Leaders guide*, King of Prussia, PA: Organization Design & Development.

Dechant K., Marsick, V. J., and Kasl, E. (1993). Towards a model of team learning. *Studies of continuing education*, 15, 1-13.

Dunnelte, M. O. (1976). Aptitudes, abilities, and skills. In M. D. Dunnelte (Ed.), *Handbook of Industrial and Organizational Psychology*, 571-607.

Forbes, D. P., and Milleken, F. J. (1999). Cognitive and corporate governance: Understanding boards of directors as strategic decision-making groups. *Academy of Management Review*, 24, 489-505.

George, J. (1990). Personality, affect, and behavior in groups. *Journal of Applied Psychology*, 75, 107-116.

Guilford, J. P. (1967). *The nature of human intelligence*, New York: Mcgrow-Hill.

Hoffman, L. R., and Maier, N. R. F. (1961). Sex differences, sex composition , and group problem solving. *Journal of Abnormal and Social Psychology*, 63, 453-456.

Huang, J. C., and Wang S. F. (2002). Knowledge conversion abilities and knowledge creation and innovation: A new perspective on team composition. *Proceedings of the Third European Conference on Organizational Knowledge, Learning and Capabilities*. Athens Laboratory of Business Administration, Athens, Greece.

Jackson, S. E., Brett, J. F., Sessa, V. I., Cooper, D. M., Julin, J. A., and Peyronnin, K. (1991). Some differences make difference: Individual dissimilarity and group heterogeneity as correlates of recruitment, promotions, and turnover. *Journal of Applied Psychology*, 76, 675-689.

James, L. R., Demaree, R. G., and Wolf, G. (1984). Estimating within-group interrater reliability with and without response bias. *Journal of Applied Psychology*, 69, 85-98.

James, L. R., Demaree, R. G., and Wolf, G. (1993). r_{wg}: An assessment of within- group interrater agreement. *Journal of Applied Psychology*, 78, 306-309.

Jones, G. R. (1986). Socialization tactics, self-efficacy, and newcomers' adjustments to organizations. *Academy of Management Journal*, 29, 262-279.

Kidd, J. B. (1998). Knowledge creation in Japanese manufacturing companies in Italy:

Reflections upon organizational learning. *Managemet Learning*, 29(2), 131-146.

Kilduff, M., Angelmar, R., and Mehra, A. (2000). Top management-team diversity and firm performance: Examining the role of cognitions. *Organization Science*, 11, 21-34.

Kirton, M. J., (1976). Adaptors and innovators: A description and measure. *Journal of Applied Psychology*, 61, 622-629.

Kirton, M. J., (1978). Have adaptors and innovators equal levels of creativity? *Psychological Reports*, 42, 695-698.

Kirton, M. J., (1989). A theory of cognitive style. In M. J. Kirton (Ed.), *Adaptors and Innovators: Styles of Creativity and Problem Solving*. London: Routledge.

Leonard-Barton, D. (1995). *Wellsprings of Knowledge: Building and Sustaining the Sources of Innovation*, Boston, M.A.: Harvard Business School Press

Leonard-Barton, D., and Swap, W. C. (1999). *When Sparks Fly: Igniting Creativity in Groups*, Boston, M.A.: Harvard Business School Press.

Louis, M. R., and Sutton, R. I. (1991). Switching cognitive gears: From habits of mind to active thinking. *Human Relations*, 44, 55-76.

Miller, C. C., Burke, L. M., and Glick, W. H. (1998). Cognitive diversity among upper-echelon executives: Implications for strategic decision process. *Strategic Management Journal*, 19, 39-58.

Milliken, F. J., and Martins, L. L. (1996). Searching for common threads: Understanding the multiple effects of diversity in organizational groups. *Academy of Management Review*, 21, 402-433.

Nonaka, I. (1990). Redundant, overlapping organization: A Japanese approach to managing the innovation process. *California Management Review*, 32(3), 27-38.

Nonaka, I. (1991). The knowledge creating company. *Harvard Business Review*, 69(6), 96-104.

Nonaka, I. (1994). A dynamics theory of organizational knowledge creation. *Organization Science*, 5, 14-37.

