
ABSTRACT

This study explores the relationship between human resource practices and individual knowledge sharing behavior in Taiwan’s high-tech industries. The cross-sectional dataset contains a sample of 368 R&D professionals from nine different high-tech companies. The findings indicate that the factor of self-efficacy of knowledge sharing plays a very important role in the integrated knowledge-sharing model. R&D professionals who believe that sharing will influence their performance will be more willing to share knowledge, and effective sharing of knowledge will be more likely to actually take place. Results also show that human resource practices, incentive compensation plans, performance appraisal systems and face-to-face communication, will foster knowledge sharing among R&D professionals via self-efficacy of knowledge sharing.

Keywords:

Human Resource Practices; Knowledge Sharing Behavior; R&D

INTRODUCTION

Knowledge has been recognized as the most important resource of organizations (Nahapiet and Ghoshal, 1998; Nonaka and Takeuchi, 1995). Firms seek knowledge management strategies to more effectively build up the foundation of competitive advantages (McEvily, Das and McCabe, 2000; Ipe, 2003). However, the knowledge creation starts from individuals in which the original knowledge resides within (Nonaka and Konno, 1998). Consequently, a useful start point for building a knowledge management strategy is to understand the role of individuals on the whole knowledge creation process. In particular, the significance of individual knowledge sharing behaviors has been widely emphasized, and it contributes to the critical foundation of organizational knowledge creation (Bock et al., 2005).

Bhatt (2002) indicate that sharing knowledge in complex situations is extremely important, since tasks are highly interdependent and individuals do not possess all required knowledge to solve interdisciplinary problems in complex situations. Thus, it is obvious that knowledge sharing has been specifically addressed in a research and development (R&D) context. R&D professionals are widely acknowledged as knowledge workers. Their works are characterized by complex system design, rapid update of technology–related knowledge, and strong competition for sustaining innovation (Assimakopoulos and Yan, 2006). In addition, the knowledge sharing patterns in R&D professionals are quite different from traditional workers (Assimakopoulos and Yan, 2006; Berends et al., 2006; Blackler, 1995; Cabrera and Cabrera, 2002; Garud and Nayyar, 1994). Since the R&D process is extremely complicated and an employee only
possesses expertise in a specific area, thus, knowledge will not be exposed to others until knowledge owners make the objects available. It is therefore valuable to investigate how R&D professionals share knowledge across members.

Since knowledge sharing is so critical for R&D tasks, how can a firm increase knowledge sharing behaviors of R&D professionals? Prior studies suggest that knowledge sharing cannot be forced, but can only be encouraged and facilitated (Gibbert and Krause, 2002; Bock et al., 2005). Scholars have explored this issue from two different viewpoints: one is focusing on how individual psychological characteristics give rise to sharing behavior (e.g., O’Reilly and Chatman, 1986; Kalman, 1999; Bock and Kim, 2002; Cabrera et al., 2006), and the other is emphasizing on specific organizational interventions that may help organizations encourage the overall knowledge sharing (e.g., Almeida and Kogut, 1999; Cabrera et al., 2006; Gruenfeld et al., 2000; Levine et al., 2000; Moreland and Myaskovsky, 2000; Rulke et al., 2000; Stasser et al., 2000; Thompson et al., 2000).

The influence of individuals’ psychological characteristics on the process of knowledge sharing becomes increasingly important recently. Some studies have analyzed what may determine individual engagement in intra-organizational knowledge sharing such as personality (Cabrera et al., 2006), willingness (Foss and Pedersen, 2002; Harvey and Butcher, 1998), self-efficacy (Bock and Kim, 2002; Cabrera and Cabrera, 2002; Cabrera et al., 2006), and organizational commitment (Cabrera et al., 2006; Kalman, 1999; O’Reilly and Chatman, 1986). From motivational perspective (Boer and Berends, 2003), it is essential for an individual to believe in their own sharing ability and to hold willingness to share with others before engage successful knowledge sharing behaviors. Thus, in this study, we emphasize the importance of individuals’ ability and willingness to share knowledge.
On the other hand, there is current interest in the organizational interventions which may help organizations encourage the overall knowledge sharing (Bock et al., 2005; Gibbert and Krause, 2002). Human resource practices are gradually recognized as essential interventions to promote knowledge sharing behaviors within an organization. Various human resource practices, such as selection criteria, performance appraisal, job definitions, career management, training (Moreland and Myaskovsky, 2000; Thompson et al., 2000), compensation (Bock and Kim, 2002; Cabrera and Cabrera, 2002; Cabrera et al., 2006; Welbourne et al., 1998), and rotation (Almeida and Kogut, 1999; Gruenfeld et al., 2000), may increase individual incentives to share knowledge, accomplished by either reducing the perceived costs or increasing the perceived benefits of contributing.

These two streams of research separately shed lights on the process of individuals’ knowledge sharing behaviors. However, existing research seldom integrate both individual psychological characteristics and organizational interventions to explore the process of knowledge sharing behaviors. There is therefore a need for research that explores an integrated model of knowledge sharing conceptualizing the influences of human resource practices, self-efficacy of knowledge sharing, willingness to share and knowledge sharing behavior.

