Knowledge Conversion in GSS-aided Virtual Teams: An Empirical Study

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Abstract

The functionalities of collaboration technologies (CT) help shape the nature of group interaction in virtual teams. This paper builds on Nonaka's theory of organizational knowledge creation, and related research, to present and test a research model that focuses on knowledge conversion in CT-supported group work. The model is validated through a laboratory experiment that involved 44 teams of geographically dispersed members. Three levels of technology support were tested. The results demonstrate that the level of technology support impacts knowledge conversion, which influences the teams' shared understanding. Implications for research and practice are highlighted.

1. Introduction

In today's complex and far reaching organizations, the importance of knowledge sharing and creation for continued innovation and competitiveness cannot be underestimated. Intense market competition and pressure to quickly respond to customer needs have led to the distribution of business processes in locations wherever expertise is available. As a result, dispersed groups of experts are often put together in virtual teams that interact using collaboration technology (CT).

Knowledge creation has been researched extensively and the bulk of the published work on the issue appears to be related to organization- level knowledge. However, an examination of knowledge creation at the more immediate levels (i.e. those of individuals or small groups) could yield a deeper understanding of knowledge evolution and traverse in organizations [24]. A fundamental aspect of organizational knowledge creation revolves around the central role played by individual group members who take part in episodes of social interaction [38]. Social interaction represents the vehicle through which often-diverse perspectives are exchanged leading to the emergence of processes of "knowledge conversion" that ultimately represent knowledge creation in organizations [38]. Prior research indicates that CT can facilitate the processes of knowledge conversion in groups [38, 35].

In light of the growing use of virtual teams in the new economy, the examination of knowledge conversion in those teams should enable us to better manage their knowledge-related exchanges and interactions. An understanding of the role of CT in supporting knowledge conversion in virtual teams should also facilitate the design and development of CT systems that are more appropriate for the knowledge-rich activities of virtual teams, and thus provides a motivation for this study.

Prior research also emphasizes the importance of the willingness to share knowledge for the effectiveness of knowledge exchange and utilization in organizations [28, 53]. In the context of virtual teams, the willingness to share knowledge becomes critical because group members do not meet face-to-face and may not even have a prior knowledge of each other. The extant literature also suggests that several socio-psychological factors need to be considered when examining work groups [7, 33, 27, 8, 49]. The

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perceptions of trust, cohesiveness, openness, and respect held by members of collaborative workgroups influence the interactions and attitudes that develop such groups [27].

Therefore, this paper surveys prior literature in the areas of knowledge creation, virtual teams, CT and GSS, and social psychology to formulate and test a research model that focuses on knowledge conversion in GSS-aided virtual teams. The following section presents the theoretical background and the research hypotheses of this study. The research methodology is described in Section 3. Data analyses and results are presented in Section 4, followed by a discussion in Section 5 and a conclusion in Section 6.

2. Theory Development

2.1 Knowledge creation

Nonaka's theory of organizational knowledge creation states that knowledge creation takes place along two dimensions: the *epistemological* dimension and the *ontological* dimension [38]. The *epistemological* dimension categorizes knowledge as being either *explicit or tacit*. *Explicit* knowledge describes what can be easily expressed, codified, and shared in forms such as numerical data and textual documents. *Tacit* knowledge represents a cognition that resides in people's minds and refers to things such as insight, intuition, wisdom, expertise, and so on. The *ontological* dimension delineates four levels of social interaction at which knowledge is created: the individual level, the group level, the organizational level, and the inter-organizational level.

Nonaka's work suggests that knowledge creation occurs as a result of an interplay between tacit and explicit knowledge that occurs at the four ontological levels resulting in four knowledge conversion processes: socialization, externalization, combination, and internalization (Figure 1). While a first glance may indicate that conventional face-to-face social interactions are necessary for the dialogue between tacit and explicit knowledge, we propose that the principles of Nonaka's work could be applied to virtual environments.

