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Case Study on Leadership, Team Climate and Knowledge Innovation in R&D Teams

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Abstract

Through studying the case of the U.S. National Aeronautics and Space Administration (NASA) , this paper focuses on the impact of leadership and climate for innovation on knowledge innovation. Besides, the paper measures knowledge innovation behavior in R&D teams on the basis of the previous researches. Then final conclusions are summarized as follows: leadership plays a very important role in improving R&D teams' knowledge innovation; team climate for innovation plays an intermediary role on relationship between them.

Key words: R&D teams; leadership; team climate for innovation; innovation capability

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INTRODUCTION

Research and development (R&D) team is the cornerstone for an organization to achieve high-performance. With the profound changes in the environment of the organization, its internal structure is also undergoing a deep transformation. The old concepts that stress on staff personal struggle have been gradually giving way to teamwork. An increasing number of organizations choose to accomplish their organizational goals by teams. As an effective organization in technological innovation, R&D team is one of the most important teams in the knowledge economy (Ancona & Caldwell, 1992; Janz, Colquitt & Noe, 2006; Newman, 2009). The previous team researches generally focus on the management teams and work teams, paying only a little attention to R&D teams, consulting teams, IT teams and other knowledge-based teams, and the majority of these sporadic researches are from the perspectives of team construction, team cooperation, team motivation, team-spirit construction, compensation design and team working mechanism. (Abbey & Dickson, 1983; Lynn & Reilly, 2000; Nonaka & Konno, 1998; Tjosvold, Margaret & Yu, 2005; Wang, Jing & Klossek, 2007). The R&D team focuses mainly on knowledge innovation, and its performance is primarily measured by the integrated innovation of the internal knowledge and the absorption and transformation of the external knowledge (Ancona & Caldwell, 1992; Janz, Colquitt & Noe, 2006). Therefore, it is of great significance to study the performance of R&D team as well as the factors affecting the performance from the perspective of knowledge innovation.

In this paper, an in-depth case study is conducted based on NASA (National Aeronautics and Space Administration), a universally renowned R&D team, hoping to draw some useful lessons from its successful management practice by reviewing and analyzing a large number of related documents. This paper comprehensively examines the knowledge innovation capability of the R&D team, analyzes and verifies the interaction between the leadership behavior, team climate for innovation and the knowledge innovation.

1. LITERATURE REVIEW

The early studies on R&D teams were all concerned about the external factors, such as external communication and other external activities, paying little attention to the in-depth description of the internal world of R&D teams. In recent years, many scholars have pointed out that the performance of knowledge innovation is a key indicator

for R&D teams, and one of the future research direction is to study the mechanisms of how internal factors of R&D teams (such as leadership style, team climate, etc.) affect their performances (Newman, 2009; Bain, Mann & Pirola, 2001).

1.1 Leadership Behavior and Knowledge Innovation

The ultimate goal of R&D teams is to achieve knowledge innovation. However, none of the previous researches on the performance of R&D teams are from the perspective of knowledge innovation, which is in fact the most important yardstick for performance measurement in high-tech R&D teams.

This study focuses on the knowledge innovation ability from a team level. In knowledge innovation, leaders act as an "architect" and "catalyst", which is one of the effective factors. It is of great significance to explore the influence of leadership behavior on knowledge innovation since it can facilitate us to better manage our R&D teams. Davenport, Delong and Beers (1998) analyzed 32 knowledge-based teams and pointed out that in order to effectively promote the knowledge innovation, team climate that facilitates knowledge flows and innovation is required and the team leader should give his public supports both in words and deeds. Bruce et al (2002) revealed that leadership behavior and knowledge innovation of teams are closely related. They also found that teams with achievement-oriented leadership and participative leadership can achieve better results in knowledge innovation than the teams which adopt supportive leadership and directive leadership and the innovative achievements of the supportive leadership is better than a directive one.

1.2 Leadership Behavior and Team Climate for Innovation

Team climate for innovation refers to team members' awareness of the work environment that affects their innovation capability, including vision, participation security, task orientation and innovation support. Generating significant, creative innovation is the fundamental requirement for research and development. Therefore, team climate for innovation is essential to R&D teams. It's like a force field in which all members are bound by it and heading for the same direction, and in this way the team keeps developing and the sense of innovation continues (Bain, Mann & Pirola , 2001).

