Relating Collaborative Technology Use to Teamwork Quality and Performance: An Empirical Analysis

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ABSTRACT: Although team-based work systems are pervasive in the workplace, the use of collaborative systems designed to facilitate and support ongoing teamwork is a relatively recent development. An understanding of how teams embrace and use such collaborative systems—and the relationship of that usage to teamwork quality and team performance—is critical for organizational success. We present a theoretical model in which usage of a collaborative system intervenes between teamwork quality

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and team performance for tasks that are supported by the system. We empirically validate the model in a setting where established teams voluntarily used a collaborative system over a four-month period to perform tasks with measurable outcomes. Our principal finding is that collaborative system use intervenes between teamwork quality and performance for tasks supported by the system but not for unsupported tasks.

KEY WORDS AND PHRASES: collaboration technology, collaborative systems, computer self-efficacy (CSE), group support systems (GSS), groupware, team performance, teamwork.

IT IS OFTEN CLAIMED THAT TEAMWORK is a crucial success factor for many organizations (e.g., [27, 31]), and the examination of teams and team performance has been a focus of research for some time [17, 48, 62]. An emerging body of research suggests that collaborative systems can facilitate and support teamwork [12, 18, 37, 42], and are being widely adopted in the workplace [15, 45, 50]. Researchers have also begun to examine the relationships between team characteristics and the use of computer support [1, 8, 28]. We extend this work by examining the relationship of team characteristics and collaborative system use to team performance.

Our research addresses two criticisms of extant team research. First, it has been argued that the use of temporary teams and teams created specifically for laboratory experiments—common in much team research—can bias research findings with respect to the relationship of system use and performance [13, 41, 46], a view that has found meta-analytic support as well (e.g., [5]). This suggests that the use of existing teams faced with significant tasks would be critical in obtaining results that may generalize to typical work settings. Second, it has been argued that the type of task being performed by the team, and the level of support for that task provided by the system, will affect the relationship between use of the system and team performance [14, 43, 47]. This suggests that the fit between the task and the tool needs to be considered in evaluating performance outcomes. We have incorporated both of these concerns into our research design, using existing teams facing meaningful tasks, and evaluating their performance on those tasks with respect to task fit.

Previous research has examined the relationships between team characteristics and performance, and between system use and team performance. Our research setting and design allows us to simultaneously assess team characteristics, collaborative system use, and team performance in a test of a theoretical model. We study these relationships in a research setting where system use is optional, the teams exist naturally and independent of the research project, and where teams are engaged in meaningful tasks on which their performance is independently evaluated. This rich setting and design allow us to address an important set of issues that have the potential to affect managerial decisions on composition of teams, support of teamwork, and team performance.

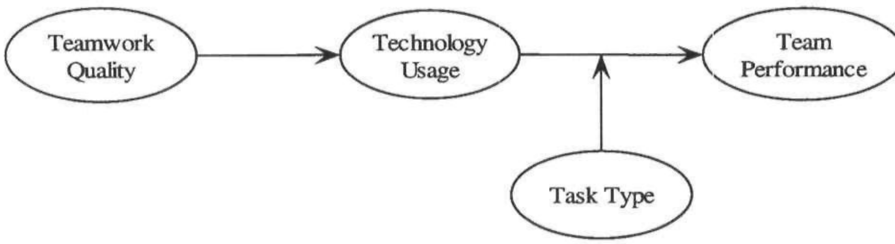

Figure 1. Research Model

Research Framework

OUR GENERAL RESEARCH FRAMEWORK, shown in Figure 1, proposes that collaborative system usage will mediate the effect of team characteristics on team performance, contingent on task fit. A theoretical underpinning of much team-level research is that team characteristics—for example, cohesiveness, norms for communication, and coordination—influence important outcomes such as team performance and satisfaction. Of course, there are often intervening processes or behaviors that mediate these relationships. We believe that in the information age, team characteristics are associated with how team members choose to complete assignments and accomplish their objectives. Of particular interest is the use of collaborative system technology to facilitate teamwork. Thus, our framework captures the idea that team characteristics will be associated with collaborative system usage, and that system usage will in turn be associated with team performance for tasks supported by the system, but not for unsupported tasks.

We operationalize the team characteristics component of the research framework through Hoegl and Gemuenden's [27] recently introduced Teamwork Quality (TWQ) construct. TWQ incorporates several other commonly studied characteristics of teams, such as cohesion and communication [17, 48]. Hoegl and Gemuenden [27] presented evidence that TWQ affects performance. We extend their work by incorporating an intervening variable—collaborative system use—that helps explain the connection between TWQ and performance in the context where a collaborative system is available and usage is optional. We argue that a team's level of use of a collaborative system is important in explaining the relationship between TWQ and team performance for tasks supported by the system.