To / From	Tacit Knowledge	Explicit Knowledge
Tacit Knowledge	Socialization	Externalization
Explicit Knowledge	Internalization	Combination

Figure 1. Knowledge Conversion Processes [38]

2.2 Virtual teams

A virtual team is a group configuration in which dispersed members are linked through a CT for the purpose of achieving organizational tasks [51]. Virtual teams are increasingly becoming integral to organizational life [23, 25]; and dispersed teamwork will constitute a larger portion of all teamwork in the near future [30]. Today, virtual teams are used by most of the larger business organizations [13; 18].

Group decision making involves social interactions, in which information and knowledge are shared and exchanged. Even though virtual team members do not generally enjoy the benefits of face-to-face interaction, this study takes the position that some form of socialization does take place in virtual settings. This type of socialization results from the feelings of togetherness that are sparked by the fact that the members work on the same task toward the achievement of a common goal. Web-based electronic discussions and chat groups are considered effective and appropriate for the transformation of tacit knowledge into explicit knowledge that is more easily communicated and understood [10]. In addition, GSS support the externalization of tacit knowledge by means of facilitating communications, information processing, and process structuring so that the ability of team members to express their tacit knowledge may be possible. Moreover, past research suggests that CT-supported collaborative environments are most appropriate for the combination process [40, 1]. As GSS support enhances the ability of the users to gain access to explicit knowledge, the contribution of GSS to the internalization process would also be expected.

2.3 CT and GSS

Collaboration technologies encompass a wide variety of technologies that makes it possible for its users to capture, store, access, and distribute information across temporal and physical boundaries [32]. A specific type of CTs that is examined in this study is group support systems (GSS). A GSS combines communication, computer, and decision modeling technologies to enable the solution of non-routine problems in a group setting [12].

The impact of GSS on the performance of virtual teams was the subject of several studies but the impact of those systems on knowledge conversion in those teams has not been examined enough [34]. With respect to knowledge-related issues, past research on virtual teams seems to focus primarily on aspects that are not related to knowledge creation per se. Most prior studies deal with issues like the creation of

shared understanding [8, 22]; the impact of work context-related information on performance [8]; and knowledge creation by means of brainstorming or idea generation [6, 9, 43, 45, 52, 55]. What appears to be lacking in prior virtual team research is an examination of the knowledge conversion process.

There are three major types of support that a GSS may provide for supporting and structuring group interactions: communication support, information processing support, and process structuring support [56]. *Communication support* refers to tools that enhance communication among group members (e.g., parallel and anonymous commenting). *Information processing support* refers to features that help in the gathering, evaluation, and aggregation of information (e.g., voting), in addition to tools for organizing and analyzing information (e.g., decision modeling). *Process structuring support* specifies the manner in which a group approaches and works on its task.

GSS support is likely to enhance knowledge conversion processes in virtual teams. As GSS may differ in the extent of support they provide, we expect that different levels of GSS support will lead to variations in the level of the resultant knowledge conversion. Therefore,

Hypothesis-1: *In GSS-based virtual teams, the level of GSS support will be positively related to knowledge conversion.*

2.4 Willingness to share knowledge

The failure of many organizational knowledge management initiatives is attributed to employees' unwillingness to share knowledge though organizational systems [28]. Several studies establish the importance of the voluntary willingness to share knowledge for knowledge creation and utilization. Knowledge utilization begins with the willingness to share by knowledge providers [53]; the notion of willingness to share is embedded in information sharing [26]; and information sharing is a voluntary activity [10]. In virtual teams, when members are willing to, and actually do, share knowledge with each other, we expect knowledge conversion to be smoother and richer. Therefore,

Hypothesis-2*: In GSS-based virtual teams, the members' willingness to share knowledge will be positively related to knowledge conversion.*

2.5 Work Atmosphere

Information sharing theory indicates that social and organizational contexts influence information sharing in organizations [7]. The theory provides evidence that organizational culture and policies, as well as personal factors, impact workers' willingness to share knowledge [7]. A virtual team, as a group, represents a microcosm that operates under similar contextual factors. Typical factors that influence the work atmosphere in which groups operate include trust, cohesion, openness, and respect [27].