In order to integrate and extend these existing views, we develop a theoretical frame and undertake an empirical study to explore the knowledge sharing behaviors of R&D professionals in Taiwanese high-tech industries. The structure of this study is present as following. In the second section, we review the related literature on human resource practices, self-efficacy of knowledge sharing, willingness to share, and present an integrated model and the hypothesized relationships of these variables. The third second describes the research methodology, and the
fourth section reports the findings. The last section is about the discussion of findings and the limitations of our study, as well as the suggestions for further research.

LITERATURE REVIEW

Knowledge Sharing among R&D Professionals

Knowledge sharing behavior among R&D professionals differs from that among traditional workers (Assimakopoulos and Yan, 2006; Berends et al., 2006; Blackler, 1995; Cabrera and Cabrera, 2002; Garud and Nayyar, 1994). First, R&D knowledge possesses the characteristics of tacit knowledge. Tacit knowledge is personal, is embedded in thought, behavior, and perception, is difficult to share (Nonaka and Takeuchi, 1995), and is not readily codified in written form (Blackler, 1995). The sharing of knowledge among R&D professionals involves the exchange of large amounts of tacit knowledge. Tacit knowledge is possessed by R&D professionals (embrained and embodied) and cannot easily be made explicit in a codifiable form. In addition, beyond emphasizing tacit knowledge sharing, the sharing of R&D knowledge also emphasizes the creation of innovative ideas through an interactive brainstorming process among employees. Since R&D process is extremely complicated and an employee only possesses expertise in a specific area, thus, knowledge sharing among R&D professionals is very important in the knowledge creation process. Scholars working in this area of research have emphasized that one of the goals of knowledge sharing among R&D professionals is to find sources of creativity, via a process of collaborative problem solving (Okada and Simon, 1997), brainstorming, and product innovation (Berends et al., 2006). Due to the personal nature of tacit knowledge and the knowledge creation process, the success of R&D knowledge sharing therefore depends on whether R&D professionals believe they are able to share tacit knowledge and whether they maintain an active attitude towards sharing (Morris, 2001).
The Psychological Process of R&D Knowledge Sharing

The sharing of R&D knowledge has the goal of “innovation” and is characterized by the exchange of “tacit knowledge.” This compels us to look at the sharing of this type of knowledge from the point of view of psychological processes. Prior research has suggested that psychological factors affecting knowledge sharing behavior include personality (Cabrera et al., 2006), willingness (Foss and Pedersen, 2002; Harvey and Butcher, 1998), self-efficacy (Bock and Kim, 2002; Cabrera and Cabrera, 2002; Cabrera et al., 2006), and organizational commitment (Cabrera et al., 2006; Kalman, 1999; O’Reilly and Chatman, 1986). From the motivational perspective (Boer and Berends, 2003), for sharing to be successful, individuals must believe in their own sharing ability and decide whether they are willing after assessing the costs and benefits of sharing. The internal psychological construction process of individuals’ beliefs and willingness are of central importance in the understanding of knowledge sharing. Thus, in this study, we emphasize the importance of individuals’ ability and willingness to share knowledge and focuses on two factors that may improve knowledge sharing among R&D professionals—self-efficacy of knowledge sharing and willingness to share knowledge.

The concept of self-efficacy entails personal motivation and belief or confidence in one's cognitive resources and course of action. This belief is necessary to successfully perform the specified behavior in the given context. Individuals can use this basic self-influence ability chiefly to initiate, control, and maintain their inherent behavior (Stajkovic and Luthans, 1998). This psychological process is explained as follows: Individuals must first assess and integrate information concerning their own self-efficacy before making an effort. Individuals’ expectations of their self-efficacy determine whether they will initiate their behavior, which tends to maintain behavior expected by the organization. Individuals who perceive themselves as...
highly efficacious will put maximum effort into carrying out a task assigned by the organization. On the other hand, individuals who perceive themselves as lacking efficacy may give up too soon and fail to complete the task (Stajkovic and Luthans, 1998).

In the knowledge sharing context, self-efficacy involves the perception of one’s ability to make useful contributions and the perceived criticality of these contributions to the provision of knowledge sharing behavior. In general, perceived self-efficacy of knowledge sharing can promote the sharing of knowledge (Bock and Kim, 2002; Cabrera and Cabrera, 2002; Cabrera et al., 2006). We can therefore hypothesize that the R&D employees’ belief in their knowledge sharing ability may affect whether they can successfully share R&D knowledge. We therefore propose the following hypothesis:

**Hypothesis 1.** The self-efficacy of knowledge sharing for R&D professionals has a positive influence on their knowledge sharing behavior.

Furthermore, Van de Kragt et al. (1983) verified that individuals who believe that their participation in knowledge sharing is important tend to be more willing to share knowledge. We therefore investigate another psychological factor--willingness to share. The concept of willingness to share refers to individuals' willingness to share knowledge based on their assessment of perceived costs and benefits (Storey and Quintas, 2001). According to social dilemma theory (Dawes, 1980; Kollock, 1998), knowledge sharing can be conceptualized as occurring in a knowledge market where knowledge possesses value and can be exchanged for other products (Davenport and Prusak, 1998). This concept assumes that individuals engage in knowledge sharing on the basis of cost-benefit analysis and compare perceived transaction benefits with costs inherent in the transaction. In keeping with economic behavior, if perceived
benefit is at least equivalent to the cost of the sharing process, the individual will continue sharing; if not, the individual will cease sharing.