Prior Research and Study Hypotheses

IN THEIR BROAD REVIEW OF THE RESEARCH on groups using collaborative technology, McGrath and Hollingshead [42] underscored the need for greater emphasis on the team itself. They argued that a key weakness of much existing research is the assumption that a group is engaged in only one task, which often leads to distortions such as activities not directly related to tasks being considered a sign of inefficiency. They state, in part:

> There may be some natural groups that do exist only for a single meeting and work on only a single topic, but by far the majority of natural groups have a life that extends beyond a single meeting on a single topic. . . . Yet the research literature on work in computer-mediated groups is quite the opposite: By far the majority of studies . . . deal with single meetings of those groups. Often they deal with groups that exist only for a single meeting; a considerable portion of that literature deals with groups whose members are using that computer-mediated system for the first (and only) time. [42, p. 76]

Our study takes a step toward addressing this weakness by following a set of 24 established teams over a four-month period in which they had unfettered but optional use of a collaborative technology designed to support many elements of group work rather than a single task.

The collaborative system used in this study would be classified as a group communication support system (GCSS)[1] using the typology presented by McGrath and Hollingshead [42]. This is consistent with the terminology used by Pinsonneault and Kraemer [51] in their comparison of group decision support systems (GDSS) and GCSS. In the typology of Fjermestad and Hiltz [19], it would be a computer-mediated communication (CMC) system. The system[2] organizes users into projects, and each team had a specific project dedicated to its use, as well as the ability to create others as needed. Within each project, team members had access to a number of functional modules, of which the most commonly used were document collaboration, threaded discussion, news posting, task management, polling, and issue resolution.

Using the most general term group support system (GSS), and following the classification scheme of DeSanctis and Gallupe [14], this would be a level 1 system, though it does not provide anonymity, and does support asynchronous communication. This latter point is important, as the collaborative system is not designed for use in synchronous meeting settings, as are most electronic meeting systems (EMS) [44, 49]. Rather than describing levels of support, Nunamaker et al. [49] focused on the difference between providing structure and providing support. Many GSS and EMS provide both process structure (e.g., agenda tools) and task structure (e.g., analytical models), whereas others may provide only process support (e.g., communications) or task support (e.g., data and analysis). The collaborative system we study primarily provides process support, though it provides some task support for search and retrieval of documents and prior communications.

Most research on the effects of collaborative system use has been performed in controlled settings, and many use the method of comparing results when teams meet with and without the technology [12, 18, 19]. It is important to keep in mind that the results of such research may not generalize to settings where teams exist for an extended period of time, and typically use both face-to-face meetings and asynchronous computer-supported communication to perform a number of different projects. For example, Pinsonneault and Kraemer [51] found that use of a GCSS, compared to use of face-to-face meetings, lead to increased total effort and depth of analysis but decreased cooperation and communication. In our setting, and indeed in any setting where GCSS use is optional and supplements other means of communication, it is not clear that decreased cooperation and communication would result. In fact, given that the GCSS provides additional channels of communication and means of cooperation, rather than substituting for face-to-face exchanges, one may expect the opposite. This is an important question, and one that we address empirically in this study.

Other studies have examined the differences between virtual teams and face-to-face teams in controlled experimental settings (e.g., [60]). Although the level of system use typically cannot be considered in a laboratory setting because subjects are assigned to either use or not use the system, in many actual implementations, and in much of the research in other areas such as technology acceptance, the level of system use is important. In our case, we have a natural setting in which use of the collaborative tool is optional (beyond the initial training and training-related exercises) and thus usage itself is variable. This provides a setting that is consistent with Kraut et al.'s [34] finding that "virtual organizing is a matter of degree." Our setting allows us to examine the extent to which colocated teams may benefit from the use of collaborative system functions associated with support of virtual teams.

Collaborative System Use and Team Performance

A number of scholars have examined the extent to which collaborative system use is associated with higher levels of team performance and sought to identify the conditions facilitating higher levels of performance. For example, McLeod and Liker [44] looked at the effect of high- and low-structure EMS on team performance, using the structure-level-based distinction introduced by Nunamaker et al. [49]. Whereas this focuses on synchronous use, it is nonetheless informative to look at the differences in level of support. They hypothesized that both high- and low-structure use will lead to improved performance, but did not find support for this in the low-structure case. This led them to modify their model to incorporate the notion of task fit, with more complex tasks requiring groups to create more structure. This view is consistent with McGrath and Hollingshead, who stated that "on theoretical grounds there is reason to expect a strong interactive relation between task type and technology in affecting both group process and group task performance" [42, p. 77]. We are able to examine this issue empirically in what would be considered a low-structure collaborative system, using performance measures for two different task types, as described below.