The role of trust as an important factor influencing knowledge sharing in groups has been the subject of several studies [20, 37, 48, 36, 41, 26, 31]. Low levels of mutual trust have been reported to be damaging to the exchange of knowledge among workers [48]. Other studies find that trust plays an important role in the realization of shared knowledge across organizational units [20, 26, 37]. Trust was also found to improve the openness and substance of knowledge sharing in groups [41, 37]. Cohesion refers to the extent to which members of a group wish to stay in and act as a team [4]. Cohesion is a factor that is of utmost importance for small groups [33] and a sufficient degree of cohesion is required in order to keep a team going and achieve desired collaboration [21]. Openness appears to be an important factor for enhancing understanding and cooperative behaviors [4]. It promotes a positive exchange of ideas and information that advances understanding and promotes cooperation [3]. Therefore, we consider openness as another perceptive factor that impacts the willingness to share knowledge in virtual teams. Respect reflects the belief that other members of a group are capable of contributing to the group effort and deserve to be revered. Mutual respect encourages members to contribute to group discussions. It entails an equal opportunity to both participate and be heard in group discourse [16].

The above factors have been commonly studied in traditional face-to-face settings and were treated as the main determinant of the work atmosphere for collaborative group assignments [27]. We expect a similar impact in a virtual environment in which work atmosphere perceptions would influence the members' willingness to share knowledge. Therefore,

Hypothesis-3*: In GSS-based virtual teams, member perceptions of the work atmosphere will be positively related to their willingness to share knowledge.*

2.6 Shared understanding

Social interaction is the basis for learning and the achievement of shared understanding [39] and a discussion is a most effective way for the discovery and sharing of tacit knowledge [15]. Thus, in a virtual environment, the social interactions that are associated with knowledge conversion can be expected to lead to the members' becoming more aware of task details

and team-level perspectives. A great deal of learning is reported to occur in virtual knowledge communities in which networked workers exchange to achieve specific business goals [44]. Knowledge conversion processes in virtual teams can have a similar effect and lead to the creation of shared understanding. Therefore,

Hypothesis-4*: In GSS-based virtual teams, knowledge conversion will be positively related to the shared understanding that occurs in the team.*

Based on the above discussion we present our research model for the examination of knowledge conversion in GSS-aided virtual teams (Figure 2).

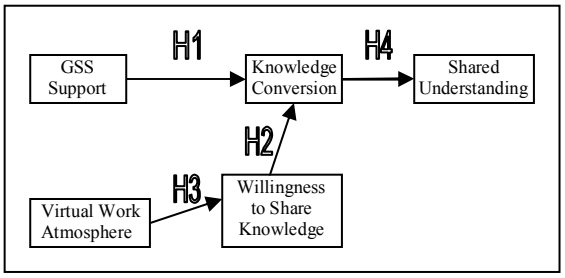

Figure 2. Research Model

3. RESEARCH METHOD

A laboratory experiment was used to validate the research model. A total of 132 volunteers from a major Midwestern U.S. university were randomly assigned to 44 three-member teams that completed the experiment. Subjects participated in detailed training sessions that consisted of a demonstration of each command of the GSS software used in the experiment and of a dummy task. The dummy task did not in any way relate to the task used in the final experiment.

Most GSS packages offer common communication support tools. However, information processing and process structuring support provided in GSS-based meetings can vary. For example, meetings may be facilitated or non-facilitated; participants may evaluate the solution using rating, ranking, voting, or multi-attribute analysis or may resort to discussions. Thus, we focused on process structuring and information processing in this study. Consequently, four possible levels of technology support emerged: high (H), low (L), and a moderate level that is either information processing-oriented (M-IPO), or process structuring-oriented (M-PSO). The four types and the related GSS features provided are shown in Figure 3.