An efficient research and innovation climate has the following features: customer-oriented, failure tolerance, strategic, supporting innovation and pursuing excellence in science and technology. To gain such a team climate, leaders must constantly examine their own attitudes and values, avoiding any behavior that is not conducive to the team climate for innovation (Newman, 2009). The previous studies on the relationship between leadership behavior and team climate for innovation have revealed that transformational and charismatic leadership are conducive to the formation of the team innovation climate (Jung, 2001; Keller, 1992). Ingrid et al (2004) conducted an empirical research based on a high-tech enterprise in Sweden and found that there's a significant positive correlation between the leadership which is both employee-oriented and change-oriented and the team climate for innovation.

1.3 Team Climate for Innovation and Knowledge Innovation

R&D team's job is to innovate new knowledge or to find new ways to apply knowledge. Many studies have revealed that team climate for innovation is a key factor to promote knowledge innovation (Newman, 2009). In a study on work atmosphere, trust and knowledge innovation, Ruppel and Harrington (2001) found that a good working atmosphere can enhance employee and organizational trust, and a mutual trust between employees will promote the knowledge innovation of the organization. Sveiby and Simons (2002), in their empirical study on the relationship between work atmosphere, knowledge sharing and knowledge innovation, found that there's a positive correlation between work atmosphere and knowledge innovation of an organization; they also found that a cooperative work atmosphere can promote knowledge sharing and knowledge innovation. Previous studies hold the view that the order (from strong to weak) of the five dimensions of the innovation climate in terms of their power to predict the enterprises' knowledge innovation are: organizational encouragement, team support, adequate resources, job autonomy and work challenges (Wang, Jing & Klossek, 2007). Team climate for innovation is the working impetus for team members. A good climate is conducive to forming a consistent group target and achieving an effective communication and exchange in the process of knowledge innovation (Huang & Jiang, 2012).

1.4 The Intermediary Role of the Team Climate for Innovation

Judge et al (2004) verified that there's a significant correlation between the transformational leadership and the team knowledge innovation, and proposed that the intermediary role played by the team climate should be considered in future researches. Based on previous studies on the relationship between the team innovation climate and the knowledge innovation, it is easy to infer that different leadership behaviors affect the teams' performance of knowledge innovation through innovation climate. Leaders, by providing the necessary conditions, can initiate a team climate which is favorable for autonomy, cooperation and openness, and promote the exchanges and knowledge sharing among team members, so as to raise the team's overall level of innovation (Ning & Jing, 2012). Earl and Scott (1999) pointed out that the senior leader must create a corporate culture and values which is conducive to knowledge innovation, and promote the exchange of knowledge and cooperation within the organization to improve both the organizational and the

individual knowledge innovation capacity as well as to increase the overall knowledge stock and the values of the organization. Delong and Fahey (2000) pointed out that in the process of knowledge innovation, leaders are supposed to figure out which activities and programs of the team support or undermine knowledge sharing and innovation, and establish a favorable team climate for innovation.

2. RESEARCH DESIGN

2.1 Case Selection

NASA (National Aeronautics and Space Administration) is an American government agency responsible for the space program. Founded in October 1, 1958, the Washington, DC headquartered agency is widely regarded as the worldwide leader in space exploration. It boasts the most advanced aerospace technology and has achieved great success in many fields like manned space flight, aeronautics, space science, etc. It has been involved in many space programs, including the U.S. Apollo program, space shuttle launches, solar system exploration, etc., and has made tremendous contributions to human's exploration of the space.

2.2 Data Collection

The data (such as NASA's general information, major events, leaders and other background information) is primarily collected from the websites, including NASA's official website and other related sites. In order to ensure the information we collect is comprehensive, a case background information checklist is specially designed, including the team development profile (development history, major events), research fields, leaders, innovation achievements and future development strategy. Besides, related books have also been reviewed, such as *How NASA Builds Teams*, a book written by Dr. Charles, former director of NASA's Astrophysics Division. The extensive data sources consolidate the research foundation and make it more effective, enhancing the construct validity and reliability of the research (Yin, 1994).