Many researchers (e.g., [19, 42, 44, 51]) have effectively argued that task fit is a critical determinant of system performance, a position that is also supported as a specific instance of the more general systems contingency approach [26]. The Group Task Circumplex provided by McGrath and Hollingshead [42] provides a useful typology of tasks, and also describes the relative extent to which the different task types place demands on the collaborative and cognitive abilities, respectively, of the groups. According to this typology, the two task types we use in developing performance measures for this study would be classified as type 2, *creativity tasks*, and type 4, *decision-making tasks*. The former is well supported by the collaborative system, whereas the latter is not.[3]

There are a number of reasons to expect improved performance from collaborative systems when there is good system-task fit. For example, it has been shown that teams that communicate electronically are less prone to domination by particular members of the group, and tend to display greater equality of participation (e.g., [16, 56]). Computer-facilitated groups have also been shown to produce more ideas than the same individuals working alone, pooling their ideas (e.g., [24, 58]). These results would all argue for improved performance in a creativity task.

A large number of studies (e.g., [19, 23, 42, 51]) have found that groups using GDSS and GSS are able to achieve better decision quality. In many of these studies, the role of the decision tools provided could not be separated from the role of the system. Perhaps this is because it is difficult to design research settings providing the same analytical tools independent of the system that embodies them. However, if system-task fit is important, we should find that it is the decision tool rather than the system itself that is critical in these cases. This is an important distinction, and one that has received little research attention. The collaborative system we studied does not contain any decision support or analytical tools, so we cannot address this issue directly. However, we can address a related point: if a particular decision tool is central to team success, a GSS that does not provide support for the decision analysis required should not benefit a group facing a decision, or in our case repeated decision problems.

> *H1: Actual use of the collaborative system will have a stronger positive impact on team performance in supported tasks, such as creativity tasks, than on team performance in unsupported tasks, such as decision-making tasks.*

Team Characteristics and Collaborative System Use

McGrath and Hollingshead argued that "empirical relations involving computer-aided groups should be regarded, at the outset, as probably a joint function of a number of group and member characteristics, task characteristics, and characteristics of the group's communication and task performance technology" [42, p. 78]. Drawing from McGrath and Hollingshead's observation, we argue that team characteristics will be associated with the use of a collaborative system.

TWQ [27] is a recently developed construct and measure of team characteristics that captures six facets of teamwork: communication, coordination, balance of member contributions, mutual support, effort, and cohesion. In an in-depth field study, Zack and McKenney [63] found that groups that exhibited more cooperation and open communications enjoyed a successful and tightly integrated use of electronic messaging, whereas groups characterized by the opposite pattern were constrained by their social context from adopting the medium in a significant way. This provides some limited evidence for EMS relating positively with at least two of the TWQ subscales. A similar result is reported from a field study by Kraut et al. [34], who found, in an interorganizational communication setting, that the use of personal relationships and electronic networks are complementary rather than competing forms of communication. Stronger personal ties were associated with increased use of electronic networks.

Malhotra et al. [38] argued that in order to effectively use electronically mediated communication, team members must first develop a shared understanding about the problem, norms, and context for interpreting knowledge. In a detailed case study, they found that if a team using a collaborative technology does not have a shared understanding when the team is initiated, its members must create it in their virtual environment. The natural corollary is that a team with an established shared understanding will have an easier time making use of a virtual environment. Chidambaram [8] provided support for this view, finding that computer-supported groups will develop relational intimacy over time, confirming a positive, rather than negative link between the use of computer support and the level of relational intimacy in a team.

The TWQ measure is comprised of communication and cooperation in a team, some aspects of the degree of shared understanding in a team, and the development of personal relationships in a team. These same factors should all generate greater use of the system. Thus, the TWQ measure should be positively associated with actual usage of the system. This leads to the following hypothesis:

> *H2: Teamwork quality will be positively related to the use of the collaborative system.*

Control Variables

We have included a number of control variables in this study to assure that any support we find for our hypothesized relationships is significant in the presence of other factors known to influence the measures under consideration. In examining the relationship between TWQ and collaborative system usage, we control for computer self-efficacy (CSE) because it has been shown to relate to system usage at the individual level.

The concept of CSE is a natural extension to the work of Bandura [3], who posited a relationship between personal self-efficacy beliefs and behavior that has been empirically validated in a number of domains [4]. Compeau and Higgins [10] defined CSE as "a judgment of one's capability to use a computer," and developed and validated a widely used measure of CSE. This work built on several other CSE-related measures that had been previously developed, for example, by Hill et al. [25] and Webster and Martocchio [61].