Numerous studies have verified the relationship between willingness to share and knowledge sharing behavior (Empson, 2001; Flood et al., 2001; Kim and Mauborgne, 1998; Morris, 2001; Robertson and O'Malley Hammersley, 2000). Among these, Morris (2001) suggested that individuals perceive knowledge as their personal property, and are only willing to share when they perceive that they will benefit from doing so. Knowledge sharing among R&D professionals includes the exchange of large amounts of tacit knowledge. Because of the personal nature of tacit knowledge, the possessor must be “willing” to share and communicate it (Flood et al., 2001; Robertson and O'Malley Hammersley, 2000; Empson, 2001; Willman et al., 2001; Kim and Mauborgne, 1998). As a consequence, the success of R&D knowledge sharing depends on whether R&D professionals maintain an active attitude (Morris, 2001). We therefore propose the following hypothesis:

**Hypothesis 2. The willingness to share of R&D professionals has a positive influence on their knowledge sharing behavior.**

From the point of view of motivation, for sharing to be successful, R&D professionals must believe in their own sharing ability and decide whether they are willing after assessing the costs and benefits of sharing. It is therefore possible to encourage individuals to engage in knowledge sharing. We hypothesize that expected outcomes determine individuals’ intention to perform specific actions. This idea can be explained using expectancy-value theory: Individuals’ willingness to engage in knowledge sharing can be predicted from their expectation of the outcome of sharing, which is to say that individuals’ “willingness” to share knowledge is affected
by the “expected outcome.” Individuals may cease sharing knowledge if they believe that sharing has no effect on results (such as performance feedback). While the key to understanding knowledge sharing among R&D professionals is to understand the internal psychological process by which individuals establish belief and willingness, prior research has not clearly explained the relationship between the three aspects of self-efficacy of knowledge sharing, willingness to share, and knowledge sharing behavior (Bock and Kim, 2002; Cabrera and Cabrera, 2002). We therefore hypothesize:

_Hypothesis 3. The self-efficacy of knowledge sharing for R&D professionals influences their knowledge sharing behavior via their willingness to share._

**Human resource practices Encouraging R&D Professionals to Engage in Knowledge Sharing**

Early literature on knowledge sharing behavior emphasized the role of organization members in promoting the flow of knowledge within the organization. Nevertheless, there is no way to guarantee that each member will actually engage in knowledge sharing (Davenport and Prusak, 1998; Connolly and Thorn, 1990; Kalman, 1999). Prior research suggests that human resource practices may solve the problem of encouraging mutual sharing of knowledge among employees. For instance, Hansen et al. (1999) suggested that reward and appraisal systems may influence knowledge sharing behavior. Argote and Ingram (2000) proposed that face-to-face communication and training may promote knowledge sharing, and Argote et al. (2000) proposed that organizations training mechanisms including training (Moreland and Myaskovsky, 2000; Thompson et al., 2000) and face-to-face communication (Levine et al., 2000; Rulke et al., 2000; Stasser et al., 2000) to encourage knowledge sharing.
The psychological process underlying knowledge sharing among R&D professionals has already been mentioned. Prior research suggests that employees' self-efficacy of knowledge sharing and willingness to sharing can be increased via human resource practices. For instance, with regard to self-efficacy, Cabrera and Cabrera (2002) suggested that training, performance feedback and face-to-face communication may influence knowledge sharing self-efficacy. With regard to willingness to share, Maurer and Tarulli (1994) verified that perceived compensation affects the willingness to share, and Cabrera and Cabrera (2002) suggested that compensation, appraisal systems and face-to-face communication may influence the willingness to share.

So, the human resource practices that we propose will foster knowledge sharing among organizational employees via psychological process -- self-efficacy of knowledge sharing and willingness to share including training and development activities, incentive compensation plans, performance appraisal systems and face-to-face communication.

**Training and development activities.** Training and development activities can be used to enhance self-efficacy of knowledge sharing among employees suggested four ways by which self-efficacy can be increased: modeling and vicarious learning, role-playing, mastery or success experiences and coaching or verbal persuasion (Bandura, 1997). All of these elements can be included in training and development activities to increase levels of employee self-efficacy of knowledge sharing. Thus, the use of cooperative training should help to increase self-efficacy of knowledge sharing among organizational employees. Consequently, employees will feel more assured of their abilities and will be more likely to sharing their knowledge with others.

According to this point of view, training and development activities increase R&D employees' opportunities for knowledge sharing, encourage R&D employees' self-efficacy of knowledge
sharing and willingness to share, and boost the sharing of knowledge. We therefore make the following hypotheses:

_Hypothesis 4a. Training and development activities have a positive effect on the self-efficacy of knowledge sharing for R&D professionals._

_Hypothesis 4b. Training and development activities have a positive effect on the willingness to share of R&D professionals._

_Incentive compensation plans._ Another potential human resource practice to increase the knowledge sharing behavior would be to combine a knowledge sharing program with incentive compensation plans, including incentive compensation, stock bonus and stock option, in which every individual receives a bonus based on the success of the knowledge-sharing program. The incentive compensation plans thus depend on the combined efforts of the individual and the other people with whom he or she shares knowledge. Thus, given the predicted impact of the perceived benefits of knowledge sharing, incentive compensation plans must be designed to encourage knowledge-sharing behaviors. Rewarding these behaviors sends a strong signal to the employees that the organization values knowledge sharing (Cabrera et al., 2006).