2.3 Data Coding

When reviewing the information, a typical event analysis method is adopted to encode the information from different sources. We first carefully checked all the web information, books and etc., and documented properly; then we encoded all the materials in accordance with the previously proposed key variables (see Table 1); next, we further branched the materials into subdivisions according to the specific dimensions of each construct. Finally, we tri-angulated the different data sources and the evidence chain to increase the reliability and validity (see Table 2). The results show that the data is of high consistency.

Table 1
Examples of Data Coding

Leadership behavior characteristics	Climate for innovation	Knowledge innovation capability
A successful leader must be a good listener and a good follower (Marc Imhoff). Leaders need to avoid a negative attitude, inspire optimism and enthusiasm, and equip the subordinates with common goals and a common vision (Gail Williams). Command and control for scientists and technical experts is no good, especially the young people. A leader is a magician, who can inspire bold innovative ideas (Carla Bitter). A leader's authority and vision can motivate the lazy and even the narrow-minded employees, so let him follow the train of his thoughts (Dilbert Cartoon). A leader must adjust the pace of the team properly. And not to oppress any part of the team at the same time (Jeanne Holm).	Even if there're major changes within the team, I would feel safe (Singell, Larry). Encourage the team members to undertake more joint research and cooperation via Blog and Wiki, and encourage new users to participate through the Second Life program. The work is flexible, but we need to face the financial and time pressures (Ross, Alexandra). There's an atmosphere of mutual trust within the team; even if someone makes a mistake, we will openly tell the truth (Fred). Everyone can have different opinions, a program can be questioned, overturned by someone at any time, people often say, "I do not agree with you, I was thinking....." (Einstein, Albert).	Learn from mistakes and failures and inspire new knowledge and technology. In December 1993, Charles Pellerin with his team successfully repaired the Hubble Space Telescope under the complex environment in space. Through reparation, they not only eliminated Hubble telescope's aberrations, but also improved its resolution, making it even outstrip the original design. The portal site of NASA is quite user friendly, either an 8-year-old kid or a scientist is able to find what they want by starting from the home page. Before 2002, scientists had to spend several hours, days, or even weeks analyzing before they publish the images and the relevant analysis. Now, the analysis results are generated synchronously with the global communities. In the *Mars Exploration Program: Phoenix*, the scientists will use tiny appliances to explore the composition of the water on the Mars; their creativity is beyond Apple's imagination.

Table 2
Triangulation of Data

Category	Leadership behavior characteristics	Team climate for innovation	Knowledge innovation capability
Time	Present and the past	Present and the past	The past
Data Source	2、3、4	1、2、3、4	1、2、3、4
Cross consistency	High	High	High

Note: 1-internal data of the team; 2-books, magazines and newspapers; 3-online information; 4-official reports

2.4 Analysis Method

The 4-D model based analysis is adopted in the case study. 4-D model is proposed by Charles (2009) based on NASA's experience and lessons learned in team management. The 4-D model (see Figure 1) will be used to analyze the factors involved in team-building; here the four dimensions are represented with orange, yellow, green and blue respectively. According to the model, any good teams or leaders are both emotional and logical; they have both real-world experience and intuition for the future. Currently, this model has become an important assessment tool for team building capacity in American business.

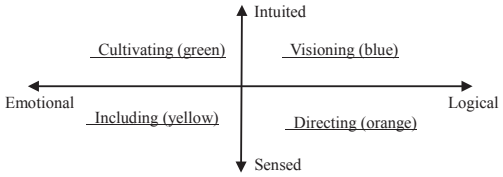

Figure 1
The 4-D Organizing System

3. RESEARCH FINDINGS

This case study adopts the "4-D model" to analyze the leadership behavior, team climate for innovation and knowledge innovation capability, trying to answer the following questions: What impact do different leadership behaviors pose on R&D team's outcome variables, namely the knowledge innovation capability? Do different leadership behaviors facilitate or constrain the formation and development of the team climate for innovation? What impact does the innovation climate have on the team's performance (knowledge innovation capability)? In other words, whether the innovation climate plays an intermediary role between leadership behavior and knowledge innovation capability?