Agarwal et al. [2] and Marakas et al. [39] have provided extensive reviews of empirical CSE research. There are numerous studies that support the conclusion that CSE affects perceived ease-of-use and usefulness of systems. Several studies [10, 11] have found that CSE is positively related with self-reported usage. On the other hand, using a different instrument to measure CSE, Igbari and Iivari [29] found no *direct* effect on self-reported usage. Straub et al. [55] have underscored the potential for

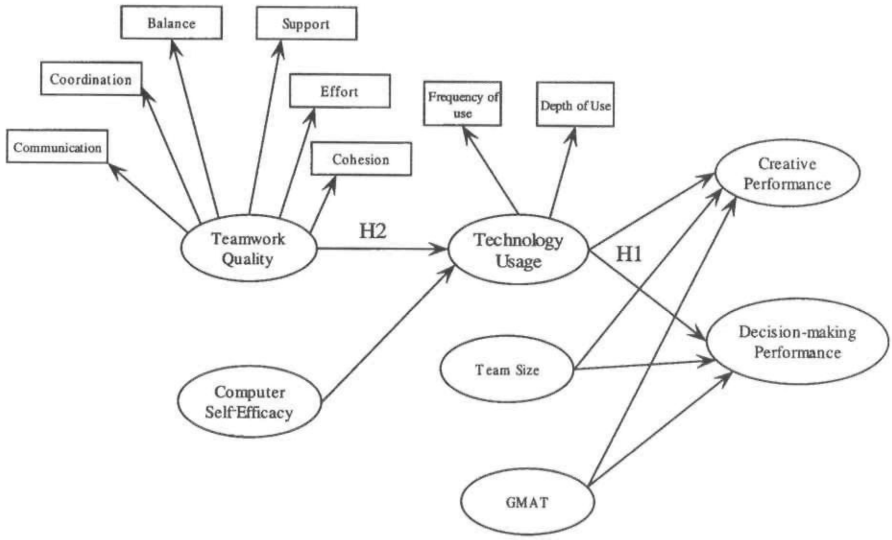

Figure 2. Operationalized Research Model

differences to arise between self-reported usage and objectively measured usage. We are not aware of other studies that have looked at the effect of CSE on actual usage. Although we state no formal hypothesis, we believe it is reasonable to expect a positive relationship between CSE and actual system usage.

To account for the effect of factors that have been shown to relate to performance, we included two additional control variables. First, there is some evidence in the teamwork literature that the size of the team may have an inverse relationship with team performance. For example, Latane [35] found that increased group size increases potential for freeloading behaviors and Mullen et al. [48] found that group performance decreased in group size. On the other hand, for some tasks, such as idea generation, research has shown a positive relationship between size and performance (e.g., [24]). Thus, we include the number of members in the team as a control variable, without any hypothesis as to the direction of the relationship. Further, since the performance measure is related to grades, and those are known to relate to graduate management admission test (GMAT) scores for individuals, we employ the average GMAT score of the team members as an additional control variable. The full operationalized model with hypotheses is shown in Figure 2.

Methods

OUR RESEARCH SETTING INVOLVED A SET OF 24 established teams that performed a variety of meaningful tasks over a four-month period (the full life of the teams). The teams had full-time Internet access to a collaborative system on which they received uniform training. Use of the system was optional and intended to supplement other team activities.

Table 1. Subjects and Response Rates for Surveys, Usage, and Control Data

	MBA students	
Number of teams	24	100%
Number subjects in population	122	100%
	N in sample	Response rate
Teamwork quality[a]	120	98%
Computer self-efficacy[b]	116	95%
Collaborative system usage[b]	122	100%
GMAT[b]	122	100%
Team performance[a]	122	100%

[a] Measured at team level.

[b] Measured at individual level and aggregated to team level.

Our research design was longitudinal—we logged the actual usage of the system by team members over the full four-month existence of the teams, during which time they were actively engaged in a number of significant team projects. Our design incorporated independent evaluations of team performance for both a team task that was supported by the collaborative system and one that was not supported.

Data

There are three types of data used in this study: self-reported survey data describing the team characteristics, actual system-usage data, and expert ratings of team performance. As shown in Table 1, the subject pool included 122 MBA students, all enrolled in their first year of courses at the time of the study. Eighty-one percent of the subjects were male, and 19 percent female, with an average age of 27 years (range: 21 to 40), and an average of 4.3 years of work experience (range: none to 18.5 years). All subjects received the same hands-on training session on the use of the Web-based collaborative system, administered in a one-hour session by the staff member who had technical support responsibility for the platform. The CSE survey was electronically administered immediately after the training session while the students were still in the computer lab. Subjects received course credit for completing all surveys.

Each MBA student was administratively assigned to a team that remained fixed for the one-semester (four-month) duration of this study. To the extent possible, instructors used those set teams for any assignments to be completed by groups of students. The TWQ survey was administered in electronic format at the end of the semester. The students were instructed to respond to all survey items with respect to their fixed team for the semester.