			Process Structuring Support	
			High	**Low**
			- Process Facilitation - Agenda description in print form	- Agenda description in print form
Information Processing Support	**High**	- Information gathering using HTML pages attached to the GSS - Information evaluation (i.e. rating and ranking)	**H**	**M-IPO**
	Low	- Information gathering using HTML pages attached to the GSS	**M-PSO**	**L**

Figure 3. GSS Support Levels and Features

3.1 Experimental Procedures

Following a pilot study, the actual experiment had eleven teams assigned to each of the four experimental conditions shown in Figure 3.

3.2 Task and GSS Used

We developed the "*Enrollment & Retention: University Image Problem*" task specifically for this study. The task describes a situation in which a large, fictional, university is attempting to find a solution for its steadily declining enrollment numbers and retention rates. The task details were geared toward a student population. The team members were required to choose three programs out of six that were recommended by a specialized committee, the Enrollment/Retention Committee (ERC) which had supposedly made some recommendations to the Chancellor. Each team was also required to come up with its own recommendations (three). A budget limit was imposed and each of the six ERC recommendations had a cost estimate. The way the six items were described and allocated costs, any team choosing any three of the ERC options would still have some funds left over to spend on its own recommendations.

The participant used Louts Sametime, an IBM collaboration software which was configured for each of the four experimental groups described in Figure 3.

4. DATA ANALYSES AND RESULTS

All experimental sessions were fully completed and no cases of missing data or outliers were detected in the dataset. Individual responses were aggregated into group-level measurement. The scales were mostly adopted/adapted from prior studies or developed for this paper. All scales underwent several rounds of evaluation and refinement by the researchers to establish their content validity. The scales for knowledge conversion and shared understanding had not been used in prior studies. However, most of the indicator items for those two constructs were obtained from previous studies (the actual scales used are shown in Appendixes A and B - a five-point scale was used and the responses ranged from a 1 indicating "strongly disagree" to 5 indicating "strongly agree." Other scales are available from the corresponding author upon request). It should be noted at this point that in light of sample size limitations, and consistent with our hypotheses formulation, we opted to test the research model using the overall construct of knowledge conversion rather than the individual processes. Construct validity was assessed using factor analysis while reliability was assessed using Cronbach's Alpha with a cut-off value of .70 (all scales exceeded that value). Reliability estimates, factor loadings, and item-total correlation ranges are given in Table 1.

Table 1. Reliability and factor loadings

Construct	Cronbach's Alpha	Factor Loading Range	Item-Total Correlation Range
Work Atmosphere	.956	.636 - .890	.590 - .847
Willingness to Share Knowledge	.873	.671 - .879	.556 - .787
Knowledge Conversion	.935	.707 - .802	.602 - .794
Shared Understanding	.847	.681 - .798	.638 - .789

4.2 Hypotheses Testing

The research hypotheses were tested using analysis of covariance (ANCOVA), mean comparisons, and regression analysis. A level of significance of .05 was used. Significance levels greater than .05 but less than .10 were to be indicative of the hypothesized relationships. The analyses were conducted using group-level composite scores.

Hypotheses 1 & 2: Because of the involvement of two independent variables in influencing one dependent variable in hypotheses 1 and 2, ANCOVA was used in the testing which revealed significant support for the two hypotheses at the .001 level (Table 2). Table 3 shows the means and standard deviations of knowledge conversion for each level of GSS support.

Hypothesis 3: The results of regression analysis indicated that the work atmosphere significantly influenced member willingness to share knowledge ($B = 0.096$, $p < 0.001$, $R^2 = .234$). Thus, the hypothesis is supported in our sample.

Hypothesis 4: Regression analysis results revealed that knowledge conversion had a significant impact on common understanding ($B = 0.079$, $p < 0.001$, $R^2 = .605$). Thus, Hypothesis 4 was also supported.

