Knowledge Conversion Abilities and Knowledge Creation and Innovation: A New Perspective on Team Composition

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ABSTRACT

Based on Nonaka's knowledge spiral theory, this study conceptualized the four knowledge conversion patterns, including socialization, externalization, combination, and internalization, 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 innovation effectiveness, including knowledge transfer, knowledge creation, and R & D performance. We found socialization, combination, and internalization abilities level owned by team members have positive relationships with knowledge transfer and creation. The completeness of knowledge conversion abilities also has positive relationships with knowledge transfer and creation. Besides, the heterogeneity of knowledge conversion abilities has negative relationships with knowledge transfer and creation.

INTRODUCTION

The critical importance of knowledge-creation and innovation as a source of competitive advantage has been recognized in recent years. Many firms use teams as a basic knowledge creation unit concurrently with engineering, project teams, software design, product development, strategy development and multi-functional working teams (Jones & Jordan, 1998; Leonard-Barton & Swap, 1999; Walz, Elam & Curtis, 1993). Corporations are searching for ways to enhance the effectiveness and the efficiency of their teams' knowledge-creation process.

However, up until now, the focus of most research studies and works on knowledge-creation and creativity has been placed on individual level only, such as

how to stimulate the potential of individual's creativity, the relationship between individual's intelligence and creativity. Researches on team level are still lacking. As for the researches on knowledge management, focuses are mostly on organizational level, such as by designing and reengineering of organizational structure and culture, or to improvement on organization-wide IT skill to transform organizations into knowledge intensive or knowledge-creating companies (e.g. Leonard-Barton, 1995; Nonaka & Takeuchi, 1995). Thus, more team level researches still needed to be done.

Nonaka is one of the earliest to develop the knowledge-creation theory on an organizational 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. However, in all these researches, they only apply Nonaka's theory in their studies, none of them examined Nonaka's theory except for Kidd (1998).

Therefore, the purpose of this study is to testify the knowledge spiral theory at team level. We argued that four basic patterns of knowledge creation: socialization, externalization, combination, and internalization, can be conceptualized as different abilities possessed by team members. In this perspective, this study 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 innovation effectiveness (including knowledge sharing, creation, and R&D performance).

Besides, because of this study introduce a new team composition variable: knowledge conversion abilities. So this empirical study not only can testify knowledge spiral theory, we also providing a new perspective on team composition study to understand how the composition of team members with different knowledge conversion abilities can affect team knowledge creation outcomes.

THEORETICAL BACKGROUND AND HYPOTHESES

Knowledge Spiral Theory

In Nonaka's knowledge spiral theory, four basic patterns for creating knowledge in any organization are suggested: socialization, externalization, combination and internalization. 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 (from tacit to tacit), externalization (from tacit to explicit), combination (from explicit to explicit), and internalization (from explicit to tacit); and this spiraling process can spread out from individual, team, organizational to inter-organizational level (Nonaka, 1994; Nonaka & Takeuchi, 1995; Nonaka, Takeuchi & Umenmoto, 1996). Hence, if the knowledge spiral can effectively predict knowledge-creation performance in organizations, then at team level, the knowledge spiral should be able to predict knowledge-creation performance as well.

Knowledge Conversion Abilities

We argue these four processes of knowledge-creation can be carried out at least through two approaches: (1) the implementation 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.

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 does not equal to the differences in creativity; they just show the differences of

how creativity is presented (Kirton, 1976, 1978, 1989; Mudd, 1996). Under this perspective, the four patterns of knowledge conversion processes can be done through personal knowledge conversion abilities possessed by team members.

Team Knowledge Conversion Abilities Composition and Innovation Effectiveness

Four different constructs of team members' 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 innovation effectiveness, and form hypotheses.

Level of knowledge conversion abilities. As previously mentioned, socialization, externalization, combination, and internalization represents four abilities that an individual may possess. According to the knowledge spiral, these four abilities will aid the process of knowledge creation to produce better outcomes. Thus, if members in a research and development (R&D) team have these abilities, it will have a positive effect on knowledge sharing, creation, and R&D performance. The following hypothesis is suggested.

Hypothesis 1: Level of team members' knowledge conversion abilities is positively related to innovation effectiveness.

Hypothesis 1a: Level of team members' knowledge conversion abilities is positively related to knowledge sharing.