According to this point of view, incentive compensation plans increase R&D employees' opportunities for knowledge sharing, encourage R&D employees' self-efficacy knowledge sharing and willingness to share, and boost the sharing of knowledge. We therefore make the following hypotheses:

_Hypothesis 5a. Incentive compensation plans have a positive effect on the self-efficacy of knowledge sharing for R&D professionals._
Hypothesis 5b. Incentive compensation plans have a positive effect on the willingness to share of R&D professionals.

**Performance appraisal systems.** Recognizing knowledge-sharing behaviors in performance appraisal systems may also help to reduce the perceived cost of these behaviors. One of the reasons often cited for not contributing to knowledge repositories is a reluctance to spend time on knowledge sharing. Employees believe that they should spend their limited time on what they perceive to be more productive activities (Husted and Michailova, 2002). When these behaviors are directly evaluated and rewarded, employees are more likely to see them as an integral part of their job responsibilities. When this is the case, the time spent on knowledge sharing will not be considered an opportunity cost or time that could have been spent on more productive activities. According to this point of view, performance appraisal systems increase R&D employees' opportunities for knowledge sharing, encourage R&D employees' self-efficacy of knowledge sharing and willingness to share, and boost the sharing of knowledge. We therefore make the following hypotheses:

Hypothesis 6a. Performance appraisal systems have a positive effect on the self-efficacy of knowledge sharing for R&D professionals.

Hypothesis 6b. Performance appraisal systems have a positive effect on the willingness to share of R&D professionals.

**Face-to-face communication.** Face-to-face communication, that is face-to-face discussion, provides a rich medium for information exchange. Scholars have explained how face-to-face communication increases the frequency of interactions among workers. This not only leads to more chance encounter during which information can be shared, but also increase familiarity,
which can result in shared understanding and feelings of community, both of which increase the likelihood of sharing (Lengnick-Hall and Lengnick-Hall, 2003). In other words, organizational employees provided strong support for the commitment explanation through mass face-to-face communication. Thus, face-to-face communication increases perceived benefit that results in more effective sharing.

According to this point of view, face-to-face communication increase R&D employees' opportunities for knowledge sharing, encourage R&D employees' self-efficacy of knowledge sharing and willingness to share, and boost the sharing of knowledge. We therefore make the following hypotheses:

Hypothesis 7a. Face-to-face communication has a positive effect on the self-efficacy of knowledge sharing for R&D professionals.

Hypothesis 7b. Face-to-face communication has a positive effect on the willingness to share of R&D professionals.

If R&D professionals are to share knowledge successfully, they must believe that their own sharing behavior will influence the expected results (self-efficacy of knowledge sharing), and they must have a sufficiently high willingness to share. Figure 1 shows the integrated model formed by the linkages between the variables proposed in this study. This model explains how training and development activities, incentive compensation plans, performance appraisal systems, and face-to-face communication generate knowledge sharing behavior among R&D professionals via the psychological processes of self-efficacy of knowledge sharing and willingness to share.
METHODOLOGY
Sampling and Respondents

R&D professionals are widely acknowledged as knowledge workers. Their works are characterized by complex system design, knowledge related to the rapid update of technology, and strong competition for sustaining innovation (Assimakopoulos & Yan, 2006). In addition, the knowledge acquisition and sharing patterns among R&D professionals are quite different from those of traditional workers (Assimakopoulos & Yan, 2006; Berends, Bij, Debackere, & Weggeman, 2006; Blackler, 1995; Cabrera & Cabrera, 2002; Garud & Nayyar, 1994). Since the R&D process is extremely complicated and an employee only possesses expertise in a specific area, knowledge will not be exposed to other individuals until knowledge owners make the objects available. Therefore, it is valuable to investigate how a firm increases knowledge sharing behaviors of R&D professionals. Since knowledge sharing behaviors are so critical for R&D professionals, the current sample consists of R&D employees employed in nine high-tech companies in Taiwan. The companies studied are engaged in applied research within the computer systems and other industries, which are pivotal for high-tech industries. These nine companies were chosen in order to control for the differences in firm size. Generally, companies with successful experience in managing knowledge management activities have a large operating scale, and the average total operating revenue of the nine companies is more than US $3 billion.

Measures
**Independent variables.** We used 12 items based on the theoretical literature to assess possible human resource practices in high-tech industries. The items were rated on a 6-point Likert scale regarding the importance of each practice in searching for solutions to knowledge-sharing problems. The 12 items used to assess practices were based on the discussion of human resource practices by Dixon (1990), Hansen et al. (1999) and Cabrera and Cabrera (2002), including discussions of ‘training and development activities’, ‘incentive compensation plans’, ‘performance appraisal systems’, and ‘face-to-face communication’.

The training and development activities include training opportunities, team building and cooperative training and on-job training. The incentive compensation plans include incentive compensation, the ratio of incentive compensation to total compensation and stock bonus or stock option. Performance appraisal systems refer to assessing from goal setting, team participation as an appraisal index and feedback from peers. Employees in high-tech industries could also acquire contact through face-to-face communication, such as vertical communication, horizontal communication and communication frequency.