Table 2. ANCOVA (hypotheses 1 and 2)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	7.735*	4	1.934	7.661	.001
Intercept	.990	1	.990	3.921	.055
Will. to Share	1.021	1	1.021	4.046	.051
GSS Support Level	5.635	3	1.878	7.441	.001

* $R^2 = .440$ (Adj. $R^2 = .383$)

Table 3. Knowledge Conversion means

GSS Support	Mean	Std. Deviation	N
High	4.17	.38	11
Low	3.12	.74	11
M-IPO	3.89	.51	11
M-PSO	3.56	.37	11
Total	3.69	.64	44

5. DISCUSSION

The major findings of this study provide overall support for the proposed research model in our sample. Based on the results of hypotheses testing, we conclude that GSS support contributes to knowledge conversion in virtual teams. The results also indicate that contextual factors play a role in determining members' willingness to share knowledge, which also has a bearing on knowledge conversion. Knowledge conversion was found to directly influence shared understanding while the willingness to share knowledge had an indirect effect.

5.1 GSS Support, the Willingness to Share Knowledge, and Knowledge Conversion

The finding that GSS support contributes to improved knowledge conversion in virtual teams appears to parallel the findings in the IS literature that GSS enhances group processes and performance outcomes [2, 17, 54, 47). In this study, the results indicate that knowledge conversion was significantly higher as the level of support increased.

The provision of communication support enables distributed teams to perform a very basic requirement for knowledge conversion which is to communicate. GSS make it possible for virtual team members to engage not in simple communications but rather in processes of intellectual exchange that are rich in processed information and deep knowledge. Prior research indicates that CT support in virtual settings contributes to the transformation of tacit knowledge into explicit knowledge [11].

The information processing support provided by GSS enables the members to carry out activities that are critical for knowledge conversion. Such tools facilitate information gathering and evaluation. GSS support appears to have assisted in the distillation of insight, judgment, and expertise that may not otherwise be possible for dispersed workgroups. Moreover, those activities need not be performed in a random fashion or in absence of a guiding force. Process structuring in GSS is a tool for orchestrating the activities of individual team members into well-conducted collective exchanges and effort. GSS support in the form of facilitation leads to improved group interactions and exchanges of information and knowledge and helps group members focus their effort on the effective and efficient completion of their task [15, 54]. Knowledge conversion is a socially-intensive process that can be enhanced by CT support, as evidenced in this study. When combined, the three types of GSS support result in a collaborative work environment that is capable of overcoming the barriers of separation. The positive impact of the willingness to share knowledge on knowledge conversion, observed in this study, confirms the importance of people's knowledge sharing tendencies in virtual teams.

5.2 Work atmosphere and the Willingness to Share Knowledge

Trust, openness, cohesiveness, and respect contributed to an overall work atmosphere that positively impacted the willingness to share knowledge in our study. In traditional work contexts where people interact with each other in-person, the way the setting feels often influences how people operate and interact with each other. The tendency to share knowledge by workers in traditional settings is directly influenced by the values of trust and openness that prevail in workgroups [36, 37]. The virtual environments in our study seem to be no different. Higher levels of trust and openness in our experiment lead people to be more willing to exchange their thoughts without debilitating reservations or concerns for taking risk or getting embarrassed. In addition, openness promotes cooperation and a positive exchange of ideas [3]. When cohesion and respect are considered, intra-team interactions and exchanges appear to also be helpful. Cohesion has been shown to be very important for collaborative work [21] and respect is seen as necessary for encouraging group members to participate in group discussions [16].

5.3 Knowledge Conversion and Shared Understanding

Support for the Hypothesis 4 lends credence to our view that knowledge conversion contributes to the level of shared understanding in the teams. Shared understanding reflects the members' shared cognition of the details, specifications, and characteristics of the task and the process to follows to achieve the task. Mutual understanding is achieved via social interaction processes [39]. As knowledge conversion is a social process by definition, it is not surprising to see that it contributed to the emergence of shared understanding in our study. When concepts and ideas are clarified, achieving shared understanding becomes more attainable.