Usage data was available from daily log files generated from queries run directly on the database supporting the collaborative environment. The log files track 70 separate action-module combinations, the most common of which are listed in Table 2. In

Table 2. Illustrative Matrix of Actions Possible Within Commonly Used Modules in the Collaborative System. All Actions Are Logged by User, Date, and Time

	Module							
Action	Appointment	Discussion	Document	Issue	News	Poll	Project	Task
Check in/out			X					
Create	X	X	X	X	X	X	X	X
Delete	X	X	X	X	X		X	X
Download/view			X					
Edit	X	X	X	X	X		X	X
Update			X				X	X
View	X	X	X	X	X	X		X
Vote						X		

Notes: X indicates that this action is possible and logged for this module. The table shows 35 of 70 module/action combinations. Those not shown are primarily module-specific variants on create and edit, such as create-reply for the discussion module.

addition, standard usage statistics such as system log-ons are also accumulated on a daily basis.

Several researchers have pointed out that the distinction between actual and self-reported usage is an important one. Straub et al. [55] examined usage of voice mail in a large financial institution, and found that actual usage and self-reported measures of usage did not correlate strongly. Szajna [57] examined the actual usage of a computerized mailing system in a classroom environment, and found that self-reported usage was only weakly associated with actual usage. There may be several reasons why self-reported usage does not provide a good reflection of actual use of a technology. First, self-reported usage relies on the recollection of the subjects who may report their usage based upon their most recent experiences. Further, users may exaggerate the extent of usage to fit in with the expectations of their superiors. Other factors that may cause biases in the self-reported measures include information processing limitations, attentional lapses, bounded rationality, and common-method variance. Wagner and Gooding [59] concluded in their meta-analyses that users are poor estimators of aspects of their own behavior. Rice [52] suggests, on the other hand, that there may be good reasons for the difference, pointing out for example that absolute usage levels of one system would not necessarily relate to the relative usage levels of different systems, which may determine perceptions of use. Rice and Tyler [53] avoid this issue by obtaining self-reports of the same value obtained from system monitoring. Following examples set in prior research such as Kraut et al. [33], we rely solely on system log files for our usage measure.

Measures

TWQ was measured with a 37-item TWQ scale recently developed and validated by Hoegl and Gemuenden [27]. This is a measure of the quality of collaboration in teams that captures six different facets of TWQ: communication, coordination, balance of member contributions, support, effort, and cohesion. Cronbach's alpha for these scales were 0.90, 0.91, 0.83, 0.97, 0.87, and 0.94, respectively.

From the usage data, we developed two measures of team-level usage of the collaborative system. The first, which essentially captures frequency of use, is the average of system log-ons for all members of the team for the full 15-week semester. The higher this number, the more frequently the team members would be apprised of any new content in the platform, which is always shown on the first screen after log-in. The other measure captures the depth of usage by the team. It is an adjusted average usage figure, based on a count of each action taken in each module for all members of the team, also for the full semester.

The MBA students were assigned to 24 teams, and there were two core courses during the semester that made extensive use of team assignments. In both courses, presentations were required of the teams, and these were evaluated and scored by the instructor. The resulting scores were normalized and averaged across the two courses to create a single score per team for presentations for the semester. In one of the courses, the student teams participated in a simulated market competition that lasted for the full semester. Weekly decisions were made by the group on a variety of variables that were then entered into the market simulation as their decisions. This ultimately resulted in a numeric score for each team that was determined entirely by the simulation results. In the other course, the teams analyzed a chosen company, applying techniques learned in the course, and presented their results in both a written formal report and in an oral team presentation. As noted above, these measures capture performance on tasks of two types, according to the typology presented in McGrath and Hollingshead [42]. The presentations were primarily creativity tasks (type 2), which are supported by the collaborative system with a variety of features ranging from communications channels to document collaboration support (see Table 2). The decisions required for the simulation were clearly decision-making tasks (type 4), and there is no decision modeling provided in the collaborative system offering support for these tasks.

As a control for actual system usage, CSE was measured with a 10-item scale developed by Compeau and Higgins [10]. The measure is designed to obtain a self-evaluation of one's ability to use a computer to accomplish a task. Given that our primary theoretical interest is in demonstrating a link between team characteristics and system usage, we include CSE only to assure that any relation we find is significant beyond what can be explained by the individual team members' self-efficacy assessment with regard to the platform. As such, it would not be appropriate to ask participants to rate the overall team-level of self-efficacy. Rather, following recent team-level research [30, 36], we used the scale to measure each team member's self-efficacy and aggregated the scores to develop a team-level index. Cronbach's alpha for this scale was 0.92.

As a control for team performance, we used the average GMAT score for the team members, since it did vary across teams, and is commonly assumed to relate to individual performance. The presentation and decision performance team scores described above both formed a significant portion of individual grades for the respective courses. The size of the team, which varied from four to six in our sample, was used as an additional control variable.

Measurement Model

Because structural equation modeling is our primary analytic technique for examining the relationships proposed in the hypotheses, we first computed a confirmatory factor analysis (CFA) on the data to test the measurement model. Our purpose was to ensure that the constructs were empirically distinct from one another and that specific items measured the constructs that they were intended to measure. CFA allows for tests to be conducted for unidimensionality, convergent validity, and divergent validity of the scales employed in the study. Unidimensionality is the extent to which empirical measures (indicators) are strongly associated with each other and represent a single concept. Convergent validity is the extent to which varying approaches to construct measurement yield the same results, and discriminant validity assesses how much a concept and its indicators differ from another concept and its indicators.