**Mediator variables.** We used six items based on the theoretical literature to assess possible self-efficacy of knowledge sharing and willingness to share among R&D professionals. The items were rated on a 6-point Likert scale regarding the importance of self-efficacy of knowledge sharing and willingness to share among R&D professionals. The six items used to assess sources were based on the discussion of knowledge sharing by Bock and Kim (2002), including discussions of ‘self-efficacy of knowledge sharing’ and ‘willingness to sharing’.

The self-efficacy of knowledge sharing refer to the perception of one’s ability to make useful contribution and the perceived criticality of these contribution from belief in their capability to
share knowledge, in their skills to share knowledge and in facing difficulties. Employees in high-tech industries could also acquire their willingness to share knowledge, such as voluntary contribution and efficient sharing.

**Dependent variables.** The patterns of knowledge sharing behaviors were the major dependent variables of interest in this study. Rated by a 5-point Likert scale and measured by three questions, was knowledge sharing among R&D professionals, which was defined as the private and public sharing of useful knowledge with co-workers belonging to the same group. The measures of these two variables were adapted from the theoretical literature (Senge, 1990).

Confirmatory factor analysis (CFA) was used to examine the validity and reliability of the research instrument. Validity was addressed in two ways. First, operationalization of the constructs drew upon an extensive literature review, and questionnaires were discussed with superiors in actual organizations. Both processes were intended to enhance content validity. Second, the results of the CFA illustrated that seven variables displayed convergent validity, since the analysis yielded seven factors with factor loading displaying the expected patterns. Table 2 shows the correlations among the seven factors of the CFA model. The diagonal of the matrix presents the internal-consistency coefficients of the reliability of the unity weighted sums of the item scores, and the $\alpha$-coefficients vary between 0.73 and 0.92. The Cronbach $\alpha$ coefficients of the seven variables of this study all exceeded the 0.70 threshold recommended by Hair et al. (1998), with the reliability and internal consistency of the variables confirmed.

| Insert Table 2 about here |

**RESULTS**

The Measurement Model
We tested the factor structure of our survey measure using Confirmatory Factor Analysis (CFA). The CFA model was developed with the purposes of testing whether the hypothesized latent variables could be identified empirically, and for examining the validity and reliability of measures.

First of all, according to the successive testing and modification of different models on the same data of course, different variables sets were combined into the final model. The final CFA model had a $\chi^2$–value of 341.19, $df = 168$ ($p = 0.00$). The RMSEA index was 0.055 for this model, with a 90% confidence interval between 0.047 and 0.063, which indicates acceptable fit of the model to the data. Other indices of fit also showed acceptable fit (GFI = 0.92, CFI = 0.97, NFI = 0.94, NNFI = 0.96). Standardized factor loadings, along with descriptive item data, are shown in Table 1.

Three items measured the *training and development activities* factor. Three items with the loadings (0.58-0.78) asked about ‘training opportunities’, ’team building and cooperative training’ and ’on-job training’. The *Incentive compensation plans* factor was related to three items. The highest loading (0.93) was observed for the item that asked about ’the ratio of incentive compensation to total compensation’. Another loading (0.89) was observed for the item that asked about ’stock bonus or stock option’. The lower loading (0.83) asked about ‘incentive compensation’. The *Performance appraisal systems* factor was related to three items. The highest loading (0.88) was observed for the item that asked about ’team participation as an appraisal index’. Another loading (0.64) was observed for the item that asked about ’goal setting’. The lower loading (0.51) asked about ‘feedback from peers’. Three items measured the
face-to-face communication factor; two items that asked about ‘horizontal face-to-face communication with colleagues from other departments’ and ‘face-to-face communication frequency’ had very high loadings (0.82 and 0.89). The third item, which asked about ‘vertical face-to-face communication between supervisor and subordinate’, had a lower loading (0.58).

Three items measured the self-efficacy of knowledge sharing factor; all items had substantial loadings (0.68-0.75) on the factor. Higher loadings (0.75) were observed for two items that asked ‘belief in their capability to share knowledge’ and ‘belief in their skills to share knowledge’. The lower loading (0.68) asked about ‘belief in facing difficulties’. Three items measured the willingness to share factor; three items had quite high loadings (0.80-0.92). These items were queried ‘willingness to share technical knowledge’, ‘voluntary contribution’ and ‘efficient sharing’. Three items measured the knowledge sharing behavior factor, and three items had substantial loadings (0.77-0.85). These items asked about ‘coaching’, ‘private sharing in small groups’ and ‘public sharing in small groups’.

On the other hand, the research instrument used Confirmatory Factor Analysis (CFA) to examine validity and reliability. Validity was addressed in two ways. First, operationalization of constructs drew upon an extensive literature review and questionnaires were discussed with superiors in actual organizations. Both processes were intended to enhance content validity. Second, the results of CFA also illustrated that seven variables displayed convergent validity, since the analysis yielded seven factors with factor loading displaying the expected patterns. Table 2 shows the correlations among the seven factors of the CFA model. The diagonal of the matrix presents internal-consistency coefficients of the reliability of unity weighted sums of the scores on the items, and the α-coefficients vary between 0.73 and 0.92. Cronbach α coefficients
of seven variables of this study all exceed the 0.70 threshold recommended by Hair et al. (1998), variables are confirmed to request reliability, and display internal consistency.

**The Structural Model**

In the next step of modeling, path models were fitted to test the proposed model. Because the hypotheses do not explicitly specify the relations among all the factors, and because some unexpected relations were found, a sequence of models was fitted. Selection criteria for the final model were (1) fit to data and (2) interpretability of the estimated relations.