3.1 Knowledge Innovation Capability

R&D activities can actually be regarded as a process in which the tacit knowledge of individuals and teams is gradually developed into explicit knowledge, and ultimately integrated into a new knowledge system through different ways of knowledge sharing and innovation. R&D team is an effective carrier for the growth of the Interactive knowledge innovation among the members. NASA team is successful in many senses, but there's one thing that cannot be ignored, that is, NASA has a very unique knowledge innovation practice and has achieved remarkable results in knowledge socialization, integration, externalization and internalization, etc.

Knowledge socialization. Tacit knowledge is the source for an enterprise to create values. The collection of external social information and the accumulation of tacit knowledge are closely related to the team's research and development capability as well as knowledge innovation capability. NASA, a very good team to learn from cooperation, takes learning from social partners as an important part of achieving knowledge innovation. By maintaining a good partnership with SunGard, Akamai, Yahoo and other industry giants, it ensures that its technology and academic vision keep pace with the development of the world advanced science and technology.

Knowledge externalization. Knowledge externalization refers to the full exploitation of the knowledge within an organization, which in most cases means to exploit the tacit knowledge. The extent to which the tacit knowledge externalizes into explicit knowledge determines the team's knowledge innovation ability; however, tacit knowledge cannot be directly shared since it is in the workers' brain. In NASA, the completion of the daily work logs fully encourages the staffs to sum up and code their own minds and experiences and they can conduct more joint research and cooperation via Blog and Wiki.

Knowledge integration. Explicit knowledge accumulation and integration is of great significance for the team to develop its knowledge innovation. The new space technology that NASA is involved in is a huge systematic project which requires integrating various technologies. NASA's *Great Observatories* program needs to integrate the technologies of the Compton Gamma Ray Observatory (CGRO) and other three famous observatories into a new set of astronomical observation database.

Knowledge internalization. NASA attaches great importance to staff training and education; it has established a comprehensive training system to facilitate the conversion of team knowledge to the members' individual knowledge, which in turn expands the team's knowledge stock as individuals gain more experience and problem-solving skills. NASA Goddard Space Flight Center provides the team members with a nine-month Leadership Alchemy Program. All the participants feel that they are benefiting a lot from the program. "This program has not only improved my technical capabilities, but also greatly helped shape my personality." Gail Williams said.

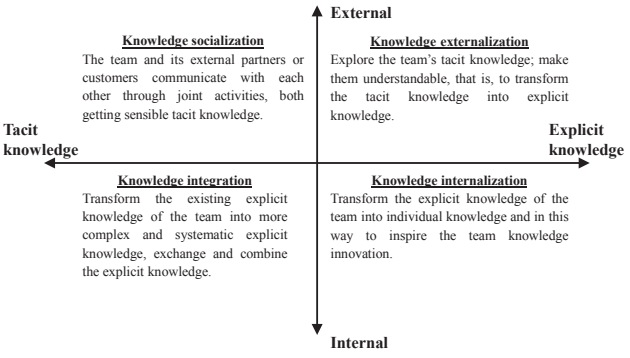

Figure 2
The 4-D System Analyzes Innovation Capability

According to the 4-D model, we found that the team knowledge innovations in this case consists of four different measurement dimensions (see Figure 2).

3.2 Leadership Behavior And Knowledge Innovation

A team leader acts as a convex lens, gathering the efforts of members from different divisions to generate huge amount of energy. NASA's team leaders play a decisive role in the development of the entire team and the successful completion of its projects (Clement, Ritsher, Saylor, Kanas, 2006). International Space Station has specially designed a CPR questionnaire to investigate the characteristics of NASA's leaders. According to the 4-D model, leaders should pay attention to their competency in four dimensions, namely, directing, including, cultivating and visioning (see Figure 3).