Hypothesis 1b: Level of team members' knowledge conversion abilities is positively related to knowledge creation.

Hypothesis 1c: Level of team members' knowledge conversion abilities is positively related to R&D performance.

Completeness of knowledge conversion abilities. In Nonaka's knowledge spiral theory, the complete process is comprised of all four modes of knowledge conversion (Nonaka, 1994; Nonaka & Takeuchi, 1995), and this seems to imply the completeness of knowledge conversion process, 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, and the team will not be benefited at all. Thus,

Hypothesis 2: Completeness of team members' knowledge conversion abilities is positively related to innovation effectiveness.

Hypothesis 2a: Completeness of team members' knowledge conversion abilities is positively related to knowledge sharing.

Hypothesis 2b: Completeness of team members' knowledge conversion abilities is positively related to knowledge creation.

Hypothesis 2c: Completeness of team members' knowledge conversion abilities is positively related to R&D performance.

Redundancy of knowledge conversion abilities. 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. Thus, if all team members possess all four of knowledge conversion abilities, then we can say that there is redundancy in their knowledge conversion abilities. This redundancy in knowledge conversion process will increase the depth of communication between members; hence, the overall amount of knowledge conversion abilities possessed by team members may influence the outcomes of innovation. The differences between redundancy and the completeness of the knowledge conversion capabilities is that the concept of completeness is focus on if a team possess all four of the knowledge conversion abilities; and redundancy assumes that knowledge conversion abilities of individual team members can accumulate and this accumulation effect can intensify a team's "innovative energy". These arguments suggest

Hypothesis 3: Redundancy of team members' knowledge

conversion abilities is positively related to innovation effectiveness.

Hypothesis 3a: Redundancy of team members' knowledge conversion abilities is positively related to knowledge sharing.

Hypothesis 3b: Redundancy of team members' knowledge conversion abilities is positively related to knowledge creation.

Hypothesis 3c: Redundancy of team members' knowledge conversion abilities is positively related to R&D performance.

Heterogeneity of knowledge conversion abilities. Past researches have shown that heterogeneity may have many impacts on a team, and one of them is the influence on team's innovation. In the early sixtieth, Hoffman and Maier (1961) found out that if team members' have more dispersed viewpoints toward a specific topic, then its creativity and decision quality are better. McLeod and Lobel (1992) found that a more ethnic diversified group will do better during group brainstorming. Bantel and Jackson (1989) did a research on banks, they also found that top management teams composed of functional diversified managers will be more innovative than homogeneous teams. Nonaka also believes that innovation teams should have members from different functional background; this will have a positive contribution to knowledge creation (Nonaka & Tekuchi, 1995).

Everyone possesses different knowledge conversion abilities, some may be good at externalization, and some maybe better at combination. In perspective of cognitive processing theory(Austin, 1997; Bargh, 1982; Louis & Sutton, 1991), this kind of heterogeneity in knowledge conversion abilities will cause team members switching to active processing mode and hence bring up team's innovation capability. Thus, because innovation is core tasks of R&D teams, a team with member of diversified knowledge conversion skills should perform better. The following hypothesis is suggested.

Hypothesis 4: Heterogeneity of team members' knowledge conversion abilities is positively related to innovation effectiveness.

Hypothesis 4a: Heterogeneity of team members' knowledge conversion abilities is positively related to knowledge sharing.

Hypothesis 4b: Heterogeneity of team members' knowledge

conversion abilities is positively related to knowledge creation.

Hypothesis 4c: Heterogeneity of team members' knowledge conversion abilities is positively related to R&D performance.

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 included in the following analysis (a 84 percent response rate of the teams). The teams in our sample had an average size of approximately 6 members (s.d. = 3.13) and a mean tenure of 27 months (s.d. = 32.48).

Measurement

Knowledge conversion abilities. 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. There were four groups of EMBA students and undergraduate business administration major students, all of them are from Soochow University in Taiwan. 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 approximately 8 participants. As for the undergraduate students, there were 20 people in the group. It is required that all of these students have participated in creative thinking class (and these students all have taken creative thinking class,) and have had experience working in small group on creative thinking projects.

Transcripts of all four focus groups were coded by authors and three other members of this study program. Each transcript was 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 major categories: 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 in Soochow University, and 171 valid samples were received. After item analysis and principle components factor analysis, we got 25 items to be used in the survey.