The path model had a test-statistic of \( \chi^2 = 366.25, df = 172 \) \( (p = 0.00) \). The RMSEA index was 0.056 for this model, with a 90% confidence interval between 0.048 and 0.064, which indicates acceptable fit of the model to the data. Other indices of fit also showed fit to be acceptable (GFI = 0.91, CFI = 0.97, NFI = 0.94, NNFI = 0.96), so we cannot reject the hypothesis that the path model correctly reproduced the correlations among the latent variables. Figure 2 shows the model.

The pattern of direct effects revealed by the path model seems to provide somewhat mixed evidence for the study’s hypotheses. According to Hypothesis 1, we expected a positive relationship between self-efficacy of knowledge sharing and knowledge sharing behavior, and we observed a positive direct effect (0.56). The result of the path model supported Hypothesis 1 – there was a strong direct effect from self-efficacy of knowledge sharing on knowledge sharing behavior.
According to Hypothesis 2, we expected a positive effect from willingness to share on knowledge sharing behavior. The result of the path model supported this hypothesis – there was a direct effect from willingness to share on knowledge sharing behavior (0.24).

Hypothesis 3 proposes that there should be a positive effect from self-efficacy of knowledge sharing on willingness to share. And the path model showed a positive effect from self-efficacy of knowledge sharing on willingness to share (0.30). The self-efficacy of knowledge sharing influences knowledge sharing behavior via willingness to share. Thus, the results of the path model support Hypothesis 3.

According to Hypothesis 4a and Hypothesis 4b, we expected positive effects of training and development activities on self-efficacy of knowledge sharing and willingness to share. However, according to the path model, there was no effect from the training and development activities factor on any other latent variable. It may be observed that training and development activities have a 0.28 correlation with self-efficacy of knowledge sharing and have a 0.22 correlation with willingness to share in the CFA correlation matrix. So had the other factors not been included in the model, this would have been the estimate of the total effect. But in the presence of incentive compensation plans, performance appraisal systems and face-to-face communication, with which the training and development activities factor was correlated, no effect could be seen. Further research will be needed to clarify the relations between training and development activities, incentive compensation plans, performance appraisal systems and face-to-face communication.

According to Hypothesis 5a and Hypothesis 5b, we expected positive effects of incentive compensation plans on self-efficacy of knowledge sharing and willingness to share, but we merely observed a direct effect of 0.15 on self-efficacy of knowledge sharing (H5a) and there
was no effect from the incentive compensation plans factor on willingness to share (H5b). But note that we cannot interpret the pattern of influences among the variables unless we consider the indirect effects – an effect from the incentive compensation plans factor on willingness to share via self-efficacy of knowledge sharing ($0.15 \times 0.30 = 0.05$). Table 3 shows the indirect effect decomposition.

According to Hypothesis 6a and Hypothesis 6b, we expected positive effects of performance appraisal systems on self-efficacy of knowledge sharing and willingness to share, but we merely observed a direct effect of 0.22 on self-efficacy of knowledge sharing (H6a) and there was no effect from the performance appraisal systems factor on willingness to share (H6b). But note that we cannot interpret the pattern of influences among the variables unless we consider the indirect effects – an effect from the performance appraisal systems factor on willingness to share via self-efficacy of knowledge sharing ($0.22 \times 0.30 = 0.07$). Table 3 shows the indirect effect decomposition.

According to Hypothesis 7a and Hypothesis 7b, we expected positive effects of face-to-face communication on self-efficacy of knowledge sharing and willingness to share. The results of the path model support Hypothesis 7a and Hypothesis 7b – there were positive direct effects on self-efficacy of knowledge sharing (0.24) and willingness to share (0.29).
DISCUSSION

A contribution of this study is our research on interventions – the knowledge sharing link was our conclusion from the integrated model, which incentive compensation plans, performance appraisal systems and face-to-face communication have a positive effect on R&D employees' self-efficacy of knowledge sharing, and thereby influence knowledge sharing behavior among R&D professionals.

Our integrated model of knowledge sharing behavior leads us to expect that “self-efficacy of knowledge sharing” and “willingness to share” will mediate the relationship between human resource practices and knowledge sharing behavior among R&D professionals. Path analysis suggests that self-efficacy of knowledge sharing may mediate “incentive compensation plans” and “knowledge sharing behavior”, “performance appraisal systems” and “knowledge sharing behavior” and also between “face-to-face communication” and “knowledge sharing behavior.” We found that three mediation models existed in our integrated knowledge sharing model. In one of these, “self-efficacy of knowledge sharing” mediated the relationship between “incentive compensation plans” and “knowledge sharing behavior”, “self-efficacy of knowledge sharing” mediated the relationship between “performance appraisal systems” and “knowledge sharing behavior”, and in the other “self-efficacy of knowledge sharing” mediated the relationship between “face-to-face communication” and “knowledge sharing behavior.” This implies that the factor of self-efficacy of knowledge sharing plays a very important role in the integrated knowledge sharing model, and is even more important than the factor willingness to share. It may be that the characteristics of the knowledge used by R&D professionals in high-tech industries - complex system design knowledge, rapid technology upgrades, and constant innovation - are necessary to maintain competitiveness (Assimakopoulos and Yan, 2006) and
increase the cost of sharing (for instance, more face-to-face communication time may be needed to share tacit knowledge). As discussed earlier, R&D professionals must believe that sharing yields a beneficial outcome according to cost-benefit analysis before they will be willing to share knowledge.