5.4 Contributions and Limitations

5.4.1 Contributions to Research. This study contributes to virtual team research by extending the principles of organizational knowledge creation theory to team-based work in virtual environments. The study fills a gap in GSS research in general and virtual teams in particular. While this study has focused on short-duration, one-session virtual teams, future studies should investigate longer-duration, multi-session teams. As each collaboration technology has its own distinctive functionality, future studies should explore the effect of other types of collaboration technologies (non-GSS) on knowledge conversion in virtual teams. Moreover, the development of a new task scenario represents an addition to the task literature that may be used by other researchers.

5.4.2 Contributions to Practice. This study enhances our insight into the functionalities of GSS and the contextual issues of virtual environments, which can be of great value for facilitating knowledge conversion in virtual settings. Such insight can be very beneficial for both the vendors of GSS and the managers of organizations that rely on virtual teams extensively. Vendor and designers of GSS technology may take the findings to incorporate features that support knowledge conversion processes further. Guided with the results regarding the functionalities of GSS (support types and tools), virtual team managers or leaders can be in a better position to evaluate GSS applications that are available in the market.

5.4.3 Limitations. One of the limitations of this study is that the research model does not cover the issues of technology appropriation and task type, which are reported in the GSS literature as having a moderating effect on the outcomes of technology supported collaboration. The use of student subjects is another limitation. Any generalizations of the results must be approached cautiously. Using short duration teams in this study is also a limitation. Future studies should examine longer-duration, multi-session virtual teams.

6. Conclusion

This paper investigated knowledge conversion in GSS-aided virtual teams. The study's hypotheses were supported. Future studies can utilize the validated model to consider virtual team arrangements that have longer durations in addition to studying the model using different task types. Contributions for practice include the possibilities for enhanced GSS designs to be considered by GSS vendors and users.

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APPENDIX A – Knowledge Conversion Scale

No.	Item	Based on
	Socialization	
1	My team members succeeded in absorbing each others' knowledge during our work on the task	[19]
2	My team's knowledge has expanded as a result of the task we completed	[29]
3	My team members collectively engaged in the generation of new ideas	[1]
4	My team members were motivated to share prior expertise in their field with each other	[29]
5	My team members collaborated in the exchange of their views and perspectives	[1]
	Externalization	
6	My team succeeded in turning our knowledge into action plans and final recommendations	[19]
7	My team members succeeded in sharing their individual knowledge among each other	[19]
8	My team members used examples and/or analogies to make their views understandable	[1]
9	My team members exchanged various ideas that were related to our task	[19]
10	My team members were actively involved in discussions and dialogue we had	[19]
11	My team members appreciated the each other's opinions regardless of differences in our views	[19]
	Combination	
12	My team members succeeded in organizing the team's information	[19]
13	I referred to published information/articles/news to explain/support my views	[5, 6]
14	I could have predicted the results my team's discussions from the information that was shared	[5, 6]
15	My team members integrated knowledge that was contributed by the members	[5, 6]
	Internalization	
16	My team members helped each other in understanding each other's ideas and viewpoints	[5, 6]
17	I attempted to verify task information using outside sources (using Web/internet links, for example)	[5, 6]
18	My team members actively searched for and shared new ideas and possible solutions	[5, 6]
19	My team members inquired about and shared each other's visions and values	[5, 6]

APPENDIX B – Shared Understanding Scale

No.	Item	Based on
1	I was able to understand the issues discussed by the other members?	[50]
2	I was able to understand the feelings and emotions of the other team members	[50]
3	I was able to understand the point of view of the other team members	R**
4	I was able to keep up with the flow of discussions during the meeting	R**
5*	Overall, I was able to develop a common understanding with the other team members about the task and the final recommendations	R**
6*	Overall, it is my opinion that my team members were able to develop a common understanding about the task and the final recommendations	R**
*	Items 5 & 6 were used for validity checks only.	
R**	Authors of current study.	