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. 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 α coefficients were between .70 and .87, shown in table 1.

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.	.49	.11	**.59**	.13	
I often encourage others to express their thoughts.	.42	.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.

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.

Innovation effectiveness. We used three different measures of innovation effectiveness: knowledge sharing, knowledge creation and R&D performance. The Knowledge sharing scale comprised seven questionnaire items adapted from Dechant and Marsick's (1993) team learning survey scale. Each item was measured on a 7-point Likert scales anchored by 1 = "strongly disagree" and 7 = "strongly agree". The coefficient alpha for this scale was .91.

Knowledge creation scale was developed according to Quinn, Anderson and Finkelstein's (1996) four levels definition about professional intellect: cognitive knowledge, advanced skill, systems understanding, and self-motivated creativity. We developed eight items on a 7-point Likert scales anchored by 1 = "strongly disagree"

and 7 = “strongly agree”. The coefficient alpha for this scale was .94.

The R&D performance measure comprised seven items on a 7-point Likert scales anchored by 1 = “strongly disagree” and 7 = “strongly agree”. The coefficient alpha for this scale was .92.

A principle components factor analysis of these 22 items measuring innovation effectiveness was conducted using varimax rotation. Three factors with eigenvalues greater than 1.0 and clean loading patterns emerged. The emergent structure was consistent with our conceptualization (e.g., knowledge sharing, creation, and R&D performance). These results established the discriminant validity of the three innovation effectiveness variables.

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 knowledge sharing, creation and R&D performance. Before creating team-level variables, We assessed the level of within-team individual agreement for the knowledge sharing, creation and R&D performance 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 knowledge sharing, creation and R&D performance ($F = 1.41$, $p < .05$; $F = 1.47$, $p < .05$; $F = 1.74$, $p < .01$). 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 knowledge sharing, creation and R&D performance

are .91, .79, and .84, all above .70(George, 1990). These scores suggest a substantial level of agreement within the teams. These findings legitimized our aggregating team innovation effectiveness by averaging the individual team member scores.

RESULTS

Table 2 presents means, standard deviation, and correlations.

Table 2
Means, Standard Deviations, and Correlations among Variables

Variables	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11
1. Knowledge sharing	5.47	.43											
2. Knowledge creation	5.39	.49	.83**										
3. R&D performance	4.76	.62	.42**	.56**									
4. Internalization	5.62	.43	.32*	.33*	- .09								
5. Externalization	5.58	.50	.17	.05	- .03	.62**							
6. Socialization	5.41	.47	.35*	.25^{+}	- .04	.55**	.66**						
7. Combination	5.37	.42	.28*	.31*	.14	.43**	.58**	.70**					
8. Completeness	2.25	1.49	.34*	.37**	.12	.71**	.71**	.80**	.77**				
9. Redundancy	12.27	6.87	- .01	.07	.04	.49**	.37**	.36**	.21	.43**			
10.Heterogeneity	.13	.05	- .19	- .24^{+}	- .03	- .63**	- .61**	- .49**	- .37**	- .60**	- .30*		
11.Team longevity in months	27.00	32.48	- .19	- .24^{+}	- .07	.08	.10	- .02	- .12	- .07	.24^{+}	- .02	
12.Team size	5.58	3.13	- .27*	- .18	.01	- .10	- .01	- .03	- .12	- .18	.60**	.02	.17

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

We conducted two types of analysis to test hypothesis. First, knowledge sharing, knowledge creation, and R&D performance were used as dependent variables in a set of hierarchical regressions. The dimensions of team knowledge conversion abilities composition were independently entered into the equation after the set of control variables (team longevity in months and team size) had been entered. Results presented in table 3.