Furthermore, the failure of “incentive compensation plans” and “performance appraisal systems” to directly influence “willingness to share” does not support hypothesis 5b. It should be noted, however, that “incentive compensation plans” and “performance appraisal systems” indirectly influence “willingness to share” via “self-efficacy.” This implies that “incentive compensation plans” and “performance appraisal systems” first influences “self-efficacy of knowledge sharing”, which in turn influences “willingness to share.” This path verifies the assumptions of expectancy-value theory. R&D professionals observe the expected results of sharing (via performance feedback systems), and the expected results of individual actions influences “self-efficacy,” which in turn influences “willingness to share.” This is why R&D professionals who believe their sharing has no influence on performance may be unwilling to share and fail to engage in sharing. R&D professionals who believe that sharing will influence their performance (for instance, via incentive compensation plans) will be more willing to share knowledge, and effective sharing of knowledge will be more likely to actually take place (Massimini and Carli, 1988).

This path model reveals that “training and development activities” have no positive effect on “self-efficacy” and “willingness to share,” which does not support hypotheses 4a and hypotheses 4b. Although past research has suggested that “training and development activities” should be correlated with “self-efficacy of knowledge sharing” and “willingness to share” (“training and development activities” has a 0.28 correlation with “self-efficacy of knowledge sharing” and has
a 0.22 correlation with “willingness to share” in the CFA correlation matrix), “training and development activities” does not directly influence any variables in the path model. One possible reason for the lack of support of hypotheses 4a and 4b is that “training and development activities” as defined by traditional learning organizations do not affect the psychological factors promoting knowledge sharing among R&D professionals (“self-efficacy of knowledge sharing” and “willingness to share”). In the “teaching organization” proposed by Tichy and Cohen (1998), not only must R&D professionals continue to share new knowledge and skills, but must also teach their learning experience to others. We therefore hypothesize that three items of “training and development activities,” namely “training opportunities,” "team building and cooperative training,” and “on-job training” may not be appropriate in an R&D context. Further research is needed to investigate “training and development activity” items that are relevant to R&D, such as training on how to share R&D experience.

**LIMITATIONS AND FUTURE RESEARCH**

This research was subject to the following limitations: First, data on independent and dependent variables was obtained from the same respondents, which may have caused the problem of common method bias. Although this bias was not detected using Harman’s one-factor test, future research should consider using different sources of data to ensure that common method bias is not a problem. Second, the sample used by this study consisted of large enterprises (with annual operating revenues in excess of US$ 3 billion). Future research may consider using data from SMEs. Third, this study employed a self-assessment of knowledge sharing frequency. The subjective assessment of knowledge sharing behavior may not objectively express real knowledge sharing performance. Future research should simultaneously employ subjective and objective assessment standards. This research may, for example,
simultaneously evaluate self-assessment scores and R&D patent results. Finally, this study focused exclusively on the initial stage of the psychological process behind knowledge sharing among R&D professionals. Future research should consider the effect of other stages on knowledge sharing among these professionals.

**MANAGEMENT IMPLICATIONS**

This research has a number of important implications for both researchers and R&D managers. This study highlights the major shortcoming in studies of knowledge sharing. Existing research has seldom discussed whether individual psychological and organizational factors may present an integrated model of knowledge sharing. A major finding of this study is that human resource practices (incentive compensation plans, performance appraisal systems and face-to-face communication) have a positive effect on R&D employees' psychological process (self-efficacy and willingness to share), and thereby influence knowledge sharing behavior among R&D professionals.

For researchers, a very important implication of this study is that the factor of self-efficacy of knowledge sharing plays a very important role in the integrated knowledge sharing model, and is even more important than the factor willingness to share. This represents that R&D professionals must believe that sharing yields a beneficial outcome according to cost-benefit analysis before they will be willing to share knowledge. Another important implication of this study is that path analysis verifies the assumptions of expectancy-value theory. R&D professionals observe the expected results of sharing (via performance feedback systems), and the expected results of individual actions influences “self-efficacy,” which in turn influences “willingness to share.” Thus, R&D professionals who believe that sharing will influence their performance (for instance,
via incentive compensation plans) will be more willing to share knowledge, and effective sharing of knowledge will be more likely to actually take place.

This latter implication is also important to R&D managers. As it is focused on organizational interventions, the model can help these managers identify the major precursor activities (e.g. incentive compensation plans, performance appraisal systems) required for knowledge sharing behavior to be encouraged. This enables R&D managers to address the likelihood of knowledge sharing practices being successful long before they are actually implemented in the organization. If R&D managers understand these factors, they may be able to address many of them ahead of time, making the knowledge sharing practices a much smoother process.