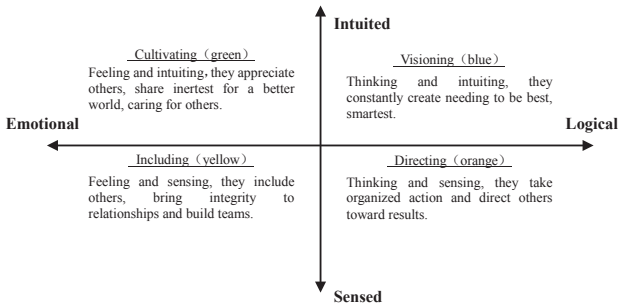

Figure 3
The 4-D System Analyzes Leadership

Knowledge innovation requires leaders to be learners, instructors, commanders and controllers. Of course, the more the leaders do to encourage sharing useful knowledge among team members, the better the knowledge flow generated from knowledge sharing when team members solve complex problems, in this way, the team's knowledge innovation capability is enhanced (Maccoby, 2008). Once NASA Compton Gamma Ray Observatory program (CGRO) got a problem with its automatic mapping system, if not fixed, the entire program was likely to be shelved. The person then in charge of CGRO required it to be fixed in 9 weeks. First, he ordered the members to speed up drawings to meet the display requirements of the radar. In order to motivate engineers and technical staff, the director of CGRO confided the current situation to every member of the team: the high failure risk, the team and each individual' honor might lose at any time and everyone was encouraged to do their utmost to solve the problem. Then the director and team members determined the specific repair plan: If the intended goals were achieved within each set time period—3 weeks, the team members and their families would be offered a sumptuous dinner at their favorite restaurants by NASA and the members could also spend the weekend with their families. "This is done to make team members feel the team's humane care and get motivated." Finally, CGRO team successfully fixed the new automatic drawing system at the lowest cost; of course, the leader's contribution cannot be left unrecognized.

3.3 Leadership Behavior and Team Climate for Innovation

A team should create an environment and climate conducive to innovation while encouraging knowledge innovation, in other words, in a successful knowledge innovation team, leaders must foster an environment in which members are eager to pursue knowledge and ensure a continuous application, dissemination and creation of knowledge. Excellent team climate is both emotional and logical; it has both real-world experience and intuition for the future. Based on the 4-D model, we outlined the different characteristics of a team climate for innovation (see Figure 4). At the different development stage of the project, the team climate for innovation shows different characteristics.

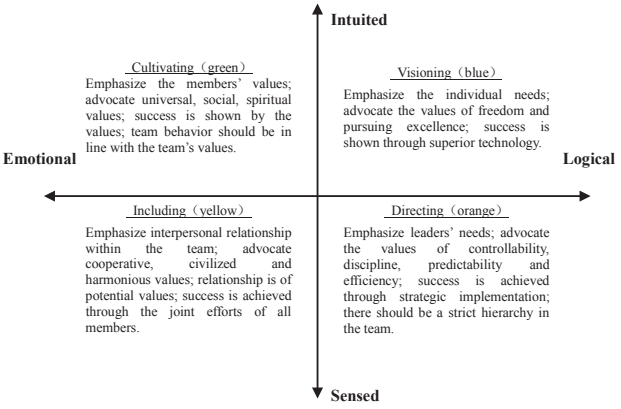

Figure 4
The 4-D System Analyzes Team Climate

The researchers of NASA are from around the world; therefore, the innovation climate conducive to communication is very important. Different leaders may advocate different innovation climate but almost all the leaders of NASA agree to keep effective communication, while 86% of them believe it important to equip members with the sense of freedom and an open mind. 57% of NASA leaders hold that common values should be actively fostered among members at the early days of a team, while 93% emphasize the importance of a harmonious interpersonal relationship and 86% believe that leaders should actively control the development of the team and emphasize discipline and hierarchy (Clement, Ritsher, Saylor, Kanas, 2006).

In the R&D team, the leaders must have the ability to promote and foster a team climate for innovation, to know the team members' ability and work requirements, to promote cooperation among the team members and to create a fair and free atmosphere. As the director and coordinator of the team work, the leader is essential to the team climate for innovation.