Nonaka, I., and Konno, N. (1998). The concept of "Ba": Building a foundation for knowledge creation. *California Management Review*, 40(3), 40-54.

Nonaka. I., and Takeuchi, H. (1995). *The Knowledge Creating Company: How Japanese Companies Create the Dynamics of Innovation*. New York: Oxford University press.

Nonaka, I., Takeuchi, H., and Umenmoto, K. (1996). A theory of organizational knowledge-creation. *International Journal of Technology Management*, 11(7-8), 833-845.

Pelled L. H., Eisenhardt, K. M., and Xin, K. R. (1999). Exploring the black box: An analysis

of work group diversity, conflict, and performance. *Administrative Science Quarterly*, 44, 1-28.

Raudsepp, E. V. 1983. *How to Create New Idea*, Englewood Cliffs, N.J.: Prentice-Hall.

Rousseau, D. (1985). Issues of level in organizational research. In L. L. Cummings, and B. M. Staw (Eds.), *Research in Organizational Behavior*, 7, 1-37, Greenwich, CT: JAI Press.

Sanderson, P. (1989). Verbalizable knowledge and skilled task performance: Association, dissociation and mental model. *Journal of Experimental Psychology*, 15, 729-747.

Schön, D. (1987). *Educating the reflective practitioner*, San Francisco: Jossey-Bass Publishers.

Simon, H. A., and Langley, P. (1989). The central role of learning in cognition. In H. A. Simon (ed.), *Models of thought*, 2, 102-115, New Hacen: Yale University Press.

Taggar, S., and Manor, B. (2002). Individual creativity and group ability to utilize individual creative resources: A multilevel model. *Academy of Management Journal*, 45, 315-330.

Tomlinson, P. (1999). Conscious reflection and implicit learning in teacher preparation, Part I: Recent Light on an Old. *Oxford Review of Education*, 25, 405-424.

Tsui, A. S., Egan, T. D., and O'Reilly, C. A. (1992). Being different: Relational demography and organizational attachment. *Administrative Science Quarterly*, 37, 549-579.

Williams, K. Y., and O'Reilly, C. A. (1998). Demography and diversity in organizations: A review of 40 years of research. In B. M. Staw and R. M. Sutton (eds.), *Research in organizational behavior*, 20, 77-140. Stanford, CT: JAI Press.

Table 1
Principle Components Factor Structure of the Knowledge Conversion Abilities[a]

Items	Factor 1	Factor 2	Factor 3	Factor 4	Alpha
Internalization					.70
After hearing a new idea or concept, I tend to compare it with my experience to help me comprehend the meaning.	.17	.12	.19	**.60**	
I understand others' thoughts better by repeating what they said and asking them "Is this what you mean?"	.03	.07	.20	**.75**	
I will tell others what I think to make sure my understanding is the same as theirs.	.09	.22	.11	**.75**	
When I have finished saying something, I will ask the other person if it is necessary to repeat to make sure he/she understands exactly what I mean.	.31	.17	- .06	**.60**	
When communicating with others, I will give others time to think about what we just discussed.	.11	.49	.08	.46	
Externalization					.87
When others can't understand me, I am usually able to give him/her examples to help explaining.	.11	**.72**	.19	.27	
Most of the time, I can transcribe some of the unorganized thoughts into concrete ideas.	.26	**.72**	.04	.13	
I can describe professional or technical terms with conversational language to help communication in a team.	.27	**.70**	.21	.18	
I tend to use analogy when expressing abstract concepts.	.24	**.79**	.20	.08	
When I try to express abstract concepts, I tend to explain with examples.	.19	**.74**	.31	.11	
I will help others to clearly expressing what he/she has in mind by encouraging them to continue what they are saying.	.20	**.42**	.36	.24	
When others cannot express themselves clearly, I usually help them clarify their points.	.45	.19	.40	.20	
Socialization					.82
In team discussion, I will actively share my experience with others.	.27	.23	**.73**	.17	
In my work team, my teammates and I will share life or work experience with each other.	.12	.23	**.80**	.07	
During group discussion, I try to find out others' opinions, thoughts and other information.	.32	.14	**.50**	.26	
During discussion, I will bring out some concepts, thoughts or ideas.	.29	.11	**.59**	.13	
I often encourage others to express their thoughts.	.32	.33	**.47**	.13	
Before team discussion, I will collect necessary information and show it to my teammates.	.65	.24	.21	.19	
I like to get to know the people whom I will work with before going into a project together.	.55	.10	.23	.16	
Combination					.84
During the discussion, I tend to help organize ideas and make conclusion to facilitate the discussion.	**.82**	.14	.13	.03	
When coming across problems, I tend to use my experience to help solving problems.	**.59**	.01	.19	.21	
After every event, I have the habit of organizing and making summary of what happened.	**.69**	.28	.10	.12	
During discussion, I will organize everyone's thoughts in my mind.	**.67**	.37	.11	.18	
I like to collect new information, and making connection of new and old knowledge to work up new concepts.	**.50**	.28	.36	.02	
I like to organize ambiguous concepts into structure.	**.58**	.37	.30	.18	
Eigenvalue	9.49	1.84	1.49	1.19	
Percentage of variance explained	37.95	7.36	5.96	4.77	