When measures are of a moderate length and when the constructs being measured are correlated, it is difficult for researchers to confirm factor structures [6, 20]. Under these conditions, the use of item parcels is recommended to reliably assess model fit [17, 32, 54]. Parceling items involves grouping related items together, thereby reducing the overall number of parameters estimated in the model. Following the parceling procedure employed by Mathieu and Farr [40], we created indicators for each longer measure—CSE, team communication, team support, and team cohesiveness—by averaging groups of items using the two highest and one or two lowest loadings to form the first indicator, then averaging the items with the next set of highest and lowest loadings to form the second indicator, and repeating the process until all items were included. We did not create parcels for the shorter measures (team coordination, team balance, and team effort).

In assessing the measurement model, no one statistic is viewed as the single best indicator of fit; rather, researchers examine an array of fit indices in order to obtain a broad understanding of the distinctiveness of the measures and the extent to which the model fits the data. Accordingly, we examined several fit indices for the complete seven-factor measurement model. Because the χ^2 statistic is dependent upon sample size, we instead used the ratio of χ^2 to degrees-of-freedom. We obtained a value of 1.68, which falls within the suggested value of three or below [7]. We also computed the following fit statistics: the comparative fit index (CFI) was 0.95, the Tucker-Lexis index (TLI) was 0.93, the root mean square error of approximation (RMSEA) estimate was 0.08, and the root mean residual (RMR) was 0.06. Values above 0.9 represent reasonable model fit for the first two statistics; values at or below 0.08 suggest good fit for RMSEA and RMR. These statistics indicate that the full measurement model provides a good fit to the data.

We then compared a series of nested models to ensure that the complete measurement model best represented the data. The full measurement model provided a better fit to the data than each of a series of reduced alternative models. We compared the full seven-factor measurement model to a two-factor model where the items comprising the six TWQ dimensions were constrained to load on a single factor ($\Delta\chi^2$ (20 df) = 178.54, $p < 0.01$) and to a one-factor model where all items were constrained to load on a single factor ($\Delta\chi^2$ (21 df) = 358.34, $p < 0.01$). Based on these analyses, we concluded that the full measurement model represents the best fit of data to the model. In subsequent structural modeling, we treat CSE and the six dimensions of TWQ as separate constructs.

Analysis and Results

We employed partial least squares (PLS)[4] to estimate our operationalized research model (shown in Figure 2). There are several important differences between PLS and structural equation modeling (SEM) that make PLS suitable for small sample sizes. Whereas SEM uses a factor analytic measurement model, PLS uses a principal components measurement. SEM aims at an overall optimization in parameter estimates through a full-information estimation technique (such as maximum likelihood), whereas PLS uses limited-information methods that impose minimal demands on the data. Finally, PLS aims to maximize the proportion of variance of the dependent variable explained by the predictor variables, whereas SEM aims to maximize and then test the degree of consistency between model and data. Given that PLS is appropriate for situations in which theory is not as well developed and that it requires small sample sizes with minimal distributional assumptions, it has been viewed as a pragmatic alternative to SEM in recent literature [1, 9, 21]. Table 3 displays the means, standard deviations, and intercorrelations among all study variables.

Structural Model

The results of the structural model estimation are shown in Figure 3. In Figure 3, path coefficients can be interpreted as standardized coefficients in regression analysis. The outer model loadings are shown separately in Table 4. Our results indicate that the use of the collaborative system in combination with the control variables for size and GMAT account for 35.2 percent of the variation in team performance on the supported creativity task. The relationship between use of the platform and this performance measure is statistically significant at the 0.01 level. As for the control variables, team size was observed to have a negative and significant (at the 0.05 level) relationship, whereas GMAT score was not significantly related to performance on creativity tasks.[5]

With decision-making team performance as the dependent variable, the R^2 was 15.7 percent. Consistent with H1, we did not observe a significant relationship between technology use and decision-making performance. The only variable that had a significant relationship with decision-making performance was team size, which was negative and significant at the 0.05 level. The finding that actual usage was significantly related to creative performance but not to decision-making performance lends support to H1. A *t*-test of the difference of these two R^2 values (t-statistic = 3.448, p-value < 0.01) also confirmed this conclusion.

The constructs for TWQ and CSE explain 20.4 percent of the variation in use of the collaborative system. TWQ is significantly associated with use of the collaborative system at the 0.05 significance level, supporting H2. And for the control variable CSE, we find, as expected, that it is positively associated with system use.