3.4 The Intermediary Role of the Team Climate for Innovation

Innovation activity is a process consisting of knowledge input and achievement production. Although the knowledge needed in this process can certainly be got externally, the internal knowledge sharing is still an important way. The internal knowledge sharing requires a good team climate whose formation is greatly influenced by leadership. Barrick et al (1998) believe that the more importance the leader attaches to team building, the greater the openness and mutual trust among team members and the better team climate will be. A good climate for innovation not only provides a "soft" environment for knowledge sharing among team members, but also creates the condition for team members' coordination and cooperation, which directly affects the R&D team's knowledge innovation performance. Therefore, both the leadership behavior and team climate are important factors in promoting knowledge sharing.

Previous studies have shown that when the environment of the team is considered, the direct impact of leadership behavior on team performance is often implicit; an explanation for this phenomenon is that the leader is likely to influence team performance through affecting the variables which are closely connected to team performance (Bain, Mann & Pirola, 2001). This study, based on the analysis of the case, supports this view. Therefore, we argue that the leadership's influence on the knowledge innovation capability of the R&D team is partly achieved through affecting the climate for innovation and propose the theoretical framework (see Figure 5). The theoretical framework can be applied to all research and development teams, but the nature and intensity of the relationship vary with research fields and teams.

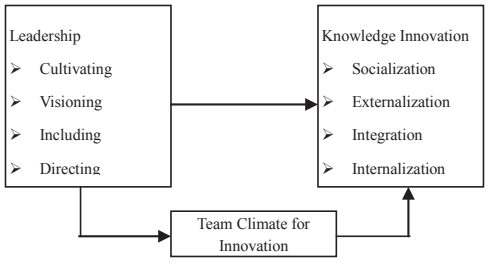

Figure 5
A Model Depicting the Effects of R&D Team Leadership on Innovation

DISCUSSION AND CONCLUSION

Team has become a universal organizational form for knowledge-based organizations and how to improve team performance has become a widespread concern. Many factors contribute to the effective functioning of a knowledge-based team. However, previous studies have mostly focused on team members, task design and other factors, and few researches have paid attention to leadership. Meanwhile, despite the fact that R&D personnel are gradually walking out from their "closed doors" and towards interdependence, communication and cooperation in recently years, these teams are still of relatively low degree of autonomy, their need for and dependence on leaders is relatively high. Therefore, the leader plays a critical role in R&D teams and his/her leadership is closely connected with the team's success. For an R&D team, what the members do is to process and create knowledge; they pay more attention to the meaning and value of the work itself and have a higher level of need----self-realization in work. In the case study, we have tested different leadership behaviors, which is a variable with significant predictive power of R&D team and able to significantly improve the team's climate for innovation as well as knowledge innovation capability.

Besides, most previous researches on knowledge innovation models focus on the process. Though many scholars have proposed their own theories on this topic, these researches are basically concerned about individuals rather than the team as a whole, and they all believe that knowledge innovation is a dynamic development process from tacit knowledge to explicit knowledge. This study systematically verifies the four dimensions of the R&D teams' knowledge innovation capability, namely, the socialization, externalization, integration and internalization of knowledge.

In addition, previous studies have revealed the critical role played by leadership in the team innovation, but are not clear about the internal mechanism. This study, considering an R&D team, establishes a relational model with team climate for innovation as its intermediary variable, so as to avoid the "black box" dilemma. It has examined and interpreted the relationship between the theoretical framework and the main variables and validated the mechanism of how different leadership behaviors improve the knowledge innovation capability through the inter-medium of innovation climate. The conclusions of the study have proved that most findings of team theory, the team climate for innovation theory of the west and the knowledge innovation theory are applicable to R&D teams. The conclusions of the study have also enriched the theory of the "low authority--high innovation" knowledge-based teams to some extent; it is of great guiding significance for R&D team management practice.

Finally, the limitations of this study cannot be ignored too since there's only a single case. The research finding of this study is not easy to promote due to the lack of universality though it has a strong pertinence. What's worse, although the data are collected from various sources, due to the difficult accessibility to the first-hand information, only a longitudinal analysis has been conducted, which may affect the reliability of the study despite the fact that it meets the triangle verification requirements. To promote the research finding, further quantitative researches are needed.

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