The results indicate that three of the knowledge conversion abilities level had significant effects on knowledge sharing and creation. The internalization was positively related to knowledge sharing ($b = .31$, $p < .05$) and knowledge creation (b

= .34, $p < .05$). Socialization was positively related to knowledge sharing ($b = .34$, $p < .05$) and marginally positively related to knowledge creation ($b = .24$, $p < .10$). Combination was marginally positively related to knowledge sharing ($b = .24$, $p < .10$) and positively related to knowledge creation ($b = .28$, $p < .05$). These results support Hypothesis 1a and 1b. In support Hypothesis 2a and 2b, the completeness of knowledge conversion abilities had significant effects on knowledge sharing ($b = .29$, $p < .05$) and knowledge creation ($b = .34$, $p < .05$). Redundancy of knowledge conversion abilities had marginally significant effect on knowledge creation ($b = .34$, $p < .10$) but no significant effect on knowledge sharing ($b = .28$, n.s.). The results confirm Hypothesis 3b but not 3a. Contrary to our prediction of Hypothesis 4b, heterogeneity of knowledge conversion abilities was marginally negatively related to knowledge creation ($b = -.24$, $p < .10$). But all dimensions of team knowledge conversion abilities composition had no significant relationships with R&D performance. Hypothesis 1c, 2c, and 3c were not supported.

Besides, we entered all team knowledge conversion abilities composition variables simultaneously into three hierarchical regression equations, predicting knowledge sharing, knowledge creation, and R&D performance respectively. When entered simultaneously, team knowledge conversion abilities composition variables were able to explain an additional 15 percent of variances ($p < .10$) in knowledge sharing, an additional 23 percent of variances ($p < .05$) in knowledge creation and an additional 13 percent of variances (n.s.) in R&D performance over what the control variables explained.

Table 3
Hierarchical Regression Analysis of Team Knowledge Conversion Abilities Composition Variables on Innovation Effectiveness

	Knowledge sharing		Knowledge creation		R&D performance	
Variables	***b***	**ΔR^2**	***b***	**ΔR^2**	***b***	**ΔR^2**
Controls [a]		.10^{+}		.08		.01
Dimensions of knowledge conversion abilities composition		.15^{+}		.23*		.13
Level						
Internalization	.31*		.34*		- .09	
Externalization	.18		.07		- .02	

Socialization	.34*	.24^{+}	- .04	
Combination	.24^{+}	.28*	.14	
Completeness	.29*	.34*	.13	
Redundancy	.28	.34^{+}	.06	
Heterogeneity	- .19	- .24^{+}	- .03	
Full equation	.25^{+}	.31*	.14	

[a] Controls included team longevity in months and team size.
$^{+}$ $p < .10$
* $p < .05$

Further analysis was conducted in order to investigate the relationship between team knowledge conversion abilities composition and innovation effectiveness, and also to discover which dimensions of team knowledge conversion abilities composition have most impact upon innovation effectiveness. 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 and the other marginally significant canonical function (*p* equals to .003 and .053). On the first canonical function of the independent variables, the level of internalization, socialization, and combination abilities load high (-.75, -.58, and -.40). Completeness and heterogeneity of knowledge conversion abilities also load high (- .53 and .40). The level of externalization abilities and redundancy of knowledge conversion abilities loads lowest (-.20 and -.05). For the dependent variables, knowledge sharing and

creation load highest (-.70 and -.67), and the R&D performance lower (.21). These results show that the level of internalization, socialization, and combination abilities, and Completeness of knowledge conversion abilities have more significant positive effect on knowledge sharing and creation. The heterogeneity of knowledge conversion abilities has more significant effect on knowledge sharing and creation. For the second canonical function, all dimensions of knowledge conversion abilities load low, so there is no obvious relationships show in the second canonical function.

Generally speaking, except the relationships between redundancy of knowledge conversion abilities and knowledge creation found in regression analysis not showed in canonical analysis. Results of canonical analysis are similar to regression analysis.

DISCUSSION

This study argued that four types of knowledge conversion process in Nonaka's knowledge spiral theory: socialization, externalization, combination, and internalization, can be conceptualized as different 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 innovation effectiveness (including knowledge sharing, creation, and R&D performance). Our results showed that the level of socialization, combination, and internalization abilities positively related to knowledge sharing and creation. Completeness and redundancy of team knowledge conversion abilities also have positive impact on knowledge sharing and creation. The overall pattern of these findings support 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.

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 knowledge

sharing and creation by team member composition. Through selection or training, team members with these different knowledge conversion abilities interact in a team to facilitate knowledge sharing and creation.

The results of this study showed the concept of knowledge conversion abilities is an research area with potential in knowledge management. The knowledge conversion abilities scale developed in this study also provided an 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; Jehn et al., 1999; Kilduff, Angelmar & Mehra, 2000; Miller, Burke & Glick, 1998). The knowledge conversion abilities composition seems to be an topic for future research.

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