Alternative Model Specifications

THE HYPOTHESIZED MODEL PRESENTED in Figure 1 represents our best theoretical predictions of the relationships between the variables of interest to this study. However, it is plausible that there may exist alternative explanations or relationships between constructs employed in this study. We evaluate two alternative models from an estimation standpoint. The first of these is a model where TWQ is depicted as having a direct effect on performance, thus technology usage does not intervene between TWQ and performance. To test this model, we dropped usage (and therefore CSE as

Table 3. Descriptive Statistics and Correlations

		Mean	Standard deviation	1	2	3	4	5	6	7
1	Creative performance	93.77	1.57							
2	Decision-making performance	88.95	3.95	0.23						
3	Frequency of use	2.14	0.14	0.42*	0.12					
4	Depth of use	1,123.38	516.43	0.31	0.28	0.59**				
5	Team size	5.13	0.45	–0.33	–0.23	–0.03	0.21			
6	GMAT	653.34	23.54	–0.37	0.04	–0.33	–0.19	0.16		
7	Teamwork quality	5.16	0.65	–0.10	–0.21	0.26	0.26	0.02	0.11	
8	Computer self-efficacy	7.38	0.71	0.14	0.07	0.34*	0.36*	0.06	0.08	0.14

** Significant at the 0.01 level; * Significant at the 0.05 level

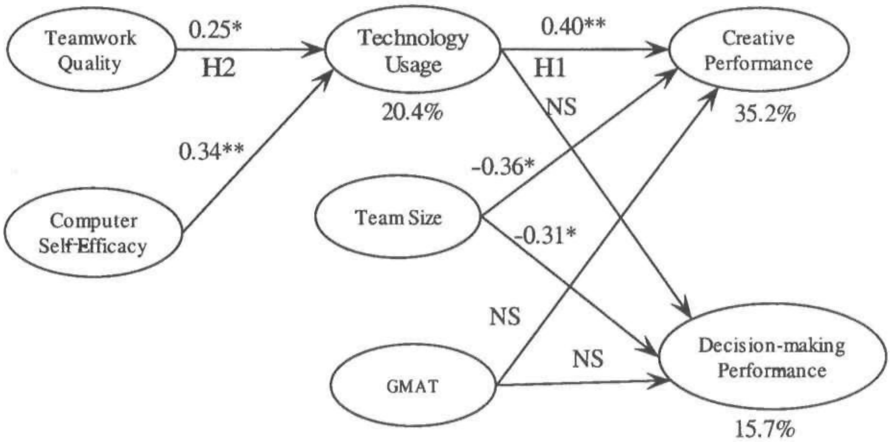

Figure 3. PLS Results

Table 4. PLS Outer Model Loadings

Construct	PLS outer model loading
Technology use	
Frequency of use	0.80
Depth of use	0.78
Teamwork quality	
Communication	0.96
Coordination	0.96
Balance	0.97
Support	0.94
Effort	0.95
Cohesion	0.98

well) and estimated a direct path from TWQ to performance. The R^2 for creative performance drops to 21.4 percent and for decision-making performance drops to 11.9 percent. These are significant declines from 35.2 percent and 15.7 percent, respectively. The substantial deterioration in model fit for this alternative model suggests that the hypothesized model provides a better fit. The second alternative model includes a direct relationship between TWQ and performance, without dropping usage from the model, to allow for the presence of both direct and mediated effects. Results for this model showed statistically nonsignificant direct relationships between TWQ and the two performance measures.

The second alternative model we examined reversed the directionality between TWQ and actual usage. Specifically, this model differs from the hypothesized model in that collaborative system usage drives TWQ, and TWQ in turn is hypothesized to be associated with superior team performance. Estimation results indicated that only 9.2 percent of the variation in TWQ would be explained by collaborative system usage.

Further, the relationship between TWQ and performance was not significant. The R^2 values for creative performance and decision-making performance are 21.3 percent and 10.7 percent, respectively. Again, these numbers represent a drop in model fit, supporting the hypothesized model as being a better fit than the alternative model.

Discussion

WITH THIS RESEARCH WE DEVELOPED and empirically validated a model linking the dimensions of TWQ to actual collaborative system usage and team performance. We found that collaborative system usage intervened between team characteristics and performance. Team characteristics, as measured by TWQ, were positively associated with usage of the collaborative system, and usage of the system was in turn positively associated with team performance for supported tasks, but not with team performance for unsupported tasks. These findings have a number of implications for both research and practice.

Broadly speaking, one theoretical contribution of this research is that it demonstrates that team-level use of a collaborative system can play an important role in team performance and success. Previous research has established that team characteristics are associated with various team-level outcomes, but relatively little was known about specific processes that accomplish this. Put another way, this research adds one answer to the question, "What intervening behaviors or processes are the mechanisms that allow teams with certain characteristic profiles to create higher performance?" The empirical support we found for our model suggests that we can extend team characteristics theory by including the use of information systems—in this case, a collaborative system—to understand why some teams succeed to a greater extent than others. It is not just the presence of particular patterns of characteristics that cause higher performance; rather, it is the fact that particular patterns of characteristics lead to helpful behaviors and processes that create success.