REFERENCE


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Table 1. Means, standard deviations, and factor loadings for the items

<table>
<thead>
<tr>
<th>Item</th>
<th>Item no.</th>
<th>Mean</th>
<th>SD</th>
<th>Standard factor loading</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Training and development activities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training opportunities</td>
<td>TD1</td>
<td>4.62</td>
<td>0.90</td>
<td>0.78</td>
</tr>
<tr>
<td>Team building and cooperative training</td>
<td>TD2</td>
<td>4.51</td>
<td>0.93</td>
<td>0.74</td>
</tr>
<tr>
<td>On-job training</td>
<td>TD3</td>
<td>4.43</td>
<td>1.04</td>
<td>0.58</td>
</tr>
<tr>
<td><strong>Incentive compensation plans</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incentive compensation</td>
<td>BC1</td>
<td>2.68</td>
<td>1.45</td>
<td>0.83</td>
</tr>
<tr>
<td>The ratio of incentive compensation to total compensation</td>
<td>BC3</td>
<td>2.88</td>
<td>1.48</td>
<td>0.93</td>
</tr>
<tr>
<td>Stock bonus or stock option</td>
<td>BC2</td>
<td>3.08</td>
<td>1.62</td>
<td>0.89</td>
</tr>
<tr>
<td><strong>Performance appraisal systems</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goal setting</td>
<td>PA1</td>
<td>4.04</td>
<td>1.07</td>
<td>0.64</td>
</tr>
<tr>
<td>Team participation as an appraisal index</td>
<td>PA2</td>
<td>4.23</td>
<td>0.99</td>
<td>0.88</td>
</tr>
<tr>
<td>Feedback from peers</td>
<td>PA3</td>
<td>3.53</td>
<td>1.36</td>
<td>0.51</td>
</tr>
<tr>
<td><strong>Face-to-face communication</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical face-to-face communication</td>
<td>CC1</td>
<td>4.58</td>
<td>0.89</td>
<td>0.52</td>
</tr>
<tr>
<td>Horizontal face-to-face communication</td>
<td>CC2</td>
<td>4.88</td>
<td>0.83</td>
<td>0.82</td>
</tr>
<tr>
<td>Face-to-face communication frequency</td>
<td>CC3</td>
<td>4.88</td>
<td>0.78</td>
<td>0.89</td>
</tr>
<tr>
<td><strong>Self-efficacy of knowledge sharing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belief in their capability to share knowledge</td>
<td>SE1</td>
<td>4.48</td>
<td>0.87</td>
<td>0.75</td>
</tr>
<tr>
<td>Belief in their skills to share knowledge</td>
<td>SE2</td>
<td>4.10</td>
<td>0.94</td>
<td>0.75</td>
</tr>
</tbody>
</table>
Belief in facing difficulties  SE3  4.34  0.94  0.68

Willingness to share
Willingness to share technical knowledge  SW1  5.04  0.69  0.89
Voluntary contribution  SW2  5.10  0.65  0.92
Efficient sharing  SW3  5.04  0.66  0.80

Knowledge sharing behavior
Coaching  KS1  4.75  0.76  0.79
Private sharing in small groups  KS2  4.76  0.69  0.85
Public sharing in small groups  KS3  4.68  0.79  0.77

Table 2. Correlations among the factors of the measurement model

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Training and development activities</td>
<td>(0.75)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Incentive compensation plans</td>
<td>0.28</td>
<td>(0.92)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Performance appraisal systems</td>
<td>0.61</td>
<td>0.41</td>
<td>(0.73)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Face-to-face communication</td>
<td>0.25</td>
<td>0.13</td>
<td>0.36</td>
<td>(0.80)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Self-efficacy</td>
<td>0.28</td>
<td>0.29</td>
<td>0.39</td>
<td>0.31</td>
<td>(0.77)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Willingness to share</td>
<td>0.22</td>
<td>0.10</td>
<td>0.26</td>
<td>0.40</td>
<td>0.41</td>
<td>(0.90)</td>
<td></td>
</tr>
<tr>
<td>7. Knowledge sharing behavior</td>
<td>0.16</td>
<td>0.10</td>
<td>0.25</td>
<td>0.47</td>
<td>0.58</td>
<td>0.43</td>
<td>(0.85)</td>
</tr>
</tbody>
</table>

N=368. Values in parentheses are Cronbach \( \alpha \)'s.

Table 3. Effect decomposition for the path model

<table>
<thead>
<tr>
<th>Independent Variable / Dependent variables</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Direct</td>
</tr>
<tr>
<td><strong>Incentive compensation plans</strong></td>
<td></td>
</tr>
<tr>
<td>Self-efficacy of knowledge sharing</td>
<td>0.15*</td>
</tr>
<tr>
<td>Willingness to share</td>
<td>--</td>
</tr>
<tr>
<td><strong>Performance appraisal systems</strong></td>
<td></td>
</tr>
<tr>
<td>Self-efficacy of knowledge sharing</td>
<td>0.22*</td>
</tr>
<tr>
<td>Willingness to share</td>
<td>--</td>
</tr>
</tbody>
</table>
Face-to-face communication
Self-efficacy of knowledge sharing 0.24** -- 0.24*
Willingness to share 0.29** 0.08** 0.37**
Self-efficacy of knowledge sharing
Willingness to share 0.30*** -- 0.30***
Knowledge Sharing Behavior 0.56*** 0.07** 0.63***
Willingness to share
Knowledge Sharing Behavior 0.24*** -- 0.24***

Note: N=368. t value>1.96 ,*p<.05; t value>2.58 ,**p<.01; t value>3.29 ,***p<.001. All direct
and indirect effects are significant at p<.05 level.

Figure 1 Hypothesized integrated model of knowledge sharing

Figure 2. Path model for relations among the latent variables