[a] Bold type indicates an item was included in the index.

Table 2

Means, Standard Deviations, and Correlations among Variables

Variables	Mean	s.d.	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Socialization	5.41	.47													
2. Externalization	5.58	.50	.66**												
3. Combination	5.37	.42	.70**	.55**											
4. Internalization	5.62	.43	.55*	.62**	.43**										
5. Completeness	2.25	1.49	.80**	.71**	.77**	.71**									
6. Redundancy	12.27	6.87	.36**	.37**	.21	.49**	.43**								
7. Heterogeneity	.13	.05	-.49**	-.67**	-.37**	-.63**	-.60**	-.30*							
8. Framing/reframing	4.91	.50	.28*	.13	.26^{+}	.20	.24^{+}	-.01	-.02						
9. Experimenting	5.15	.55	.05	.05	.07	.27^{+}	.15	.19	-25^{+}	.38**					
10.Crossing boundaries	5.02	.55	.26	-.04	.17	.18	.24^{+}	.13	.03	.38**	.23				
11.Diverging	5.03	.62	.29*	.10	.37**	.14	.23	-.08	.05	.72**	.21	.49**			
12.Integrating perspectives	5.29	.45	.30*	.12	.39**	.25^{+}	.37**	.05	-.10	.70**	.49**	.49**	.69**		
13.Team size	27.00	32.48	-.03	-.01	-.12	-.10	-.18	.60	.02	- .19	.04	-.05	-.21	-.25^{+}	
14.Team longevity in months	5.58	3.13	-.02	-.10	-.12	.08	-.07	.24^{+}	-.02	- .06	.00	- .10	-.21	-.14	.17

$^{+}$ $p < .10$
* $p < .05$
** $p < .01$

Table 3

Hierarchical Regression Analysis of Team Knowledge Conversion Abilities Composition Variables on Team Learning Processes

	Framing/reframing		Experimenting		Crossing boundaries		Diverging		Integrating perspectives	
Variables	***b***	**? R^2**	***b***	**? R^2**	***b***	**? R^2**	***b***	**? R^2**	***b***	**? R^2**
Controls [a]		.04		.00		.01		.08		.07
Dimensions of knowledge conversion abilities composition		.12^{+}		.14^{+}		.21*		.20*		.23*
Level										
Socialization	.27^{+}		.06		.26^{+}		.29*		.29*	
Externalization	.14		.05		- .03		.12		.13	
Combination	.24^{+}		.08		.16		.33*		.36**	
Internalization	.19		.28^{+}		.19		.14		.23^{+}	
Completeness	.21		.16		.24^{+}		.19		.33*	
Redundancy	.17		.26		.29^{+}		.12		.35*	
Heterogeneity	- .02		- .25^{+}		.03		.05		- .10	

[a] Controls included team longevity in months and team size.

$^{+}$ $p < .10$

* $p < .05$

** $p < .01$