By studying established teams operating in their natural setting, rather than ad hoc teams formed solely for experimental purposes, we were able to examine the relationship of team characteristics themselves—such as TWQ—with system usage and ultimately with team performance. The TWQ measure would have little value or meaning for a temporary team, and our setting has permitted us not only to validate the measure, but also to empirically confirm its potential importance in the study of teams. A further important contribution is that we establish the relationships between team characteristics, collaborative system use, and team performance with a research design that allows us to avoid many of the known problems in studies of this kind. We measure team characteristics for teams that have a natural and lengthy existence, we measure actual system usage, and we use independent evaluations of performance on both supported and unsupported tasks.

Our finding that actual usage is related to team performance on creativity tasks but not to team performance on decision tasks may stem from the fact that the collaborative system provided rich support for the creativity task type but not the decision task type. This underscores the need to disentangle performance into more specific metrics that tap the benefits of collaborative technologies. Many prior studies suffer from confounding the use of a GSS with the use of an analytical model to support the decision process. When the alternate condition in such a study has neither the system nor the model, as is often the case, one cannot really conclude whether it is the GSS or the model that is responsible for the effects found. Our results lend support to the notion that in some cases it may be the model more than the system that drives positive results for decision outcomes. We hope this will encourage a richer set of studies that examine the task-fit hypothesis in the context of GSS.

An additional contribution of this research stems from the methodology and design of the study. The context of this research—the optional use of a collaborative system as part of established teams working together over time, with independently evaluated performance outcomes—provides us with a rich context to examine not only actual usage but also actual performance of teams on team projects. Our finding that actual usage has a significant mediating role may have theoretical implications for technology-task fit models where a fit between the two constructs is seen as sufficient condition for higher performance. Our results suggest that those may be necessary but not sufficient conditions, and that actual usage may play a significant role.

There are also some important managerial implications of our results. The relationship between collaborative system use and team performance on supported tasks suggests that managers should consider providing incentives for the use of such technologies, particularly in settings where such use is voluntary. Since TWQ was clearly related to a team's use of the system, managers should also consider supporting the development of team characteristics related to TWQ. Further research relating individual and team characteristics—as well as team composition—to the adoption of technologies holds promise for helping managers design teams in a manner that supports their use of technology and ultimately enhances their performance.

Of course, as with all research, our study has some limitations that must be acknowledged. One potential limitation concerns the use of a student sample and its implications for the generalizability of the results. Scholars are rightly cautious in generalizing from student-based studies to working adults, especially when students participate in an experiment that reflects a departure from their normal work/school life. However, because the students in this study were engaged in naturally occurring tasks and using a collaborative system that offered support for their day-to-day performance on tasks assigned by their supervisors (professors), we believe generalizability is less of an issue. When people engage in a task that is meaningful to them, an accurate description of participants' judgments is more likely [22]. In addition, the participants in this study were graduate students with an average of over four years of full-time work experience, and may well be among the workers most likely to make use of such collaborative systems in their careers.

A second limitation is the relatively small sample size of 24 established teams; one natural extension to our study will be to examine the posited relationships in a larger and more representative sample. We chose a statistical methodology (partial least squares modeling) that minimized the impact of the sample size on our results. However, if our findings can be replicated in a broader context, more confidence can be placed in the robustness of our findings. An additional limitation of the present study is that all relationships examined are correlational and no claims of causality can be made given the cross-sectional nature of the data on most variables. To infer causality implies the collection and analysis of longitudinal data. This is another opportunity for future research.

Conclusion

THE USE OF TEAMS IS AN INCREASINGLY prevalent phenomenon in organizations, and collaborative systems designed to support the teams' work is one way companies attempt to improve the effectiveness of those teams. The primary contribution of this research is a model relating team characteristics (as measured by TWQ), collaborative system usage, and performance. Our findings suggest that the use of a collaborative technology system is associated with team performance on supported tasks, and that system usage is a function of TWQ.

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Notes

1. The collaborative system also has some features of what McGrath and Hollingshead [42] would call Group Information Support Systems and Group External Communication Support Systems, the former because all content is stored for easy search and retrieval, and the latter because the platform supports linking to users external to the organization, though subjects were not trained on, and did not make significant use of, this feature.

2. The collaborative system used in this study was developed by eProject. Information on the product and free use of a simplified hosted version are available at www.eproject.com.

3. A more detailed description of the two tasks and their fit with the collaborative system follows in the measurement section below.

4. PLS Graph Version 3.0.279 was used for the analysis of the structural model.

5. The R^2 after dropping GMAT are 31.6 percent and 12.7 percent for creative and decision-making performance, respectively. When estimated without including GMAT, the results for the effect of technology use on performance did not change, so we chose to retain it in the model.

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